MOLAR

Mountain Lake Research

PROGRESS REPORT 3/1999

March 1998 - March 1999

Measuring and modelling the dynamic response of remote mountain lake ecosystems to environmental change

A programme of **Mo**untain **La**ke **R**esearch

MOLAR

ENV4-CT95-0007
IC20-CT96-0021

Norwegian Institute for Water Research

REPORT

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Title	Serial No.	Date
MOLAR Progress Report 3/1999. March 1998 - March 1999. Measuring and modelling the dynamic response of remote mountain lake ecosystems to environmental change: A programme of Mountain Lake Research - MOLAR	4070-99	8.6.1999
	Report No. Sub-No. 96061-1	Pages Price 124
Author(s) Bente M. Wathne (Ed.)	Topic group Acid Rain	Distribution
	Geographical area Europe	Printed NIVA

Client(s)	Client ref.
Commission of the European Communities	ENV4-CT95-0007 IC20-CT96-0021

Abstract

MOLAR is an extensive European co-operative research project with 23 partners. It is funded within the European Commission Framework Programme IV: Environment and Climate with assistance from INCO. It is co-ordinated by the Environmental Change Research Centre (ECRC) at University College London (UCL) and the Norwegian Institute for Water Research (NIVA). The project has four major strands also called Work Packages, and progress within the third and last working year of each of the Work Packages (WP) is reported here. Part A is a summary of the activities under each WP, while in part B detailed reports from each of the contract partners are given. The overall conclusion is that the progress has been according to plan, reviced time table and economy. Finalising activites are in full progress.

4 keywords, Norwegian	4 keywords, English
1. Høyfjellsjøer	1. Highmountain lakes
2. Vannkjemi	2. Water chemistry
3. Biologi	3. Biology
4. Europeisk samarbeid	4. European co-operation

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ISBN 82-577-3675-9

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ENVIRONMENT & CLIMATE RESEARCH PROGRAMME (1994-1998)
MOLAR Summary Progress Report 3/1999

March 1998 - March 1999

Contract no.: ENV4-CT95-0007 / IC20-CT96-0021

Measuring and modelling the dynamic response of remote mountain lake ecosystems to environmental change:

A programme of Mountain Lake Research - MOLAR

MOLAR co-operative partners:

01	University College London, UK (*administrative coordinator*)	(UCL)
02	University of Helsinki, SF	(UHEL)
03	University of Edinburgh, UK	(UED)
04	Norwegian Institute for Water Research, N (*scientific coordinator*)	(NIVA)
05	Universität Innsbruck, Institut für Zoologie und Limnologie A	(UIBK)
06	Austrian Academy of Sciences, Limnological Institute, A	(ILIMNOL)
07	Universidad de Barcelona, ES	(UBCN.DE)
08	Universidad de Granada, ES	(UGR-ES)
09	University of Bordeaux (URA CNRS), Arcachon, F	(CNRS)
10	Consejo Superior De Investigaciones Cientificas, Barcelona, ES	(CSIC)
11	University of Bergen, Botanical Institute, N	(UIB-BI)
12	University of Bergen, Institute of Zoology, N	(UIB-ZI)
13	CNR-Istituto Italiano di Idrobiologia, Pallanza, I	(CNR-III)
14	University of Liverpool, UK	(ULIV)
15	Institute for Environmental Science and Technology, Dubendorf, CH	(EAWAG)
16	University of Zurich, CH	(UZurich)
17	Charles University, Prag, Czech Republic	(FSCU)
18	Hydrobiological Institute, Ceske Budejovice, Czech Republic	(HBI-ASCR)
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21	National Institue of Biology, Ljubljana, Slovenia	(NIB)
22	Kola Science Centre, Apatite, Russia.	(INEP)
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Preface

MOLAR is an extensive European research project with 23 co-operative partners. It is funded within the European Commission Framework Programme IV: Environment and Climate with assistance from INCO. MOLAR builds on the success of the EU funded AL:PE projects.

MOLAR was launched March 1st 1996, and the first project meeting was held two weeks later in Prague, Czech Republic. Annual project meetings have been held in Barcelona, Spain in March 1997, in Bled, Slovenia in March 1998 and in Arcachon, France in February 1999.

For wide spread information MOLAR has a home page on Internet (http://prfdec.natur.cuni.cz/hydrobiology/molar/welcome/htm).

When the Project Proposal was prepared, there were 22 co-operative partners involved in MOLAR. After the project had been accepted by the European Commission, a Swiss Group from Laboratorio Studi Ambientale, Sezione aria e aqua, Ticino (LSA) joined the project and is now working voluntarily under the same programme as the rest of the project group.

This Progress Report summarises the activities during the last working year of the project. It is compiled from contributions given by all project partners. Convenors for the four different parts (Work Packages) of the project have been responsible for reporting of the progress within each part.

Oslo, 8. May 1999.

Bente M. Wathne

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Summary

MOLAR is an extensive European co-operative research project with 23 partners. It is funded within the European Commission Framework Programme IV: Environment and Climate with assistance from INCO. It is co-ordinated by the Environmental Change Research Centre (ECRC) at University College London and the Norwegian Institute for Water Research (NIVA). MOLAR was launched March 1st 1996, and the first project meeting was held two weeks later in Prague, Czech Republic. Annual project meetings have been held in Barcelona, Spain in March 1997, in Bled, Slovenia in March 1998 and in Arcachon, France in February 1999.

This project has four major strands also called Work Packages, and progress for the third and last working year of each of the Work Packages (WP) is reported here. Part A is a summary of the activities under each WP, while in part B detailed reports from each of the contract partners are given. Convenors for the four different Work Packages have been responsible for reporting of the progress within each part.

The main conclusion after evaluations at the annual project meeting and reports from the project partners is that the project is on schedule and has been working according to plan. The finalising activities are in full progress through production of publications for scientific journals and the final report.

SUMMARY PROGRESS REPORT OF MOLAR

PART A

1. GENERAL OBJECTIVES

MOLAR is an extensive European co-operative research project originally established with 22 partners. After voluntary participation from a third Swiss group (participant no. 23 on the first page) it was extended and is working with 23 partners.

MOLAR is funded by the European Commission Framework Programme IV: Environment and Climate with assistance from INCO. It is co-ordinated by the Environmental Change Research Centre (ECRC) at University College London (UL) and the Norwegian Institute for Water Research (NIVA). A Steering Group of senior scientists from laboratories engaged in the key areas of MOLAR has been established. The Steering Group is responsible for harmonisation of administrative and scientific co-ordination, and an important tool for optimal administration of the total MOLAR project.

The arctic and alpine regions of Europe represent the most remote and least disturbed environments in Europe, yet they are threatened by acid deposition, toxic air pollutants and by climate change. The remote lakes that occur throughout these regions are especially vulnerable for a number of related reasons:

- many mountain lakes have little ability to neutralise acidity because of their low base status, and acid deposition often increases with altitude;

- nitrate levels are often higher in mountain lakes because their catchments have little soil and vegetation to take up nitrogen deposition;

- toxic trace metals and trace organics accumulate in the food chain more easily in soft water than hard water lakes, and some pollutants (e.g. mercury, volatile organics) accumulate progressively in cold regions;

- the productivity and ecological dynamics of mountain lakes is strongly controlled by climatic influence on the length of the ice-free season and the period of thermal stratification, yet climatic warming in Europe is predicted to be greatest in arctic-alpine regions.

Because of this sensitivity, remote mountain lakes are not only vulnerable to environmental change, they are also excellent sensors of change, and their sensitivity and high quality sediment records can be used to infer the speed, direction and biological impact of changing air quality and climate. The MOLAR project builds on the success of the EU funded AL:PE (Acidification of Remote Mountain Lakes: Palaeolimnology and Ecology) project, which represented the first comprehensive study of remote mountain lakes at an European level (Wathne *et al.* 1995, 1997).

This project has **four overall objectives**, each corresponding to a major strand, also called Work Package in the proposal:

- to measure and model the dynamic responses of remote mountain lake ecosystems to acid (sulphur plus nitrogen) deposition;
- to quantify and model pollutant (trace metals, trace organics) fluxes and pathways in remote mountain lakes and their uptake by fish;
- to measure and model the temporal responses of remote mountain lake ecosystems to climate variability on seasonal, inter-annual and decadal time-scales.
- To continue the development of a high quality environmental database on remote mountain lake ecosystems in Europe and to disseminate results widely to enhance public awareness, environmental education and environmental decision making.

The main deliverables of this project will be the development of predictive models for acidity, pollutant flux and climate variability that can be used in scenario assessment studies, especially those scenarios associated with present and forthcoming UN-ECE protocols and General Circulation Model (GCM) predictions for Europe. A desirable future objective would be the linking of these models to evaluate the interaction between acidity, trace pollutant and climate. However this must inevitably wait until a later phase of the research. In addition to model development, much of the field and laboratory work proposed is innovative for studies of such remote sites, especially:

- the focus on the seasonal dynamics of the lake system;
- the emphasis on nitrogen deposition and its biological impact;
- the study of microbial food webs in relation to acidity;
- the on-site collection and measurement of atmospheric pollutants;
- the use of radio-tracers to validate pollutant transport models;
- the study of trace metals (especially mercury) and trace organic uptake by fish;
- the on-site monitoring of climate conditions and their relationship to water column behaviour;
- the development of a methodology to infer climate trends from the high resolution analysis of recent sediments.

These objectives were unachievable four years ago because of the almost complete lack of information on remote arctic and alpine lakes. It is now possible to carry out such work because of the knowledge gained about individual sites from the AL:PE project with respect particularly to accessibility, morphometry, chemistry, biology, sediment accumulation rate and pollution status.

2. SPECIFIC OBJECTIVES FOR THE REPORTING PERIOD

Within work packages 1 - 3 (WP1, WP2 and WP3) the last working year of the project has been an intensive period, where the full sampling programme has been in operation until August /September 1998. After finishing the sampling period, sample preparation and analysis have been major topics. The integrating activities in work package 4 (WP4) follow the activities within the first three WPs. For the reporting period the specific objectives have been the following:

- Meteorology sampling and analysis, WP2 and WP3
- Deposition sampling and analysis, WP1 and WP2
- Snow sampling and analysis, WP2
- Major water chemistry sampling and analysis, WP1, WP2, and WP3
- Micro organic and heavy metal sampling and analysis, WP2
- Water column , WP1, WP2, and WP3
- Invertebrate analysis, WP1
- Zooplankton analysis, WP1
- Diatom analysis, WP1 and WP3
- Chironomid, Chrysophyte and Cladocera analysis, WP3
- Sediment trap sampling and analysis, WP2 and WP3
- Sediment core analysis, WP2 and WP3
- Soil core sampling and analysis, WP1 and WP2
- Fish analysis, WP1 and WP2
- Climate data collection and harmonisation, WP3
- Transfer of data, WP1, WP2, WP3, and WP4
- Critical load and food web modelling, WP1
- Pollutant flux modelling, WP2
- Climate/lake dynamics modelling, WP3
- Work package Workshops, WP1, WP2, WP3
- Quality Assurance programme, WP4
- Steering group meetings in Bled and Barcelona, WP4
- Project meeting in Bled in March 1998
- Project meeeting in Arcachon February 1999

3. SPECIFIC OBJECTIVES FOR THE FINALISING PERIOD

During six months from the end of February the project shall be entirely completed, and the final report summarising an in-depth evaluation of the results will be produced as a closing activitiy. The listed activities describe the specific objectives:

- Completion of the MOLAR databases
- Completion of all outstanding analysis and modelling work
- Preparation of manuscripts for publication in international journals, including two special volumes of Mem. Ist. Ital. Idrobiologia, and a special issue of the Journal of Paleolimnology
- Completion of a final report
- Preparatory work for presentations at the International Symposium on High Mountain Lakes and Streams, 4 – 8 September 2000, Innsbruck

4. MAIN ACTIVITIES UNDERTAKEN

4.1 MOLAR Work Package 1 (WP1)

MOUNTAIN LAKE ECOSYSTEM RESPONSE TO ACID DEPOSITION

Bente M. Wathne, NIVA

Activities within Workpackage 1 (WP1) and the twelve primary lakes chosen for study have been proceeding according to plan. The progress reported within MOLAR WP1 at the annual project meetings in Bled and Arcachon followed the main headlines given in the project proposal. The listed topics are addressed:

1. On site measurements of sulphur and nitrogen deposition
2. Seasonal variability of water chemistry
3. Seasonal variability of biota
4. Test hypothesis: histological and physiological attributes of fish indicate early acid stress
5. Test hypothesis: microbial activity in pelagic food web increases with acidification intensity
6. Evaluate applicability of various critical load models to mountain lake ecosystems, and develop a linked chemical-biological model for scenario assessment

Deposition and water chemistry
Measurements of deposition have been performed at 11 of the 12 primary lakes. All results are reported after QA procedures at the laboratories. All 12 lakes have been sampled for water chemistry, and all analytical laboratories have delivered their results. Results from deposition and lake water chemistry for 1996, 1997 and 1998 are stored by CNR and NIVA and after QA sent to the MOLAR database at UIB. Intercalibration exercises have been carried out both by CNR and NIVA. In November 1998 a Workshop on deposition and water chemistry was held in London, UK. Special emphasis was put on the intercalibration exercises, and analytical problems for some of the components and their possible solutions were discussed. Gradients in Europe within deposition of pollutants and water chemistry are now studied. Seasonal variations are followed at the sites, and present results show that the most important event affecting water chemistry is the snow melt, which in all the lakes cause a more or less distinct decrease in alkalinity, pH, calcium, and major ions. The synthesis paper on deposition and water chemistry of WP 1 for a special volume of Journal of Limnology, edited by the Istituto Italiano di Idrobiologia is in progress.

In the *benthic* invertebrate programme in WP 1, sorting and processing of qualitative and quantitative invertebrate samples is finished by UIB-ZI, Bergen. Species lists and data on seasonal variation have been obtained. The results are now being evaluated and manuscripts prepared. New information about biodiversity in remote mountain lakes of Europe has become available. The effects of altitude (as a proxy for climate), latitude, longitude, water quality and other physical and biological variables for the composition of benthic invertebrates have been evaluated. Altitude (indirectly climate) and pH of the water so far seems to be the most important variables determining the fauna composition (Fjellheim *et al.*, in press). Further statistical treatment, combining results from other workpackages, is expected to give more detailed understanding and improved conclusions. An overview of habitat use of different benthic organisms in remote mountain lakes in Europe has been compiled and will be available as a database. A manual has been prepared with the aim to ease chironomid identification and promote a more uniform approach to taxonomy by the different workers within the project (Schnell, 1998). Also, a coding system for European chironomids has been published. (Schnell *et al.*, 1998).

Test-fishing and following age determination are finalised in seven lakes as planned. All heavy metal analysis in kidney and liver, as well as mercury in muscle has been carried out. Liver histology, blood plasma ions and liver enzymes activities have been analysed and measured. Analysis of micro-organic pollutants in fish have been finalised and reporting of the results is in progress.

Pelagic food webs 1st level has been investigated in 12 lakes. Field work was completed last year, and microbiological analyses of preserved samples from 1997 are now completed and the database established. In lakes with the highest total biomass, total organic C concentrations were the highest, the biomass of phytoplankton were high, and the ratio of autotrophic to heterotrophic microbial biomass was above 10 or more. No relation of total biomass or their particular components to pH or alkalinity was found. *Pelagic food webs 2nd level* is investigated in 6 lakes during the ice-free seasons in 3 to 5 depths. Field work has been completed. Analyses of data have been carried out, and their final interpretation has been completed in conjunction with 1st level data (biomass plus species composition of phyto- and zooplankton), and with chemical data (chlorophyll, organic carbon, nutrients). A project workshop on pelagic food webs was organised in November 1998 in Pallanza, covering summary of results, comparison of methods, discussion on structure of databases, and preparation of a special volume of Memorie del Istituto Italiano di Idrobiologia devoted to pelagic food webs.

The *MAGIC model* for trends and prognosis has been used for three lakes and work is ongoing for the last three. Special workshops have been arranged to carry out the calculations and discuss the necessary data from the sites. Reporting for the sites are planned and started. A Workshop for deposition, water chemistry and modelling was arranged in London in November 1998.

4.2 MOLAR Work Package 2 (WP2)

MEASURING AND MODELLING MAJOR ELEMENT AND POLLUTANT FLUXES IN MOUNTAIN LAKES AND THEIR IMPACT ON FISH

Roland Psenner, UIBK

Workpackage 2 (WP2) comprises 6 primary (Gossenköllesee (GKS), Estany Redó (RED), Lochnagar, Øvre Neådalsvatn (NED), Jörisee III, Starolesnianske Pleso) and 3 secondary sites (Stavsvatn, Laghetto Inferiore, Lago Paione Superiore). Topics of WP 2 are: Bulk deposition and snow pack: ions, ^{210}Pb, PCB, PAH, SCP; Lake water physics, chemistry (including hydrology); Distribution (speciation) of ^{210}Pb, PCB, PAH, and metals in lake water; Sedimentation of ^{210}Pb, PCB, PAH, SCP; Sediment cores: PCB, PAH, ^{210}Pb, ^{137}Cs , SCP; Soil inventory of ^{210}Pb and ^{137}Cs in the catchment; PCB, PAH, and metals in fish; Modelling the transport of elements and pollutants.

The main goal of WP2, i.e. to measure the fluxes and pathways of ions, metals, radionuclides, persistent organic pollutants and spheroidal carbonaceous particles, has been achieved and high quality data on concentrations, inventories, distributions and fluxes of these parameters have been collected. An almost complete list of depositional fluxes to catchments, lake surface and sediments have been obtained for three lakes (GKS, RED, NEO) and an impressive number of measurements is now available for all six primary sites. Data analyses have been completed, and evaluation and cross-comparison are under way. Conceptual models for the transport of particles, the deposition of radionuclides and the uptake of organic pollutants by fish have been developed. The results clearly show that high mountain lakes are remote though not pristine, and the selection of lakes has evidenced that there exists a degree of impact across Europe, for instance regarding the deposition of acids, heavy metals and organic pollutants. Since transport and redistribution of particles, acids, metals, natural radioisotopes (^{210}Pb), anthropogenic radioisotopes (^{137}Cs) and chlorinated hydrocarbons such as DDT and DDE are dominated by very different meteorological, physical and chemical factors, a complex picture of impacts and responses emerges: beside distance of source, air temperatures, altitude, geographical location, water chemistry, water renewal time, and snow melt processes play an important role. The reaction of the biota shows that chemical analysis of toxic substances can explain only part of the measured impact, and there are other environmental factors (including food web structures) that modulate the response of organisms. Although our results reflect the complex pattern of impacts, pathways and effects, there are still some open questions remaining, for instance regarding the role of hydrology and catchment characteristics.

WP2 workshops on data gathering and comparisons was held in January '99 in Blatna, Czech Republic and in February `99 in Arcachon, France (fish).

4.3 MOLAR Work Package 3 (WP3)

CLIMATE VARIABILITY AND ECOSYSTEM DYNAMICS AT REMOTE ALPINE AND ARCTIC LAKES

Richard W. Battarbee, UCL

4.3.1. Introduction

In this work package we have explored the relationships between short-term variations in weather patterns (from automatic weather stations) and water column behaviour and between longer term climate trends (from 200 year long instrumental records) and proxy climate records from dated sediment cores. We have also attempted to calibrate dynamic lake models using water column data from the study sites with a view to forecasting probable lake behaviour under different climate scenarios.

4.3.2. Sites selected

The lakes in this study share the same basic limnological characteristics. They are oligotrophic, typically dimictic and have a winter ice-cover and a summer thermocline. They are all situated above or beyond the regional tree-line, and they have poorly vegetated catchments.

Most of the sites were included in the AL:PE 2 study, and belong to the group of sites identified in that study to be least influenced by acid deposition and other pollutants. Additional sites that provide the study with a wider geographical and chemical range are located in Finland, Austria, Switzerland and Slovenia.

The sites are: Øvre Neådalsvatn (Norway), Saanajärvi (Finland), Gossenköllesee (Austria), Hagelsee (Switzerland), Jezero Ledvicah (Slovenia), L. Redo (Spain, Pyrenees), L. Cimera (Spain, Gredos, secondary site) and Terianske Pleso (Slovakia).

4.3.3. Objectives and results

Objective 1:

-To obtain and harmonise instrumental weather records over the last 200 years for all study regions,

- to model the relationship between climate records for mountain weather stations (at study sites) with those for lowland stations, and

- to calculate surface water temperature and ice-cover at the study sites.

Ten regions of Europe were selected for new homogenisation studies. In each region a local network of stations was identified allowing the construction of an independent climate series. Following homogenisation, time-series and spatial analysis of the 16 data sets (from 1781 to the present day) was used to provide an accurate base for validation work across the full range of remote sites in the project.

The accuracy of the individual reconstructions was tested using data from the on-site automatic weather stations. These showed a high skill factor for the model, especially for the Scottish and Norwegian sites. The poorest performance was observed for the Alpine sites owing to the occurrence of summer inversions.

The on-site temperature reconstructions allowed the calculation of annual and decadal means for each calendar month, an index of continentality (winter – summer means) and the period of ice-cover. Ice cover was calculated simply as the number of days with temperature below zero, or more accurately by subtracting the number of negative degree days from the number of positive degree days for each year. However, at Hagelseewli in Switzerland the relationship between air temperature and water temperature was poor due to the shading effect of a high cliff face on the south side of the lake.

Objective 2:
To assess the seasonal variability of physical, chemical and biological characteristics of study lakes.

In order to assess how lake chemistry and biological communities respond to changes in ice-cover, light penetration, temperature change, stratification and mixing, essential water column data (temperature, oxygen, pH, conductivity and chlorophyll-a) were collected at bi-weekly intervals in the ice-free season, and at the beginning, middle and end of the ice-cover period depending on conditions. Samples for major ion (Ca, Mg, Na, K, alkalinity, Cl and SO_4) and nutrient (N, P, dissolved SiO_2) chemistry, phytoplankton (diatoms and chrysophytes) and zooplankton analysis were, on average, collected at monthly intervals. Benthic diatoms and chironomid sampling was carried out along transects perpendicular to the shoreline using scuba to sample deep-water habitats.

The data show that the lakes have surface temperature minima from 3.4 – 7.6^0 C to 9.6 – 14^0 C, range in chlorophyll a (Chl a) values from less than 1 mg l^{-1} to about 4 mg l^{-1} and are well oxygenated. However, several sites show severe deeper water oxygen reductions in winter with values between 0 and 4 mg l^{-1}. The pH of the lakes reflects their catchment bedrock. The two calcareous lakes (Hagelseewli and Ledvicah) have pH values varying between 7.8 and 8.0, whilst most other sites on crystalline bedrock have acidic pH values varying between 5.3 (associated with the spring melt period) and 7.0.

The lakes vary seasonally with respect to heat flux, pH and Chl a concentration. The pH fluctuations are greatest at the most productive sites reflecting seasonal differences in production and respiration. Chl a values also fluctuate markedly through the year. In most cases peak values occur during autumn turnover, although at sites with longer ice-free periods, two maxima (spring and autumn) occur.

Vertical gradients are also marked with up to a 10^{0}C difference occurring between the epilimnion and hypolimnion during summer stratification. The Chl a maximum typically occurs at the metalimnion, reflecting the optimum combination of light and nutrient concentration for algal photosynthesis. Rates of oxygen depletion vary according to lake depth and productivity, with losses being rapid and episodic in shallower lakes, slower and more progressive at deeper, oligotrophic sites. At some sites low hypolimnetic oxygen concentrations are accompanied by an increase in Mn indicating probable releases of phosphorus taking place.

Objective 3:
To harmonise taxonomy of key indicator taxa and model their distribution in relation to environmental

variables.

In MOLAR we have built on previous ALPE knowledge by (i) harmonising taxonomic procedures with those of new participants (from Switzerland and Finland); (ii) developing a taxonomic system for chrysophytes and chrysophyte cysts and (iii) refining local and regional training sets for pH and temperature reconstruction.

Objective 4:
To establish long-term variability in ecosystem dynamics from recent palaeolimnological records and to compare the sediment record with the instrumental record of climate variability (see above).

The longer term (decadal) lake variability was assessed from a high resolution analysis of recent sediments. The key biological remains (benthic and planktonic diatoms, chrysophyte cysts, cladocera and chironomids) were analysed, along with analysis C, N, pigments and the mineral fraction of the sediment derived from the lake catchment.

Replicate core samples of the upper sediment were taken with a wide-diameter piston corer from each site. The uppermost 20 cm of sediment was sub-sampled at contiguous 2 mm or 2.5 mm intervals to provide an average sample resolution of 5-10 years. In the laboratory the dry weight, wet density and loss-on-ignition of each sample was measured.

One core from each site was dated using ^{210}Pb, ^{137}Cs and ^{241}Am and a calendar year chronology was constructed for each dated core to allow comparisons between the sediment record and the instrumental temperature record.

Cores were correlated at each site on the basis of dry weight and loss on ignition measurements using sequence slotting procedures. This exercise allowed chronologies to be transferred between cores.

Data from all core analyses were transferred to the central database, and processed to make comparisons with the reconstructed instrumental climate record for the last 200 years. Linear regression analysis was used to find any potential relationships between the biological and sediment response variables and the instrumentally reconstructed climatic variables (= predictor variables). The species composition data for diatoms, chironomids, chrysophytes, and cladocerans, were summarised as principal component axes prior to being used as response variables. To harmonise the climatic predictors and the response variables, the climatic variables were smoothed along time with a LOESS regression.

Although many of the relationships between climate predictors and sediment responses were statistically weak the analyses indicated significant correlations between temperature and loss on ignition, diatom-inferred pH, and PCA axis 1 for diatoms and chironomids at some sites.

Data from cores at several sites shows clear evidence for the impact of climate change with increases in the proportion of planktonic diatom taxa occuring at a number of sites over recent decades.

Objective 5:
To model the relationship between weather patterns and water column dynamics and chemistry.

The lake model DYRESM was explored to relate weather patterns to water column dynamics and chemistry. Despite progress in customising the model to mountain lake conditions difficulties were experienced with simulating the break-up of ice in spring. In addition the requirements for frequent wind input to the model were greater than the field data available.

The model AQUASIM was also evaluated. In this case the model simulates water column turbulence quite sensitively, but does not yet include the capacity to model ice behaviour.

4.3.4. Conclusions

Air, water temperatures and ice-cover can be modelled with good skill at remote mountain lakes, using data transferred from lowland meteorological stations.

Fine resolution analysis of cores from remote mountain lakes situated in relatively unpolluted regions of Europe show coherent variations over the last 200 years that are probably related to climate influences.

Core records can be compared with instrumental climate records, although the accuracy of the comparison depends on sediment accumulation rates and the accuracy of sediment dating. A decadal resolution is possible in most cases.

Climate impact on mountain lakes is registered most clearly in the sediment by changes in organic matter, changes in diatom phytoplankton and changes in chironomid assemblage composition.

Currently available lake models need substantial modification, especially with respect to ice behaviour, if they are to be used to predict accurately the impact of future climate change on mountain lakes.

4.4 MOLAR Work Package 4 (WP 4)

INTEGRATING ACTIVITIES

Simon Patrick, UCL

The MOLAR programmes of chemical and biological harmonisation and quality control have proceeded as planned.

The relational database established at the Botanical Institute, University of Bergen, Norway has been re-structured to consist of two parts. One part is an 'Access' database where all the data of an approved quality will be stored. Data that are not meaningful by themselves are not stored here. For example, biological species data with inconsistent taxonomy are not stored in this part of the database. The data are being sorted hierarchically by work-package, lake, and thereafter according to the importance of the data within a specific work-package. The second part will consist of 'Excel' files for placement on the WWW. Here all the available data are being placed on a server in Bergen and admission to the data will be restricted by a password. The data on the WWW will hopefully be accessible during July 1999, and the 'Access' database will hopefully be ready within the same time schedule. An ongoing examination of ways in which the database should be amended to maximise its efficiency for ongoing MOLAR purposes is being undertaken. The system of transferring data from site operator and/or laboratories to scientists with overall responsibility for key scientific areas, for checking prior to onward transfer to the database has proceeded smoothly.

The MOLAR WWW site:
(http://prfdec.natur.cuni.cz/hydrobiology/molar/welcome/htm) has been updated, enlarged and its format restructured. Hypertext links to individual laboratories and other relevant projects and an on-line list of reports, publications and presentations from the AL:PE/MOLAR project have been inserted. A facility to access MOLAR data from the Bergen database via the MOLAR Web site is currently being developed (see above).

Advanced arrangements are in place for an international conference "High Mountain lakes and Streams, indicators of a Changing World", to be held at Innsbruck, Austria in September 2000. Funding support has been secured from the EU and national organisations. The first call for papers has been circulated, Organisation and Scientific committees have been appointed and the conference advertised widely via brochures, posters and the WWW.

Publicatios and presentations

The list of MOLAR publications and conference presentations, published, or in press to date are given below in the joint publication list.

5. JOINT PUBLICATIONS

Both publications that are submitted to different journals and publications already published are cited.

MOLAR Home page on Internet (http://prfdec.natur.cuni.cz/hydrobiology/molar/welcome/htm)

Agusti-Panareda, A., Thompson, R. and Livingstone D. M. (1999). Reconstructing climatic variations at high elevation lake sites in Europe during the instrumental period. *Verh. Internat. Verein. Limnol.*, 27 (in press).

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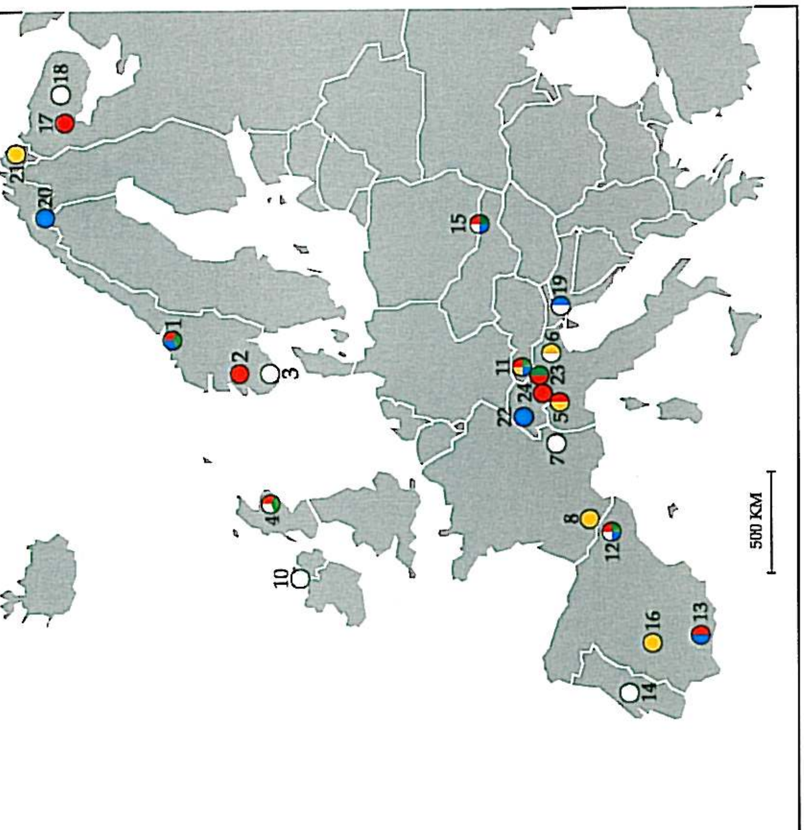
Figure 1. MOLAR sites: distribution, location of Work Packages and relationship with the AL:PE network



Site nr.	Site name MOLAR/AL:PE	MOLAR WP1	MOLAR WP2	MOLAR WP3	MOLAR secondary	Other AL:PE site
1	Ø. Neådalsvatn	●	●	●		
2	Stavsvatn	●				
3	Lille Hovvatn					○
4.1	Lochnagar	●	●			
4.2	Sandy Loch					○
4.3	Loch nan Eun					○
5.1	Lago Paione Superiore	●				
5.2	Lago Paione Inferiore.				●	
6.1	Lago Lungo					○
6.2	Lago di Latte				●	
7.1	Lac Rond					○
7.2	Lac Combeynod					○
7.3	Lac Blanc					○
7.4	Lac Noir					○
8	Etang d'Aubé				●	
9	Arresjøen				●	
10	Lough Maam					○
11.1	Schwarzsee ob Sölden				●	
11.2	Gossenköllesee	●	●	●		
12.1	Lago Aguilo					○
12.2	Lago Redo	●	●	●		
13	La Caldera	●				
14	Lagua Escura					○
15.1	Starolesnianske Pleso	●	●			
15.2	Terianske Pleso			●		
15.3	Dlugi Staw	●				
15.4	Zieloni Staw					○
16	Laguna Cimera				●	
17	Chuna	●				
18	Chibini					○
19.1	Zgornje krisko jezero					○
19.2	Jezero Ledvicah			●		
20	Limgambergtjørn				●	
21	Saanajärvi			●		
22	Hagelsee			●		
23	Jörisee	●	●			
24	Laghetto Inferiore	●				

SUMMARY PROGRESS REPORT OF MOLAR

PART B

DETAILED REPORTS OF THE INDIVIDUAL PARTNERS

01	University College London, UK (*administrative coordinator*)	(UCL)
02	University of Helsinki, SF	(UHEL)
03	University of Edinburgh, UK	(UED)
04	Norwegian Institute for Water Research, N (*scientific coordinator*)	(NIVA)
05	Universität Innsbruck, Institut für Zoologie, A	(UIBK)
06	Austrian Academy of Sciences, Limnological Institute, A	(ILIMNOL)
07	Universidad de Barcelona, ES	(FBG)
08	Universidad de Granada, ES	(UGR-ES)
09	University of Bordeaux (URA CNRS), Arcachon, F	(CNRS)
10	Consejo Superior De Investigaciones Cientificas, Barcelona, ES	(CSIC)
11	University of Bergen, Botanical Institute, N	(UIB-BI)
12	University of Bergen, Institute of Zoology, N	(UIB-ZI)
13	CNR-Istituto Italiano di Idrobiologia, Pallanza, I	(CNR-III)
14	University of Liverpool, UK	(ULIV)
15	Institute for Environmental Science and Technology, Dubendorf, CH	(EAWAG)
17	Charles University, Prag, Czech Republic	(FSCU)
18	Hydrobiological Institute, Ceske Budejovice, Czech Republic	(HBI-ASCR)
19	Institute of Zoology, Bratislava, Slovak Republic	(IZ-SAS)
20	Polish Academy of Sciences, Institute of Freshwater Biology. Kracow, PL	(IFB-PAS)
21	National Institue of Biology, Ljubljana, Slovenia	(NIB)
22	Kola Science Cebtre, Apatite, Russia.	(INEP)
23	Laboratorio Studi Ambientale, Sezione aria e aqua, Ticino, CH	(LSA)

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period:
March 1998 - February 1999

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I. OBJECTIVES FOR THE REPORTING PERIOD:

Ongoing project coordination

Work Package 1
1. completion of catchment/soils database for WP1 sites,
2. application of static critical load models to all WP1 sites,
3. application of dynamic critical load model (MAGIC) to 6 selected WP1 sites; 3 acid sensitive/acidified (Lochnagar, Starolesnianske Pleso, Stavsvatn) and 3 less sensitive/non-acidified (Estany Redó, Gossenköllesee, Øvre Neådalsvatn),
4. data interpretation,
5. production of draft manuscripts for publication,

Work Package 2
1. complete MOLAR sampling at Lochnagar,
2. complete SCP analyses of all received samples,
3. data interpretation,
4. production of draft manuscripts for publication,

Work Package 3
1. harmonisation of diatom samples to be added to the AL:PE training set,
2. completion of diatom, chrysophyte analyses for cores, living communties and sediment trap samples,
3. transfer of data to central database in Bergen,
4. application of calibration datasets to down-core assemblages,
5. integration of WP3 sub-areas

II. OBJECTIVES FOR THE NEXT PERIOD:

Work Package 1

1. Completion of all modelling and intercomparison of acidification status of WP1 sites and modelling approaches,
2. assessment of the modelling issues specific to high mountain lakes,
3. completion of final report and manuscripts for publication.

Work Package 2

1. Completion of all outstanding sample analyses,
2. completion of final report and manuscripts for publication.

Work Package 3

1. Completion of few remaining analyses,
2. writing papers for Journal of Paleolimnology and Mem. Ist. Ital. Idrobiol. MOLAR special issue volumes, editing of those volumes.

PART B

III. Are there any particular problems ? Is your part of the project on schedule ?

Work Package 1

The first of the above objectives has not yet been achieved, with catchment soils data outstanding from 3 sites (Laghetto Inferiore, Stavsvatn and Øvre Neådalsvatn). However, site operators have completed primary data collection at these sites and modelling work can now proceed when these data have been transferred to the WP1 catchment database at ECRC. As a result of the incomplete soils database, static modelling has yet to be completed for intercomparison of WP1 sites. Dynamic modelling has however been completed for three of the six selected sites (Estany Redó, Gossenköllesee, Starolesnianske Pleso) and is ongoing at the remaining three sites. All acidification and critical load modelling work should therefore be completed by the end of March 1999.

Work Package 2

Of the above objectives the first two are completed, whilst the latter two are in progress. This part of the project is therefore on schedule. However, problems have arisen due to the delay in receipt of samples from other site operators. Consequently, although analyses of all received samples have been completed, some samples are still to be received and therefore analysis and interpretation have been delayed. The operators of these sites are well aware of the outstanding requirements and all samples should be received soon.

Work Package 3

No particular problems. WP3 is more or less on schedule. Draft manuscripts are expected by May 1999 for both volumes.

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS* (use other pages as necessary but preferably no more than 2)

Work Package 1

1. *Gossenköllesee (GKS)*: Calibration of the MAGIC model for GKS highlighted several important issues for acidification and critical load modelling. The first major problem identified was that the water budget for the lake was highly uncertain and the lake catchment poorly defined because of a complex geology/geomorphology with unknown subsurface flow routing. This prevented the calculation of mass balances for the acidic species of interest. The site operator has since resolved the problem with a lithium tracer experiment in the lake which has provided a value for the residence time of the lake and an estimate of the catchment area, both of which appear to change on a seasonal basis. The issue of complex hydrology may prove to be a characteristic of high alpine lakes. A second finding of the modelling work was that a sulphur mass balance can only be achieved if weathering inputs of sulphur are greater than atmospheric inputs. The weathering input would cause problems in critical load applications if the site were acidified, because it would be important to accurately quantify the weathering flux of sulphur in order to attribute the proportion of sulphur derived from atmospheric inputs and hence the critical load exceedance. However, GKS is the least acid of the six dynamic modelling sites, and there is no critical load exceedance or reported damage to acid sensitive biota. The atmospheric input of acidity is very small compared with the buffering effects of weathering, and because weathering is the primary source of sulphur, different future deposition scenarios with reduced sulphur deposition show little effect on lakewater chemistry according to the MAGIC model.

2. *Estany Redó*: In order to calibrate MAGIC at Estany Redó, it was first necessary to balance sulphate and chloride fluxes, and this could only be achieved by a reduction in measured deposition inputs by a third. The assumed explanation for this mismatch in acid anion fluxes was that much of the winter precipitation runs off as snowmelt under the ice without mixing into the body of the lake, and monthly water sampling would miss this peak output of acid anions. This is likely to be an important process at all high mountain lakes which are frozen for a large part of the year. MAGIC was successfully calibrated for Estany Redó, and the hindcast showed only minor changes in acidification status, with a reduction in ANC from pre-industrial levels of c. 75 μeq/l to the current value of c. 50 μeq/l. The lake is not acidified in the sense of having an ANC which has been depressed below a critical threshold (taken here to be 20 μeq/l or 0 μeq/l), and there has been no reported damage to acid-sensitive biota. An interesting observation is that only 25% of N deposition is retained in catchment soils, a much lower proportion than observed in lower altitude lake catchments, and this is attributed to the thin, sparse soil and vegetation cover along with low temperatures. Again, these characteristics are likely to be found at most high mountain lakes, and could be particularly important at more acid sensitive sites where low terrestrial N retention could contribute to acidification and ANC decline. A mismatch between hindcast calcium concentrations in lakewater and measured values could not be attributed to changes in base cation deposition (which follow the opposite trend) or dilution by greater precipitation levels in recent years (because other ions were not similarly affected) and it is hypothesized that climatic changes may have increased the weathering rate of calcium in the catchment from the more weatherable calcite rocks, relative to the weathering inputs of other ions. Three future deposition scenarios were tested, including possible changes in base cation deposition (which is potentially very variable at this site due to changing contributions of Saharan dust from the south) but none were found to lead to acidification using the MAGIC model.

3. *Starolesnianske Pleso*: The MAGIC model was successfully calibrated for Starolesnianske Pleso, and this was the first of the dynamic modelling sites to show a strong historical acidification. MAGIC hindcasts indicate a steady decrease in soil base saturation from the mid-nineteenth century to the present, with lakewater pH declining from a pre-industrial level of c. 6.4 to a minimum of c. 4.8 in the early 1980s, since when it has recovered slightly to the present value of c. 5.0. Lakewater ANC declined from a pre-industrial baseline of c. 35 μeq/l to a minimum of -30 μeq/l in about 1985, indicating a very severe acidification. While ANC had recovered to c. -15 μeq/l by 1997, MAGIC forecasts indicate a recovery to just c. 10μeq/l within the next 50 years even assuming that the large predicted reductions in emissions under the EU "REF" scenario are met (equivalent to a c. 60% reduction in S deposition from a 1990 baseline across all Europe). The MAGIC model therefore indicates that much more stringent reductions in acidic emissions would be required to allow full recovery of lakewater chemisty at this site. Preliminary inspection of the data indicates that the modelled patterns of acidification and recovery fit well with observed chemical and biological data, and this will be explored more fully in the ongoing report writing.

Similar methodologies to those employed above will be applied to the three outstanding dynamic modelling sites (Lochnagar, Stavsvatn, Øvre Neådalsvatn), and the effects of comparable future depostion scenarios on the total number of six lakes will be assessed. MAGIC model outputs will also be critically compared with static critical load model outputs at all WP1 sites, using three model, the steady-state water chemistry model (SSWC), the diatom model and the first-order acidity balance model (FAB).

Work Package 2

Many of the analyses undertaken had not been attempted previously (SCP in atmospheric deposition, lake and stream waters, snow) whilst others had no established sampling or analytical protocols in the literature (e.g. SCP in soil profiles). Protocols therefore had to be established and developed as part of the project. In addition, no attempt had previously been made to determine the representativity of a single SCP core in a whole lake basin, or how an SCP profile from the deepest part of the lake might over-estimate the whole basin inventory. Similarly, it was unknown how episodic SCP deposition was at remote mountain sites subjected to varying depositional regimes. More than 900 SCP analyses have been undertaken so far and as a result a significant body of information now exists on these questions.

Samples of atmospheric deposition and snowpack were taken such that at all sites an annual deposition of SCP per unit area could be calculated. Therefore a total number of SCP deposited directly on to the lake and catchment could be calculated. In addition, dry only and wet only sampling at Redo suggested approximately equal contributions to total deposition. A single lake sediment core was taken from the deep water areas of each of the six sites, ^{210}Pb dated and analysed for SCPs. At Lochnagar, 16 sediment cores were analysed for SCP. This multi-core approach showed that extrapolation from a single deep water core can overestimate the SCP storage by 2-3 times. A single soil core was analysed for each site and in general these data agreed with expected results i.e. highest concentrations at Lochnagar, Starolesnienske > Redo > Gossenkollesee > Øvre Neådalsvatn. At Lochnagar it was found that 67% of total deposited SCPs were stored within the soils and 33% in sediments. This is in reasonable agreement with Pb and Hg.

Sediment trap sampling varied considerably within the sites and little interpretative work has so far been done on the data. Lake and stream samples represent the source of greatest uncertainty in the SCP dataset and this is due to the impracticality of sampling large volumes at a high frequency. Such work had never been attempted before. It is expected that SCP in lake water will vary considerably depending on depositional episodes, the particle settling velocities and the water residence times of the lakes. The scant data appear to support this, but much more detailed work is needed for confirmation.

When these data have been fully interpreted a great deal of previously unknown information regarding the distributions of SCP within mountain lake ecosystems as well as information regarding deposition patterns and even possible source regions for episodes will have been produced.

<u>Work Package 3</u>

For the comparison of sediment records with the instrumental climate record a different approach from the transfer function approach has been used. (although in the near future we will harmonise taxonomy and add the new MOLAR and a number of other sites to the AL:PE diatom calibration set). At a workshop in Bergen (November 1998) response variables were compared directly (reduced to Principal Components) with the instrumental reconstructions of climate. r^2 and p values tabulated for these data and significant correlations have been found (Grytnes & Birks).

Diatom & chrysophyte work has been completed with the exception of some epilithic diatom work which will be completed for the 'Memorie' data volume within the next month (February/March 1999).

Following the Bergen workshop all data: instrumental climate; chronology; response variables, have been transfered to Bergen (with the exception of that from Laguna Cimera). Following discussions at the Arcachon MOLAR meeting (February 1999), data from a number of sites will be revised (chronologies) or added to (pigments) and data from the 'secondary site' Laguna Cimera also included. A number of analyses will be repeated before producing the discussion of the two WP3 volumes.

As outined above a new approach to climate instrumental-core data comparison has been used. Essentially in this part of MOLAR WP3 we know with some confidence what the climate (eg. mean annual temperatures, ice cover period) at each mountain lake was 1781-present. We therefore have moved away from the transfer function approach (used to reconstruct past climate from core data) and have attempted to compare core response variables with the known climate variables (validation). In this way we have integrated all parts of WP3, along with parts of WP1 (monitored response of diatoms to climate at some sites) and WP2 (reconstruction of on-site climate data). In this way WP3 (and WP1/WP2) has been highly successful in integrating different types of research and has produced data which will enable us to select appropriate climate response variables for climate reconstruction from sediment core data in pre-instrumental times (eg. using a transfer function approach) and for further research into the processes of climate response at mountain lakes.

V. List of Publications arising from the project (include copies):

Rose, N.L., Harlock, S. & Appleby, P.G. (in press). The spatial and temporal distributions of spheroidal carbonaceous fly-ash particles (SCP) in the sediment records of European Mountain lakes. *Water, Air and Soil Pollution.*

N. G. Cameron, H. J. B. Birks, V. J. Jones, F. Berge, J. Catalan, R. J. Flower, J. Garcia, B. Kawecka, K. A. Koinig, A. Marchetto, P. Sánchez-Castillo, R. Schmidt, M. Šiško, N. Solovieva, E. Stefkova & M. Toro Valasquez (1999). Surface-sediment and epilithic diatom pH calibration sets for remote European mountain lakes (AL:PE Project) and their comparison with the Surface Waters Acidification Programme (SWAP) calibration set. Journal of Paleolimnology (in press)

Patrick, S., Battarbee, R.W., Wathne, B. & Psenner, R. (1998) Measuring and modelling the dynamic response of remote mountain lake ecosystems to environmental change: an introduction to the MOLAR project. In: K. Kovar, U. Tappeiner, N.E. Peters & R.G. Craig (Eds), *Hydrology, Water Resources and Ecology in Headwaters.* IAHS, 403-410.

Battarbee, R.W., Patrick, S., Wathne, B., Mosello, R. & Psenner, R. Measuring and modelling the dynamic response of remote mountain lake ecosystems to environmental change (the MOLAR project) - Proceedings of SIL, Dublin, August 1998 (in press).

Signature of Partner:

Date: February 16th 1999

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: 1 March 1998 – 28 February 1999

Partner: University of Helsinki, UHEL

Principal Investigator: Atte Korhola

Scientific staff: Sanna Sorvari, Milla Rautio, Laura Forsström, Seppo Hassinen

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I. OBJECTIVES FOR THE REPORTING PERIOD:

- Complete all physico-chemical and biological analyses of the contemporary data
- Collect and analyse all meteorological data
- Collect supplementary cores for pigments and cladocera and analyse them
- Complete all analyses for core material, including dating, SCP, mineral magnetics, pigments, C, N, S, chrysophytes, chironomids, diatoms, and cladocera.
- Carry out statistical analyses of the data
- Report the results

II. OBJECTIVES FOR THE NEXT PERIOD:

PART B

III. Are there any particular problems ? Is your part of the project on schedule ?

No problems.
The project is on schedule.

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS* (use other pages as necessary but preferably no more than 2)

METHODOLOGY

Methods for water column profiling and phyto- and zooplankton sampling has been reported in previous progress reports. Only one water column sampling was performed (12.5.1998) during this reporting period. All the analyses from water (NH_4-N, NO_3-N, TN, TP, Ca, Na, Mg, K, Cl, SO_4) and from biota (chlorophyll a, phyto- and zooplankton) samples were carried out in autumn 1998.

Two new sediment cores were collected in May due to non-sufficient amount of material for pigment and Cladocera analyses in the previous cores taken in 1996. The cores were collected with a Glew corer from the deepest part of the lake (24 m) from ice near the place where the cores were taken in 1996. The cores were extruded in the laboratory within two hours from the sampling, the pigment core at 2 mm intervals from 0 to 10 cm and the Cladocera core at 5 mm intervals from 0 to 15 cm. Loss-on-ignition analyses were carried out immediately after extruding. The pigment core was stored frozen and transported to Dr. Andrea Lami, Pallanza (Italy) for pigment analyses.

Samples for Cladocera analysis were first heated for half an hour in 10 % KOH and then poured through a 50 µm sieve. The remaining sediment on the sieve was washed into a 15 ml tube, and 2-3 drops of safranin-glycerin solution were added to colour the Cladocera remains. 200 µl of the sample was examined for Cladocera remains.

Diatoms from transect samples and sediment traps collected during earlier reporting periods were analysed in autumn 1998. In the laboratory extra water from transect and trap samples was centrifuged and Lugol's Iodene was washed away. Like subfossil diatom samples, transect and trap samples were treated with H_2O_2 and HCl, afterwards slides were mounted in Naphrax. Microspheres were added to the trap samples.

All analyses (Pb-210, Cs-137, SCP, magnetics, dry-weight, LOI, pigments, diatoms, chrysophytes and cladocera) from sediment cores have now been completed. Statistical analyses and reporting these results are in progress.

RESULTS

The sediment of lake Saanajärvi was found to be poor in cladoceran remains; only 10 taxa were identified and mostly in very low numbers. *Daphnia longispina* dominated throughout the core with the proportions always exceeding 50% of the total number of Cladocera remains. Until 1900 the cladoceran community seemed to have been extremely scarse, after which there is a distinct increase especially in the *D. longispina* population. Similar increased abundances were observed among *Bosmina longispina*, *Alona affinis*, *A. quadrangularis*, *Acroperus elongatus*, *Alonella nana*, *Al. excisa*, *Chydorus sphaericus*, and *Eurycercus lamellatus*, althought the shift in these species occurred about 20 years later than in *D. longispina*.

A total of 132 diatom taxa were enumerated from transect samples. First 7 epilithon samples were dominated by *Achnanthes minutissima*, *Brachysira vitrea* and *Denticula tenuis*. These taxa were accompanyed with *Cocconeis placentula* and various *Achnanthes*, *Cymbella* and *Gomphonema* species. The shift from epilithic communities to sediment-associated and planktonic communities was clear; planktonic species like *Cyclotella comensis*, *C. glomerata*, *C. rossii* and *Thalasiosira pseudonana* increased markedly when moving from rock surfaces to sediments. Also certain benthic species such as *Fragilaria brevistriata*, *F. pseudoconstruens*, *Navicula minima v. minima and Navicula schassmannii* occurred in high numbers in sediment samples.

Planktonic and tychoplaktonic taxa *Aulacoseira subarctica* type I, *Cyclotella comensis*, *C. rossii*, *C. glomerata* and *Thalassiosira pseudonana* were the most dominant diatoms in sediment trap samples. These taxa were present in high numbers in 1996 but were almost absent during open-water period in 1997. In the beginning of the autumn overturn 1996 *Cyclotella comensis* had its production maximum (5.1 $x10^5$ valves/l suspension), followed by a production peak of *C. rossii* (max. 1.9 $x10^5$ valves/l suspension) later in overturn period. *Thalassiosira pseudonana* had a clear under-ice production maximum (1.6 $x10^5$ valves/l suspension) in winter 1996/97. *Aulacoseira subarctica* type I was the dominant taxon in July 1997 (max. 0.4 $x10^5$ valves/l suspension). Total chrysophyte cysts numbers varied from 1.1 $x10^5$ to 6.9. $x10^5$ cyst/l suspension; the highest values were observed in July 1997.

Saanajärvi is a dimictic and ultra-oligotrophic lake (mean chlorophyll a = 4.4 mg/m^2) with phytoplankton maximum during autumn overturn. The most dominant algae group is golden algae, Chrysophyta. Zooplankton density is low, only four species appear in reasonable abundances. Most chemical parameters are relatively constant throughout the year; mean pH is 7.1, alkalinity 164.4 μeq/l and conductivity 27.6 $\mu S\ cm^{-1}$. The only clear exception occurs during the very short period in the spring when meltwaters feed the lake with acid compounds and nutrients. Despite the spring support from the catchment, nutrient status of Saanajärvi is extremely low: PO_4-P is most of the time under detection limit, nitrate (NO_3-N) varies from 0 to 383.5 $\mu g\ l^{-1}$ and ammonium (NH_4-N) between 0 and 68.9 $\mu g\ l^{-1}$.

Core investigations suggest that there was a marked increase in lake productivity starting from the 20th century. Measured values of total carotenoids and chlorophyll derivates increased, and there was a reciprocal change in diatom community toward the dominance of planktonic taxa. At the same time a distinct increase in *Daphnia longispina* population and a rise in accumulated organic matter were also observed. The community and production changes are most likely associated with a marked post-Little Ice Age increase of 1.5-2°C in mean annual and summer temperatures that started around 1850 and culminated at 1930's and affected the stratification and thermal stability of the lake. All biostratigraphical proxies showed significant correlations with mean annual temperatures, reconstructed specifically for the site for the last 200 years using an European-wide meteorological data-set.

V. List of Publications arising from the project:

Sorvari, S. & Korhola, A. 1998. Recent diatom assemblage changes in subarctic Lake Saanajärvi, NW Finnish Lapland, and their palaeoenvironmental implications. *Journal of Paleolimnology* 20: 205-215.

Korhola, A. 1996. Northern lakes as key witnesses for climatic change. *Universitas Helsingiensis* 3/1996: 16-19.

Korhola, A. 1996. Ilmasto jättää jälkensä järveen. Syrjäiset vuoristojärvet tutkijoiden arkistoina. [Climate leaves traces in lakes. Remote mountain lakes as archives of investigators] *Helsingin Sanomat*, Tiede ja Ympäristö. 17.2.1996.

Sorvari, S., Rautio, M. & Korhola, A. 1999. Seasonal dynamics of subarctic Lake Saanajärvi in Finnish Lapland. *Verheissungen der Internationalen Vereinigung der gesamten Limnologie* (in press).

Korhola, A., Sorvari, S., Rautio, M., Appleby, P., Dearing, J., Rose, N., Lami, A. & Cameron, N.G. 1999. A multi-proxy analysis of climate impacts on recent ontogeny of subarctic Lake Saanajärvi in Finnish Lapland. *Journal of Paleolimnology*. (in prep.)

Sorvari, S., Forsström, L., Rautio, M. & Korhola, A. 1999. A two-year record of phytoplankton and diatom succession in subarctic Lake Saanajärvi in Finnish Lapland. *Polar Biology*. (in prep).

Present and past hydrobiology of a subarctic lake in Finnish Lapland. *Mem. Inst. Ital. Idrobiol.* (in prep).

Conference presentations:

Sorvari, S., Rautio, M., Forsström, L. & Korhola, A. Climate impacts on ecosystem dynamics and recent ontogeny of the subarctic lake Saanajärvi, NW-Finnish Lapland. 29th Arctic Workshop, University of Washington, Seattle, USA. April 11-13, 1999.

Sorvari, S., Rautio, M. & Korhola, A. 1998. Seasonal dynamics of subarctic Lake Saanajärvi in Finnish Lapland. XXVII SIL'98 Congress, Dublin, Ireland, 9-14 August 1998.

Korhola, A., Weckström, J. Olander, H., Seppä, H., Blom, T. Sorvari, S., Virkanen, J., Birks, H. J. B., Toivonen, H. & Mannila, H. 1998. Climate Change as Recorded by Ecologically Sensitive Arctic Lakes in Fennoscandia. *International SCANTRAN Meeting: An IGBP terrestrial transect for Scandinavia/Northern Europe. 19-23 March 1998, Arktikum, Rovaniemi, Finland: 50-52.*

Korhola, A. 1997. The suitability of northern freshwater ecosystems as indicators of climatic change. *Symposium on Climate Change Effects of Northern Terrestrial and Freshwater Ecosystems. Arktikum, Rovaniemi, Finland, 18th - 20th September, 1997.*

Sorvari, S. & Korhola, A. 1997. Recent diatom assemblage changes in subarctic Lake Saanajärvi, NW Finnish Lapland - A Paleolimnological Approach. *Symposium on Climate Change Effects of Northern Terrestrial and Freshwater Ecosystems. Arktikum, Rovaniemi, Finland, 18th - 20th September, 1997.*

Sorvari, S., Korhola, A. & Blom, T. 1997. Recent diatom assemblage changes in subarctic Lake saanajärvi, NW Finnish Lapland. *7th International Symposium on Palaeolimnology, 28 Aug. - 2 Sept. 1997. Heiligkreuztal, Riedlingen, Germany. Würzburger Geographische Manuskripte* 41: 205-206.

Signature of Partner: Atte Korhola

Date: 28 February, 1999

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period:	March 1998 to February 1999	
Partner:	The University of Edinburgh	
Principal Investigator:	Roy Thompson	
Scientific staff:	Anna Agusti-Panareda	
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Telephone:	0131 650 4907	
Fax:	0131 668 3184	E-Mail: egph08@holyrood.ed.ac.uk

I. OBJECTIVES FOR THE REPORTING PERIOD:

1. To apply the multiple regression method of climate reconstruction to all WP3 and AWS sites.

2. To integrate our climate work with data obtained from the automatic weather stations and hence to take into account local climatic effects in our reconstructions.

3. To reconstruct variations in growth season and ice cover duration for use in modelling studies of the temporal responses of remote mountain lakes to climatic variability.

4. To compare the sediment record at study sites with instrumental records of temperature and precipitation.

II. OBJECTIVES FOR THE NEXT PERIOD:

Production of final report..

III. Are there any particular problems ? Is your part of the project on schedule ?

No major problems have arisen. Objectives 1 through 3 have all been completed. The final part of objective 4 is being carried out at Bergen using our core correlation and climate reconstruction results which have been made accessible to all MOLAR participants via our www site.

One surprise has been the relative paucity of good quality data on ice-cover on mountain lakes. Despite the visual observations and the spot water temperature readings taken throughout MOLAR1 the exact timing of ice-cover remains problematical. A technological advance during MOLAR1 has been the development of sealed mini-thermistors that allow continuous monitoring of water temperatures. It would be very beneficial to ice-cover studies if these mini-thermistors were more widely deployed in future monitoring campaigns.

IV. MAIN RESULTS OBTAINED: ***METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS*** **(use other pages as necessary but preferably no more than 2)**

1. Long term climate reconstructions

217 year long climate reconstructions have been generated for all AWS sites (Figure 1). The skill of our method, at the transfer sites, ranges between 58% and 93%, while the mean absolute error, on the annual temperature, varies between 0.36 $^{\circ}$C and 0.16°C. The oceanic sites tend to have the lowest errors. As anticipated the more remote Iberian and Arctic sites have the largest errors. One completely independent check on our reconstructions is through a comparison of our model of 1997/98 temperatures and the AWS air-temperature measurements made at the MOLAR lake sites. Figure 2 shows the excellent agreement between our model temperatures and the AWS measurements.

2. Reconstruction of ice-cover and growth season

Ice-cover and growth season has been reconstruced from climate analyses for all WP3 sites. The error of our thermal exchange model has been validated at two lakes in Fiinland. The average error in the duration of ice-cover as estimated from our model is found to be only four days.

3. Core correlations

Sequence slotting has been successfully applied to sediment core logs from all eight WP3 sites in order to generate core correlations. At many of the WP3 sites the correlations are of extremely high quality demonstrating stratigraphically intact sediment.

4. Chronology of sub-master cores

At six of the WP3 sites the above correlations allow the chronology of the master dated cores to be transferred to the sister (undated) cores. Hence we have been able to position all the biostratigraphical, magnetic and geochemical data on a common time frame for between site comparison and for comparison with the climatic reconstructions.

5. Data base

A protected www data base *http://www.glg.ed.ac.uk/home/Roy.Thompson/* with 29 web pages has been set up at Edinburgh in order to provide direct access to our results of core correlation, chronology and climate reconstructions. The password has been circulated to all MOLAR participants so allowing unrestricted access.

V. List of Publications arising from the project (include copies):

Anna Agustí-Panareda, Roy Thompson and David M. Livingstone, 1999, Reconstructing temperature variations at high elevation lake sites in Europe during the instrumental period, *SIL* (In Press)

Signature of Partner:

R Thompson

Date 2 February 1999:

Fig 1 Air-temperature reconstructions at AWS sites. Annual and decadal (solid line).

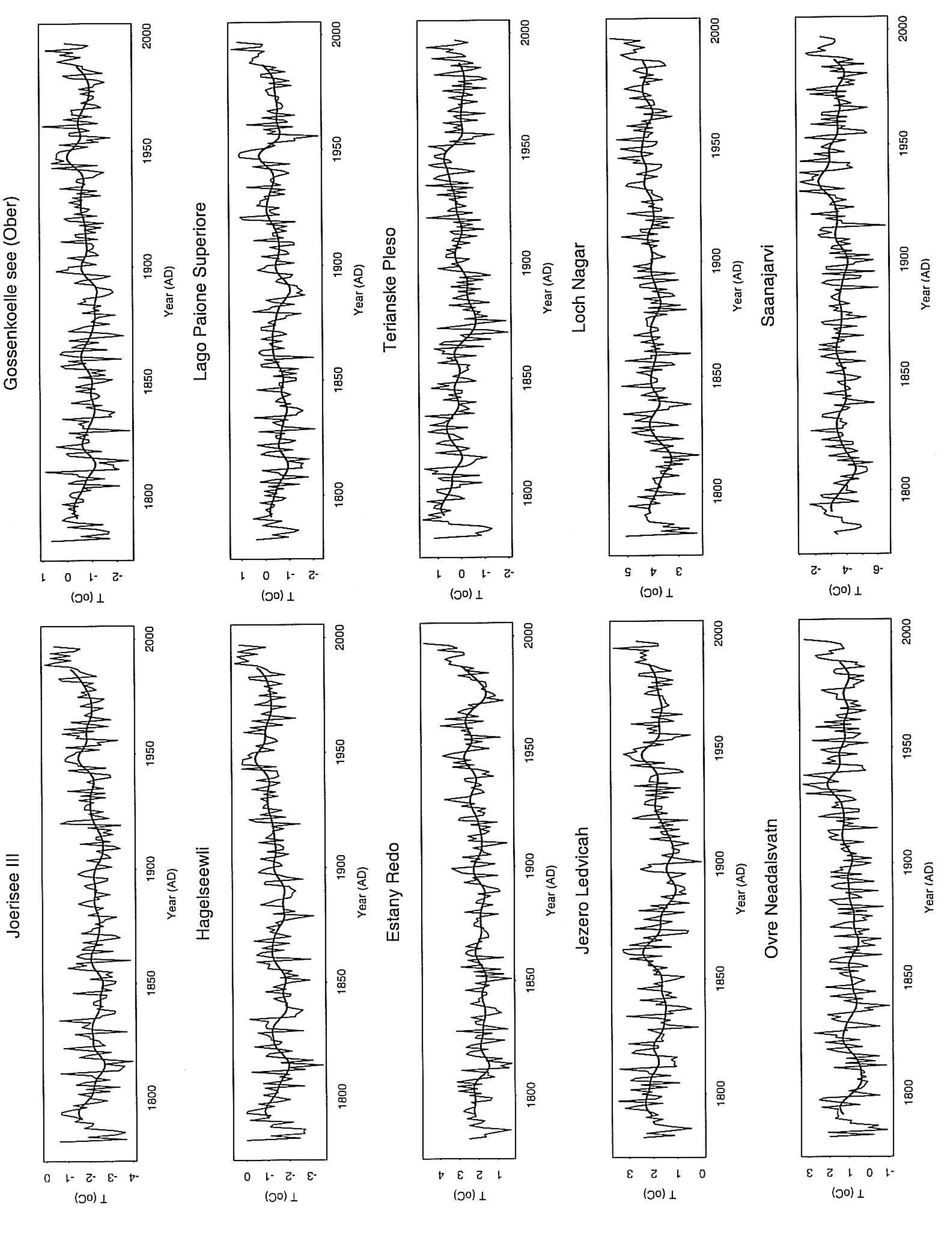
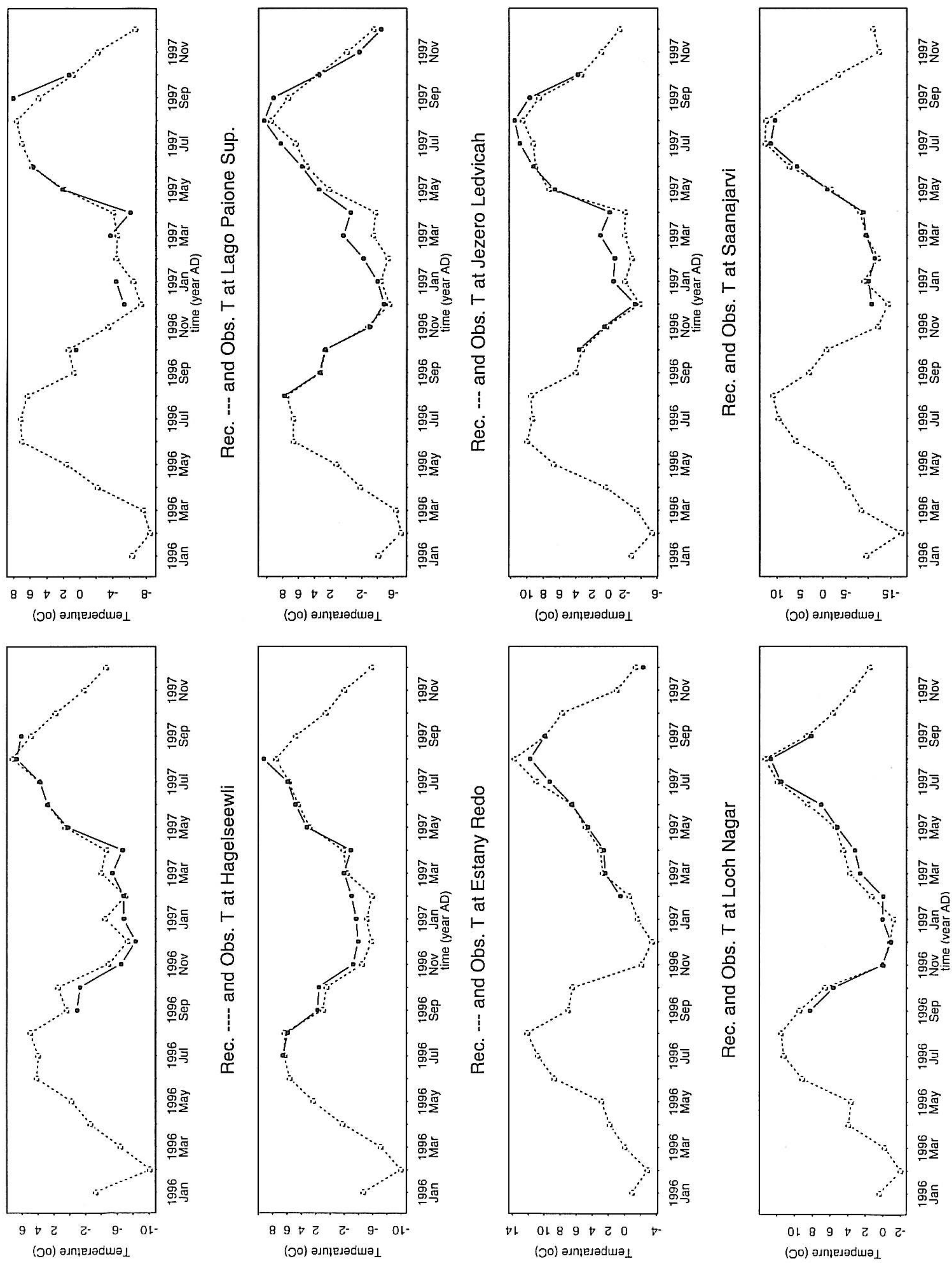


Fig 2 Comparison of modelled air-temperatures and AWS measurements.



PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period:	01/03/98	to	28/02/99

Partner: Norwegian Institute for Water Research (NIVA)

Principal Investigator: Bente M. Wathne

Scientific staff: Bjørn Olav Rosseland, Leif Lien, Sigurd Rognerud, Richard Wright, Ann Kristin Buan, Einar Kleiven (NIVA)
Torunn Berg (Norwegian Institute for Air research, NILU).

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I. OBJECTIVES FOR THE REPORTING PERIOD:

- Scientific co-ordination of MOLAR
- Co-ordinate WP 1 activities, including special responsibility for fish in WP 1,2, and water chemistry
- Sampling and analysis after the agreed MOLAR programme for Øvre Neådalsvatn, Stavsvatn, and Arresjøen
- Report WP 1 results and edit annual progress for the total project
- Accomplish modelling activities within WP 1
- Complete database for chemistry and fish
- Prepare draft manuscripts for publication in international journals

II. OBJECTIVES FOR THE NEXT PERIOD:

- Scientific co-ordination of MOLAR
- Contribute to the final report for the total project
- Report modelling activities within WP 1
- Complete database for chemistry and fish
- Prepare manuscripts for publication in international journals, including a paper on deposition and water chemistry for a special volume of Mem. Ist. Ital. Idrobiologia.

PART B

III. Are there any particular problems? Is your part of the project on schedule?

There are no special problems with regard to the water chemistry data. But due to some delay in the data delivery, the last quality control will be finished in first weeks of March and the data sent to the data base at the University of Bergen. The modelling work has been waiting for catchment data for Stavsavtn and Øvre Neådalsvatn. These data are now present and the last part of the modelling work can proceed. Nitrogen isotope ratios (N14/N15) were analysed in muscle from individual fish, sampled from the populations in 7 MOLAR lakes, by a laboratory at the University of Stockholm. The data was delivered in March 1999. The isotope ratio was originally not a part of MOLAR program, but recent scientific papers have shown the need for such data to interpret bioaccumulation of Hg and persistent organic pollutants (POP's) in fish flesh and organs. The data will be used in multivariate statistical analysis and probably also included when discussing histological data in WP2.

IV. MAIN RESULTS OBTAINED:

Water chemistry, WP 1.

A Workshop on water chemistry and deposition was organised in London November 5. – 6. 1998. Status of the data delivery and the data bases for deposition and water chemistry was discussed. Intercomparison/intercalibration results from the 1998 exercises lead by CNR-III and NIVA were presented, and special topics that needed attention were treated in more detail. To summarise the results, it was concluded that the MOLAR labs as a total performed well compared to the total number of laboratories participating in the intercailbrations. Also status for catchment data and critical loads modelling were on the agenda. Necessary input to the model calculations are annual mean values of deposition and water chemistry in addition to catchment data, so the processing of the model work are succeeding the finalising of these results. Finally the synthesis paper of WP 1 on deposition and water chemistry was discussed and its structure planned and agreed.

Water chemistry data for all lakes with planned sampling have been reported to NIVA and CNR-III in Pallanza. Annual variations are described and annual means are calculated for each site. The water chemistry data base is under completion at NIVA and at the University in Bergen.

Metal analysis in fish, WP2.

In 1997, a broad screening of the metal concentrations (Na, Mg, Ca, Ti, Mn, Fe, Hg, Co, Cu, Zn, As, Se, Pb, Sr, Mo, Ag, Cd, Cs, La, Ce) in kidney and liver, as well as Hg in muscle, was performed on a total of 89 individuals from 4 lakes (Arresjøen, Jörisee, Etang d'Aubé and Stavsvatn). The fish sampled from the MOLAR lakes in 1997 (Øvre Neådalsvatn, Redo, Gossenköllesee and resampling of Stavsvatn, Etang d'Aubé and Jörisee were analysed at NIVA in 1998 for mercury (Hg) in muscle, and metals in kidney and liver (Cd, Pb, Cu, and Zn, as well as Se, Cs and As). A total of more than 140 fish from the seven MOLAR lakes have been analysed.

As a part of a QCP, reanalyses of mercury in fish from lakes with old fish (>10 years) and populations possibly being piscivorous where performed. In addition, muscle samples from 143 fish sampled in MOLAR have been analysed at the University of Stockholm, Sweden, for the isotopes of N^{14}/N^{15}. This has been an additional project not originally planned for MOLAR. The relatively high fractionation rate of nitrogen through a food web can result in a difference in the isotope ratio of 0.3–5%. The relative distribution of nitrogen isotopes in different individuals, indicative of specific trophic classifications, can be used as a continuos variable by which trophic position may be quantified. Isotopic measurements will therefore provide a time-integrated measure of assimilated diet and an independent means of evaluating the diet of the consumer. This is an important variable especially when detailed stomach analyses are impossible to obtain. As an example, the mercury concentration in Arctic charr from Arresjøen is shown in Fig. 1. The variation in concentration in fish from similar age group is probably a "food chain effect" and illustrates the need for better understanding of the feeding habitats.

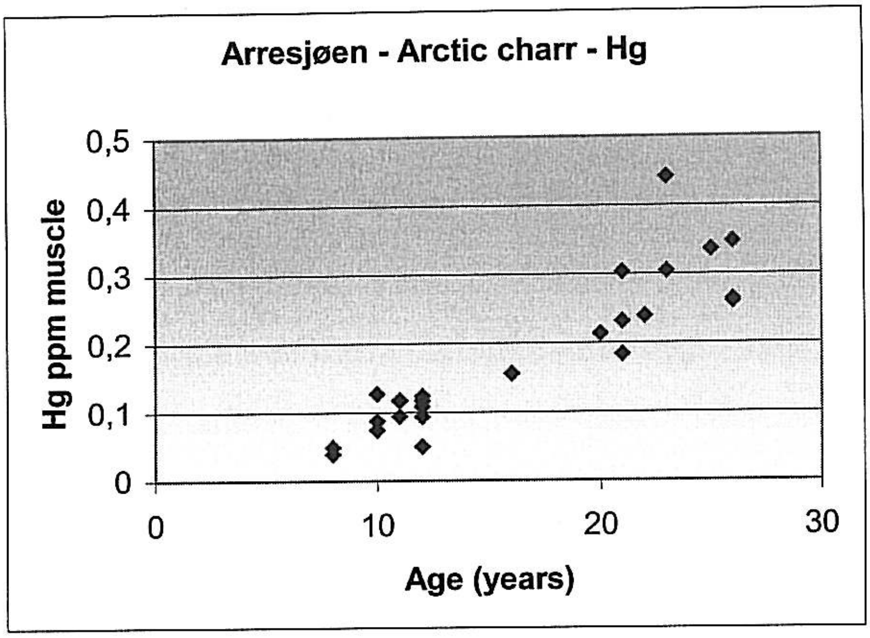

Figure 1. Mercury concentration in muscle versus age of individual fish sampled from a population of Arctic charr (*Salvelinus alpinus* L.) at Arresjøen, Spitsbergen, Norway.

All data analysed at the other institutes (UIBK, CID-CSIC, CNRS) have been stored in a database at NIVA, in a form which might be used in a future ENSIS database. The data will be analysed in a multivariate statistical model. The results can also be coupled with the data from physiology and histology of each individual fish.

Sediment analysis.
Observed concentrations of contaminants in fish are also a function of the "dose". We will use concentrations and accumulation rates of Hg, Se, Pb, Cd, Zn, As, Cs and POP's in surface lake sediments as a surrogate variable for the dose in each lake. Sediments are known to reflect atmospheric depositions of pollutants but they are also influenced by the local water quality and lake specific data as water renewal time and catchment size. Concentrations of metals in sediments have been analysed at SGab in Luleå, Sweden and the lead 210 datings necessary for calculating accumulation rates at the University of Liverpool. The basic hypothesis is that by including the "dose", water quality and food web position it will be possible to sort out the most influencing variables for bioaccumulation of contaminants in fish.

Fish Workshop
Prior to the Annual MOLAR Meting in Arcachon, France, in February 1999, a fish workshop was held in Arcachon at the Laboratory of CNRS-University of Bordeaux. The main focus was on the physiology of fishes in high mountain lakes, and the gill histology. Besides the fish group in MOLAR, special invited participants were professor Pierre Laurent from Centre d'Ecologie et Physiologie Energétiques, CNRS Université de Strasbourg, France and François Guerold and Laure Giamberini, Laboratoire d'Ecotoxicologie, UPRES EBSE/CREUM, Metz Cedex, France.

Sampling WP 1,2,3.
The Norwegain lakes Øvre Neådalsvatn and Stavsvatn have been sampled according to the agreed plans. The secondary sites Arresjøen were sampled once in 1998. Seasonal variations in water

chemistry are followed for Øvre Neådalsvatn and Stavsvatn until the end of the sampling period in August 1998. Deposition sampling at Kårvatn close to Øvre Neådalsvatn and Møsvatn in the same area as Stavsvatn has also followed the plans. Deposition sampling and analysis at Kårvatn and Møsvatn are the responsibility of NILU. The results from the MOLAR field sampling 1998 is shown below:

ØVRE NEÅDALSVATN

In addition to seventeen samplings of outlet water, the water column of the lake was sampled on two occasions for among other factors: Chlorophyll, oxygen pH and conductivity. Water samples were also taken on two occasions for analyses of metal speciation, and for organic micro pollutants. Organic micro pollutants were collected in air at the same periods. The times of the different samplings are listed below.

Climatic records were sampled during the period 1/1 – 21/7 from the automatic weather stations (AWS) located near the outlet of the lake. Snow depths were also recorded during each visit to the lake. Clinometer skyline measures were taken from the AWS site and from the middle of the lake during the spring.

Snow profiles were taken on two occasions and analysed for i.a. organic micro pollutants.

A few fish bones were collected for preliminary analyses of lead 210 content.

After the last sampling (25/7-98) the automatic weather stations (AWS) and most of the MOLAR sampling equipment was removed from the lake site. However, water sampling from the outlet will probable continues for years for another project, and the base bed for the AWS is present of the spot.

Water sampling outlet:	16/1, 7/2, 20/2, 4/3, 6/3, 30/3, 13/4, 16/4, 1/5, 11/5, 16/5, 31/5, 6/6, 21/6, 5/7, 18/7, and 25/7.
Water column profile (Temp, pH, O2, Cond. Chl-a):	2-7/3, 15-17/4.
Metal speciation of water:	2-7/3, 20-25/7
Climatic records:	1/1 – 21/7-98. AWS + snow depths
Clinometer skyline measures:	4/3
Snow profiles sampling:	2-7/3, 15-17/4
Organic micro pollutants:	2-7/3, 20-25/7
Fish bones: 20-27/7	

STAVSVATN

The outlet of Stavsvatn was sampled four times during 1998. In addition a water column profile was examined on one occasion. Also from Stavsvatn the MOLAR sampling equipment were removed.

Water sampling outlet:	15/2, 2/4, 13/5, and 7/7.
Water column profile:	2/4

V. List of Publications arising from the project (include copies):

Mosello, R., Boggero, A., Marchetto, A. Wathne, B.M., and Lien, L. 1998. Chemistry of headwater lakes studies in the EU projest "Acidification of mountain lakes: palaeolimnology and ecology (AL:PE)". - In: KOVAR, U. TAPPEINER, N.E. PETERS, R.G. CRAIG (Eds), *Hydrology, water resources and ecology in headwaters, Proceedings of the HeadWater'98 conference,Merano:*

395-401. International Association of Hydrological Sciences Publ. No. 248, IAHS Press, Wallingford.

Patrick, S., Battarbee, R.W., Wathne, B.M., Psenner, R. 1998. Measuring and modelling the dynamic response of remote mountain lake ecosystems to environmental change: An introduction to the MOLAR project.). - In: KOVAR, U. TAPPEINER, N.E. PETERS, R.G. CRAIG (Eds), *Hydrology, water resources and ecology in headwaters, Proceedings of the HeadWater'98 conference,Merano:* 403-410. International Association of Hydrological Sciences Publ. No. 248, IAHS Press, Wallingford.

Psenner, R., Mosello, R., Boggero, A., Marchetto, A., Wathne, B.M., Lien, L 1998. Mountain lake research (MOLAR): Atmospheric deposition and Lake Water Chemistry. Proceedings of SIL Congress Dublin August 1998.

Battarbee, R.W., Patrick, S., Wathne, B.M., Mosello, R., Psenner, R. 1998. Measuring and modelling the dynamic response of remote mountain lake ecosystems to environmental change (the MOLAR project.). Proceedings of SIL Congress Dublin August 1998.

Signature of Partner: Berit M. Wathne

Date: 1/3-99

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: March 1, 1998 to February 28, 1999

Partner: UINN-IZ University of Innsbruck
Institute of Zoology & Limnology

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I. OBJECTIVES FOR THE REPORTING PERIOD

- Recording of meteorological data
- Sampling of lakewater, tributaries and precipitation
- Whole lake tracer experiment with lithium chloride
- Chemical analysis of atmospheric deposition (wet only, bulk) and of the snow cover
- Sampling of organic micropollutants, SCP's, ^{210}Pb and ^{137}Cs in precipitation, water and soils
- Microbial food webs studies: abundance, biomass and carbon flux within microbial compartments
- Completion of biochemical and histological analyses of fish
- Data processing and comparison with preliminary results from other sites

II. OBJECTIVES FOR THE NEXT PERIOD

- Comparison of data from Gossenköllesee with results from other sites and/or workpackages
- Preparation of publications
- Preparation of the *International Symposium on High Mountain Lakes and Streams*, 4-8 September 2000, Innsbruck

III. ARE THERE ANY PARTICULAR PROBLEMS? IS YOUR PART OF THE PROJECT ON SCHEDULE?

In order to have two hydrological years we terminated the fieldwork at Gossenköllesee on 30 September 1998, thus we have a time lag in data evaluation compared to other study sites where the fieldwork ended earlier. Nonetheless, it would be important to fix a hydrological year for all sites – especially if one wants to mesure water and mass fluxes – and we suggest to use the period from 1 October to 20 September. A particular problem is the availability of processed and verified data from each site which takes time. In a second stage, those data have to be compared with results from other sites, this creates an additional time lag. There is no obvious solution to this problem except reducing the fieldwork period to just one year which may create other types of problems. To compensate for the restricted time for data evaluation, we will organize an International Symposium at Innsbruck on 4-8 September 2000, intended as a forum for presenting data from MOLAR and other high mountain lake studies.

IV. MAIN RESULTS OBTAINED

A) Meteorology, hydrology, water chemisty

At Gossenköllesee sampling and data collection has been completed by the end of September 1998 in order to cover a period of two hydrological years. Analysis of major ions and nutrients in precipitation, lake water and brooks has been finished. Both labs (Institute of Meteorology and Geophysics – analysis of major ions, Institute of Zoology and Limnology – analysis of nutrients) participated successfully in the analytical quality control in cooperation with Rosario Mosello.

Meteorological data of the 2 years have been summarized as an issue of the Series of the Institute of Meteorology and Geophysics (Nickus, 1999 – in press). Special emphasis has been paid to the catchment precipitation amount, which is a key parameter for the determination of both atmospheric trace substance fluxes and the hydrological balance of the catchment. Data on detailed chemical analyses of snow profiles in the catchment of Gossenköllesee have been presented at the International Conference of Hydrology in Meran (April 1998) and a corresponding paper has been published (Nickus et al. 1998).

Lake water chemistry data of the first hydrological year have been presented at the International Conference of the SIL in Dublin (August 1998) and a manuscript has been accepted for publication in the Conference Proceedings (Thies et al. 1999 – in press).

The hydrological and chemical data of three gauged lake tributaries from two hydrological years are currently processed in order to calculate corresponding water and mass fluxes. These activities are financially supported by two additional projects (EU Post Doc study of H. Thies; Austrian Ministry of Science). Data of the first hydrological year of two contrasting lake tributaries have been presented at the International Conference of Hydrology in Meran (April 1998) and a corresponding paper has been published in the Red Book series of the IAHS (Thies et al., 1998).

The determination of the lake water residence time of Gossenköllesee was assessed with a hydrological field experiment using an artificial tracer substance (LiCl). This experiment is financially supported by two additional projects (EU Post Doc study of H. Thies; Austrian Ministry of Science) and lasted from July 3, 1997 to October 1, 1998. Results of this experiment have been presented at the final MOLAR meeting in Arcachon (February 1999) and are now prepared for publication.

B) Microbial food webs, fish

Results from the study of Microbial Food Webs investigated in summer 1996 and 1997 have been published in a special volume of *Memorie dell' Istituto Italiano di Idrobiologia* (Wille et al., 1999). Additionally, some data of 1996 have been published (Pernthaler et al. 1998). Results of the 2nd level have been presented at the

International SIL Conference in Dublin (August 1998) and the extended abstract of the poster presentation has been accepted for publication in the Conference Proceedings (Wille et al., 1999). The total results of the 2nd level approach will be published in a volume of the *Memorie* still in preparation.

Fish were caught by gill nets and dissected at the lakes. A piece of the kidney and liver as well as one gill arch were fixed in bufferd fomaline for histology and sent to Innsbruck. From three lakes also frozen liver samples were brought to Innsbruck for biochemical analysis. Fish from these three lakes, Øvre Neådalsvatn, Gossenköllesee, and Redo were studied in more details.
Analyses revealed that fish from Øvre Neådalsvatn show significant signs of environmental impact. Biochemical and histological data give evidence that these fish are stressed (Fig. 1).

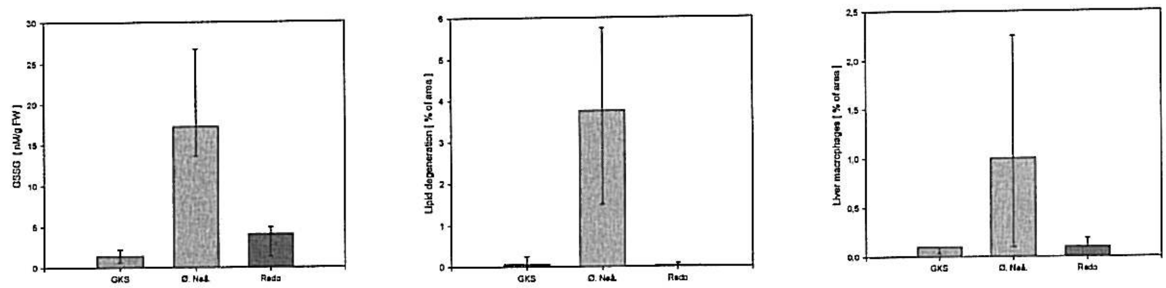

Fig. 1: Biochemical and histological parameters of fish liver. Glutathione disulphide (GSSG) is a measure for oxidative stress. Lipid degeneration of liver cells and an increased number of macrophages are also possibly induced by pollutants.

However, data for metal accumulation (NIVA analyses) and organochlorine pollutant accumulation (J. Grimalt's analyses) indicate that Øvre Neådalsvatn is the least polluted site. One possible source for the observed environmental stress in Øvre Neådalsvatn are polycyclic hydrocarbons (PAHs) as visualized by bile analysis. The fish from this lake are especially rich in metabolites of PAH detoxification (J. Grimalt, unpublished).

V. CONCLUSIONS

The importance of having reliable hydrological data has been demonstrated with the used approach, i.e. using the LiCl tracer, gauging of surface discharge, and precipitation and lakewater chemistry. The major aim has been achieved and we can now provide data on atmospheric deposition and mass fluxes to the lake. Food web studies have been continued during the winter season (funded by another project) and this showed the importance to continue biological measurements throughout the year if one wants to compare biological and chemical analyses of the pelagic zone. The winter situation is a very imporant (and long lasting) period for alpine lakes: the ice cover is a physical barrier but also a microbial habitat, and flushing in springtime is a crucial situtaion for the chemistry and the organisms of the lakes. We recognize that this is more difficult to achieve at other lake without fully equipped stations. The study of fish has shown that in addition to indicators of environmental pollution (metals, organochlorinated compounds etc.) it is essential to measure the stress status of animals (see Fig. 1).

VI. LIST OF PUBLICATIONS

Nickus, U., Thies, H., Kuhn, M. & Psenner, R. 1998. The snow cover at a headwater site in the Tyrolean Alps: seasonal and local variability of atmospheric trace substances in the snow pack. in: Hydrology, Water Resources and Ecology of Mountain Areas (Tappeiner et al., eds.), 39-42. European Academy Bozen.

Nickus, U. 1999. Meteorological records of Gossenköllesee (2413 m, Kühtai, Tyrol). Mitteilung Nr. 3, Institute of Meteorology and Geophysics, University of Innsbruck (in press)

Thies, H., Nickus, U. & Psenner, R. 1998. Response of discharge and water quality in headwater brooks on distinct hydroclimatic conditions in the Tyrolean Alps. IAHS Publ. no. 248, 491-497.

Thies, H., Nickus, U., Arnold, C., Schnegg, R., Wille, A. & Psenner, R. 1999. Biogeochemistry of a high mountain lake in the Austrian Alps. Verh. Int. Verein. Limnol. (in press)

Pernthaler, J., Glöckner, F.O., Unterholzner, St., Alfreider, A., Psenner, R., & Ammann, R. 1998. Seasonal Community and Population Dynamics of Pelagic Bacteria and Archaea in a High Mountain Lake. Appl.Env.Microbiol. 64(11) 4299-4306

Wille, A., Sattler, B., & Psenner, R. 1999. Lake Ice Microbial Communities (LIMCO) – Biology of a periodic ecotone. Extended abstract. Verh. Int. Verein. Limnol. (in press)

Wille, A., Sonntag, B., Sattler, B., & Psenner, R. 1999. Abundance, Biomass and Size-Structure of the Microbial Assemblage in the high mountain lake Gossenköllesee (Tirol, Austria) during the ice-free period. Mem. Ist. Ital. Idrobiol. (submitted)

Signature of Partner:

Date: 28 February 1999

PART B

Partner:
ILIMNOL
Institute of Limnology, Austrian Academy of Sciences

Principal Investigator:
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I. OBJECTIVES FOR THE REPORTING PERIOD:

- Collection of sediment traps for diatoms and chrysophytes, soot particles and ^{210}Pb
- Collection of an additional core for analyses of organic micro-pollutants (PCB, PAH)
- Completing of analyses of contemporary diatoms (sediment traps, epilithic diatoms, transect, plankton) and chrysophytes (sediment traps)
- Intensive data processing, validation of all results and first analyses of data
- Comparison of all palaeolimnological data available from Gossenköllesee: diatoms, chrysophyts, chironomids, cladocera, pigments, magnetics, grain size, geochemistry, soot particles.

II. OBJECTIVES FOR THE NEXT PERIOD:

- Preparation and publication of manuscripts for the final report.
- Presentation of results for forthcoming international meetings.

III. ARE THERE ANY PARTICULAR PROBLEMS ? IS YOUR PART OF THE PROJECT ON SCHEDULE ?

Problems with the CHN analyser (Carlo Erba) meanwhile were settled. All data are available now for all core sections of GKS Core 3 – according to the working frame. The project is on schedule: all palaeolimnological core analyses have been finished and sent to the MOLAR data base in Bergen and to the site operators.

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS*

Preliminary Results and Discussion

Contemporary diatoms of GKS

Planktonic diatoms were dominated by *Cyclotella gordonensis* and *Cyclotella comenis*, respectively. During the onset of the ice cover, the diatoms were the dominating species in the phytoplankton. In the epilihtic samples, mainly *Fragilaria* and *Achnanthes* were observed. In the sediment traps, all species were present but *Cyclotella* usually covered the largest proportion.

Diatom evaluation of the sediment core GKS (200 years record)

The diatom stratigraphy of GKS is dominated by *Cyclotella* and *Fragilaria*. The latter frequently occur at habitats with changing environmental conditions, being common in alpine areas. Although there have been no major shifts in species composition, abundance fluctuations were observed, predominantly within *Cyclotella*. When compared these fluctuations with the mean annual air temperature, higher abundances mainly correspond with increasing temperature (Fig. 1). Probably planktonic diatoms were favoured by longer ice-free periods.

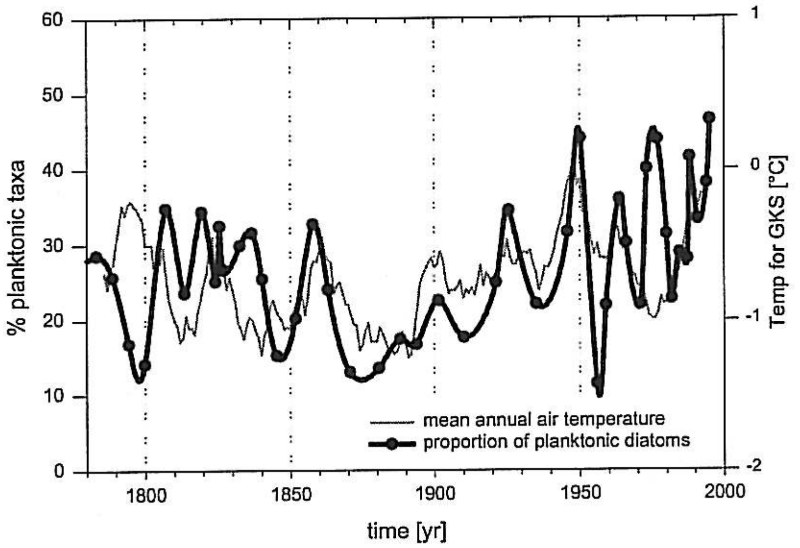

Figure 1: Abundance fluctuations of planktonic diatoms in the core GKS in time *versus* mean annual air temperature.

Chrysophycean evaluation of sediment cores

The sediment cores of Gossenköllesee, Hagelseewli, Terianske Pleso and Jezero v Ledvicah were investigated for Chrysophycean remains by means of SEM and an image analysing system.
Special emphasis was put on detailed taxonomic studies because of the high number of unknown stomatocyst types (e.g. Gossenköllesee: 10 out of 36, Jezero v Ledvicah: 7 out of 23 cyst types with a minimum occurrence > 3%). Due to the high morphological variability within certain cyst types, SEM studies were important. A database with the description of all the cyst types was established,

including pictures and more than 4000 size measurements. A workshop on taxonomic harmonisation of cyst types was held from 30. Nov. – 4. Dec. '98 in Pallanza / Italy, where Sergi Pla (Spain), Aldo Marchetto (Italy) and Christian Kamenik (Austria) participated. A total of 248 cyst types was harmonised.
The stomatocyst assemblage composition of GKS was analysed down to a core depth of 33.5 cm (sample intervals 0.25 cm). 85 of the Jezero v Ledvicah samples were examined. Because of very low numbers in 25 samples (less than 200 per sample) only 60 samples could be used for further statistical treatment. The core from Hagelseewli was analysed for the uppermost 10 cm (dating back to approx. 1815). For Terianske Pleso the same samples as for diatom analysis were examined.
Preliminary statistical analysis of the Chrysophycean assemblages in the four cores by Detrended Correspondence Analysis and CONISS (Constrained Incremental Sum of Squares Cluster Analysis) show distinct shifts. A first test on the significance of zone boundaries in the GKS core, using the broken stick model, indicates significant zones from 0 – 3.25 cm, 3.25 – 10 cm and 10.25 – 33.5 cm (Fig. 2). Further tests on significance as well as comparisons of results derived from different palaeoindicator groups need to be done.

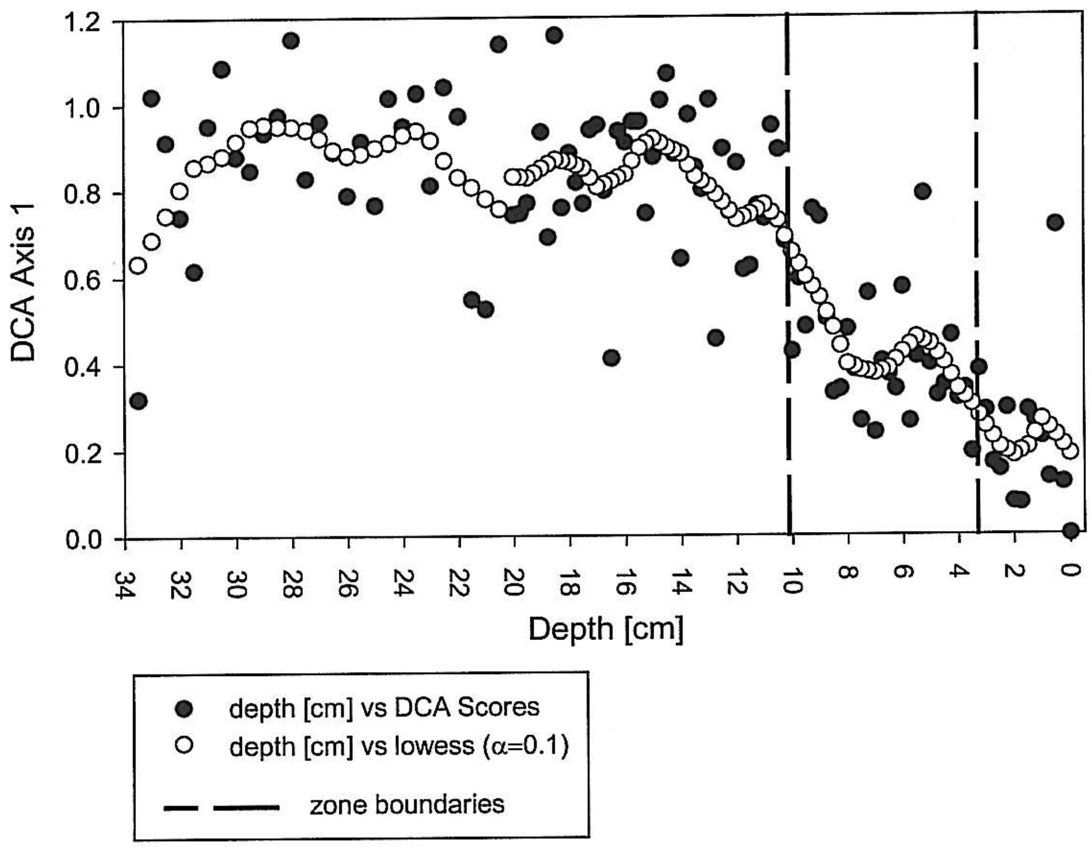

Fig. 2: DCA scores (significant Axis 1) and smoothed DCA scores (LOWESS smoother) *vs.* depth

GKS sediment trap samples (chrysophytes)

Sediment trap samples from 1996-1998 of Gossenköllesee were analysed using SEM and an image analysing system. Total cyst numbers were counted in the light microscope.
Both, total and percentage data show distincte seasonal pattern. The highest total cyst numbers occurred from beginning of July until mid August 1997. This peak was not found in 1996. A smaller peak in the absolute cyst number was observed just before the onset of ice cover in autumn 1996 and 1997. Due to their time of appearance, stomatocysts can be divided into winter/spring, summer and autumn forms. Stomatocyst composition in autumn differed remarkably from year to year, as was shown by Correspondence Analysis. Furthermore, Correspondence Analysis revealed that 75% of the variance in the stomatocyst sediment trap data are not random, being probably influenced by factors, which need further investigation.

Climate signals in GKS?

After screening of all the data of GKS, no significant climate signal was dedected for the last 200 years, with the exception of chironomids and the following sedimentological parameters: Loss on ignition (LOI) increased when temperature increased, probably due to enhanced production of organic matter. *Vice versa* median grain size decreased during these warm periods with probably less hydrological energy.

In GKS cores, low accumulation rates and time resolution of the samples are the major problems when changes in air temperature and in biostratigraphy were compared. If, for example, one core sample equals a period of 15-25 years (Table 1), only larger trends may be reflected.

TABLE 1: Palaeolimnological analyses in 5 sediment cores taken from Gossenkoellesee

Analyses	samples analysed period 1780-1996:	time resolution period covered by samples
diatoms	40	5 years
chrysophytes	40	5 years
cladocera	22	8-11 years
pigments	22	8-11 years
chironomids	11	15-25 years
DW, LOI	20-40	5 – 40 years
geochemistry	20	10 years
grain size	20	10 years
magnetics	40	5 years
temperature data	(daily data available)	daily – annual !

Conclusions:

Signals for environmental changes depend on the sensibility of the bioindicators (functional groups), accumulation rates and time resolution of the samples. In contrast to benthic diatoms, planktonic diatoms and chrysophytes respond faster to short-term environmental fluctuations which characterise the alpine environment. This is supported by the distinct seasonality in the chrysophyte and diatoms sediment trap data of GKS. The change in the stomatocyste assemblage composition from 1800 to the present in GKS was significant. Planktonic diatoms possibly indicate the influence of other parameters than only climate for this period.

V. LIST OF PUBLICATIONS ARISING FROM THE PROJECT (INCLUDE COPIES):

KAMENIK, C. (1997): Chrysophyceae als Paläoindikatoren am Beispiel des Gossenköllesees. Diplomarbeit Universität Innsbruck und Institut für Limnologie, Mondsee.

KOINIG, K.A. (1998): Palaeolimnology of high mountain lakes – The impact of climate change and atmospheric deposition on past pH changes and sediment chemistry, Thesis, University of Innsbruck and Austrian Academy of Sciences.

KOINIG, K.A., SCHMIDT, R., PSENNER, R. (1998), Driving forces for pH shifts in high alpine lakes – The impact of climate change versus acid deposition, Würzburger Geographische Manuskripte 41: 109.

KOINIG K.A., SOMMARUGA-WÖGRATH, S., SCHMIDT, R., TESSADRI, R., PSENNER, R. (1998): Acidification processes in high alpine lakes – Impacts of atmospheric deposition and global change. In: Haigh, M.J., Krecek, J., Rajwar, G.S., Kilmartin, M.P.: Headwaters: Water Resources and Soil Conservation. Proceedings of Headwater '98: 45-54

Signature of Partner: Prof. R. Schmidt

Date: 23.02.1999

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: 1-3-1998 to 28-2-1999

Partner: UNIVERSITAT DE BARCELONA, DEPARTAMENT D'ECOLOGIA. (UBCN.DE)

Principal Investigator: Jordi Catalan

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I. OBJECTIVES FOR THE REPORTING PERIOD:

- To continue the regular sampling in L. Redó and L. Cimera until June 1998.
- To continue all the analytical work to finish by July 1998.
- Intensive data processing of the data obtained in the different work packages for L. Redó and L. Cimera
- Intensive modelling in work packages 1, 2 and 3 subjects in relation with L. Redó.
- Model development and application related to the objectives of work package 3.

II. OBJECTIVES FOR THE NEXT PERIOD:

This was the last reporting period for the project.

III. Are there any particular problems? Is your part of the project on schedule?

There was not any major problem in the development of the project during the reporting period. The only problem in field measurements were episodic troubles with powering the automatic weather station and the sensor recording the lake level, which has shown to be very sensitive to lighting. However, we obtained data for most of sampling period. All analytical work was finished on schedule, and results have already been presented in different thematic workshops (Pallanza, Blatna, London, Arcachon,...) to the rest of participants. Physical modelling of the water column has resulted in limited success due to the difficulties when using mean daily values of weather forcing as input. As a consequence, the link between high-resolution dynamic physical models (using hourly or higher frequency data inputs) and interannual variability (considered in monthly basis) has not been successfully established. Further research is needed in how physical response can be introduced in an analysis of interannual variability using a dynamical approach.

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, and DISCUSSION, CONCLUSIONS (use other pages as necessary but preferably no more than 2)*

WP1: *Mountain lake ecosystem response to acid deposition*

Due to the difficulties to reach the lake, deposition measurements have been made on monthly-integrated samples. However, we collected weekly and daily samples at a lower altitude and we have compared them with the monthly lake deposition. In 1997-98, we found no differences between the two sites; thus we can use the data on the lower station to follow the deposition in the lake catchment with much higher resolution. However, in 1998-99, although for most of the period the two sites were comparable, the annual deposition was significantly higher in the locality at higher elevation due to a few episodic events of much higher deposition. This sets the question on which is the role of episodity in establishing altitude differences in ion deposition. A longer time series is needed to properly answer this question. The comparison of the chemical composition of the deposition with data from previous years (1987, 1994) has shown a trend of decreasing base cations in the past two years.

In co-operation with R. Wright (NIVA) and C. Curtis (UCL), FAB and MAGIC models have been applied to Lake Redó. The lake is not acidified; thus the models have been used to test future scenarios related to possible changes in sulphur and nitrogen emissions and to possible climate change and associate variations in dust deposition. The main conclusions is that the lake could hardly be acidified, even under the worse case considerate; but on the other hand, it is very sensitive to changes in base cation deposition; its alkalinity can vary up to 100% within reasonable future scenarios. Models were calibrated using measured data from 1997. Hindcasting of previous years chemistry for which data was available (1984, 1994) was poor, indicating that a key process in the alkalinity balance of the lake is not properly taken into account by the model. The catchment of this lake (like most mountain lakes at high elevation) is poorly vegetated, chemical weathering of rocks may be more significant than in more vegetated catchments, we guess that this process might be the main source of discrepancy for hindcasting.

WP2. *Measuring and modelling major element and pollutant fluxes in mountain lakes and their impact on fish*

A large set of data have been collected on organic contaminants, SCPs and metals in collaboration with other partners, which using Pb-210 as tracer allowed to develop a first model illustrating the process from atmosphere to sediments. Concerning organochlorinated compounds, it has appeared that fish are responsible for a large part of the flux of these compounds through the lake. Their importance is similar to sediments, but given their much lower surface, it means that their role is extremely important. Further research is needed, therefore, to understand the basis of the mechanisms supporting this fish role.

WP3. *Climate variability and ecosystem dynamics at remote alpine and arctic lakes*

Mean monthly temperature reconstructions for the last 200 years on L. Redó and L. Cimera sites was carried out by Roy Thompson and Anna Panareda from Edinburgh. Reconstructions were based on instrumental record from different meteorological stations around Europe and local and on-site weather stations measuring during the MOLAR project development. The trends that appeared in the reconstruction were compared with the sediment record of multiple variables (loss on ignition, pigments, diatoms, chironomids, cladocera, ...). In the case of L. Redó, a clear response to an October warming during the last 50 years was demonstrated for two plankton diatoms (*Cyclotella pseudostelligera*, and *Fragilaria nanana*), and two epilimnetic invertebrates (*Acroperus harpae* (cladocera), and *Psectrocladius octomaculatus* (chironomid). Seasonal water column sampling, sediment traps, and an analysis of the physical consequences of this warming using a dynamic physical model (DYRESM) indicated that the responses in biota were likely due to a warming of the epilimnion during October, rather to any significant change in the depth and deepening patterns of the thermocline.

L. Cimera reconstructions showed that the locality is very sensitive to climate changes. Unfortunately, the unstable water column during the whole ice-free period allows frequent sediment resuspension and, thus, disturbance of the time sequence recorded in the sediments. The fact was made evident in the seasonal studies of the water column and confirmed by the Pb210 measurements in the sediments.

Studies on water column seasonality at 9 WP-3 sites provided the basis for analysing the implications of seasonal variability for finding climatic signals in the sediment record of these lakes. The lakes studied covered a broad range of size and latitudinal distribution; nevertheless, they share a series of features (deep oxygen maxima, oxygen depletion in deep layers during winter, pH drop during thaw, etc.) that show that the underlying main processes are the same for all of them. From the patterns of variability we can distinguish mainly two sort of potential signatures, which can be described as "species responses" and "system responses". The former comprehends episodic, short but strong events, which signal in the sediments must be carried by species signatures that immediately responded to such variability: e.g. pH drops during thaw, temperature peaks in the water column, intensity of specific productive periods. The latter comprehends changes that affect to the whole lake biochemistry and are reflected in the sediments either by changes in total fluxes of materials or by changes in the in the whole set of species. Shallow, small lakes are in general more suitable for recording responses to episodic fluctuations in annual weather forcing; large lakes may succeed better in recording trends, because of their higher inertia. However, there are not yet established rules and interpretation is still highly specific for each lake.

Signature of Partner:

Jordi Catalan

Date: Barcelona 1 March 1998

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: March 1, 1998- February 28, 1999

Partner: Instituto del Agua. Universidad de Granada; ES (UGR-ES)

Principal Investigator: Prof. L. Cruz-Pizarro

Scientific staff: Dr. P. Sanchez-Castillo; Dr. P. Carrillo; Dr. I. Reche; M. Villar-Argaiz; JM. Sanchez-Medina

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I. OBJECTIVES FOR THE REPORTING PERIOD:

Spring (March-June) measurements of:
Bulk deposition, snow chemistry; Major water chemistry.
Additional measurements of biological parameters (1st level microbiology); processes (2nd level microbiology) and contemporary zooplankton

II. OBJECTIVES FOR THE NEXT PERIOD:

Publication and dissemination of results

PART B

III. Are there any particular problems ? Is your part of the project on schedule ?

Lake La caldera remained frozen until middle of July 1998.
It was absolutely impossible to perform any sampling during spring as we were not able to reach the lake. Unlike for the previous autumn period we could not be assisted by the army especial rescue group

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS*
(use other pages as necessary but preferably no more than 2)

During the reporting period we have finished with processing of 1977 data; we have discussed all gathered results and tried to find patterns of carbon flux through the pelagic food web.
By the time we submitted the second report we could not get results on phytoplankton and yet the data from bacteria, ciliates and heterotrophic nanoflagellates needed further analysis.
Now, we can report:
Phytoplankton abundance (mean for the water column) range from 5587 and 16988 cell/ml, showing an almost steady increase along the ice-free period until middle of the summer, then decreasing during early autumn. *Chromulina sp* shows population values between 2155 and 10691 cell/ml with peaks by the end of the ice thawing. It is replaced by *Chlorella sp* (730-11995 cell/ml) by the middle/end of the summer period. Both of them show a remarkable population decline at the end of the ice-free period.
This pattern roughly match with that observed in the "community" biomass which ranges from 21.7 to 50.0 ug C/l, although seasonal differences became much more attenuated as *Chromulina sp* increases individual size after the population peak.
Ciliates are very scarce in lake La Caldera. Individual samples never surpassed 24 cell/l, which represents 3491 pg C/l. Such values are much lower (by three ordres of magnitude) than those reported for 1996 and a negative correlation with greater sized (Rotifera and Crustacea) zooplankton densities seem to be evident. Maximum densities were reported during thawing and no any individual record was observed since middle of the ice-free period.
Heterotrophic nanoflagellates are also very poorly represented in the pelagic community. Average values for the water column (total HNF assemblage) were around 100 cell/ml which mean biomass values never greater than 0.3 ug C/l. Their contribution to the particulate organic carbon pool in the lake is more than two orders of magnitude lower than bacteria one.
We have not found autotrophic picoplankton in the lake.
We have paid particular attention to methods for bacterial enumeration and biomass estimation. Because of the very small size of bacteria (especially cocci forms) in the lake, the usual image analysis technique did not allow reliable measurements of cells, so we have quantified cell volume using electron microscopy and flow citometry techniques, repeating the measurements performed previously (1996). Now we can be sure that bacterial abundance is extremely low in La Caldera (single depth counting in the range of 72000 to 768000 cell/ml, and mean water profile values, within the range of 227000 and 445000 cell/ml) and so it is their biomass: mean values for the water profile, between 8.54 and 17.25 ug C/l.
These data and those about autotrophic production; bacterial heterotrophic production and (partly) on zooplankton bacterivory, allow us to depict a pattern of the carbon flux in the pelagic food web.

We have gathered data on bulk deposition using our own (and simple) meteorological station installed installed 20 Km away from the site and 1500 m lowered. The results seem to be not very fine and we have serious doubts of their representativeness.

V. List of Publications arising from the project (include copies):

Villar-Argaiz, M., JM. Medina-Sanchez, L. Cruz-Pizarro & P. Carrillo. Life history implications of calanoid *Mixodiaptomus laciniatus* in C:N:P stoichiometry. Verh. Internat. Verein. Limnol. In press.

Cruz-Pizarro, L., P. Carrillo, M. Villar-Argaiz & JM. Sanchez-Medina. Plankton biomass and species structure in lake la Caldera. Mem. Ist.Ital. Idrobiol. In preparation.

Carrillo, P., JM. Medina-Sanchez, M. Villar-Argaiz, I. Reche & L. Cruz-Pizarro. Primary production and heterotrophic bacterial production in lake la Caldera. Seasonal dynamics. Mem. Ist. Ital. Idrobiol. In preparation

Villar-Argaiz, M. & P. Carrillo. Nutrient dynamics at the consumer-prey interface: the influence of allochthonous vs aotochthonous inputs in lake La Caldera. Arch. Hydrobiol. In preparation.

Signature of Partner: [signature]

L. CRUZ-PIZARRO

Date: February 26, 1999

MOLAR REPORT 1999

Jean-Charles Massabuau

Contractor: Centre National de la Recherche Scientifique (CNRS)
Subject area: Fish, fish physiology
Leading scientist: Jean-Charles Massabuau
Scientific staff: Suzanne Dunel-Erb (CNRS, Strasbourg), Jean Forgue (Univ. Bordeaux I), Bernard Rivier (Cemagref, Aix en Provence), Charles Roqueplo (Cemagref, Bordeaux).
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I OBJECTIVES FOR THE REPORTING PERIOD

- Interpreting fish blood data combined with gill histology (scanning microscopy) for the lakes sampled during the programme.
- Organising the 1999 Molar meeting in Arcachon.
- Producing a draft for an interdisciplinary paper on "the water-chemical constraints limiting trout *Salmo trutta fario* adaptation in remote mountain lakes".

II MAIN RESULTS OBTAINED

Physiological analysis

When studying the ecology of remote mountain lakes and the role biodetectors can play as early alarm of air born pollution and climate changes, a basic question is to understand how fish succeed to live in such extreme biotopes where low mineralisation is the first major stress. Taking advantage of the palette of water ionic composition observed in the Molar lakes, we studied the minimal concentration of key ions (Na, Cl, Ca, alkalinity) compatible with fish life. The aim of the study was to gain more insights into the basic knowledge necessary to interpret secondarily contamination processes in the brown trout *Salmo trutta*.

Basically, it is worthwhile noticing that fish in such situation must develop two strategies of adaptation:

- First, they must reduce the ionic leaks by decreasing their gill permeability. It was classically known from laboratory experiments that the calcium ion play a key role to solve this problem but, to our knowledge, there was no field data about values of minimum water calcium concentration compatible with fish life in these biotopes.

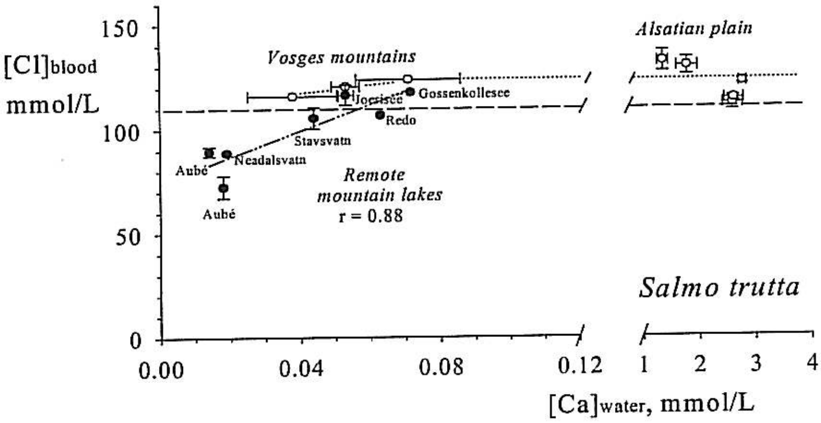

Figure 1: Relationship between blood chloride concentration ([Cl]b) in brown trout *Salmo trutta* and water calcium concentration in remote mountain lakes. It is only in lakes where [Ca]w < 30 $\mu mol \cdot L^{-1}$ that brown trout caught with gill nets can not maintain a normal [Cl]b.

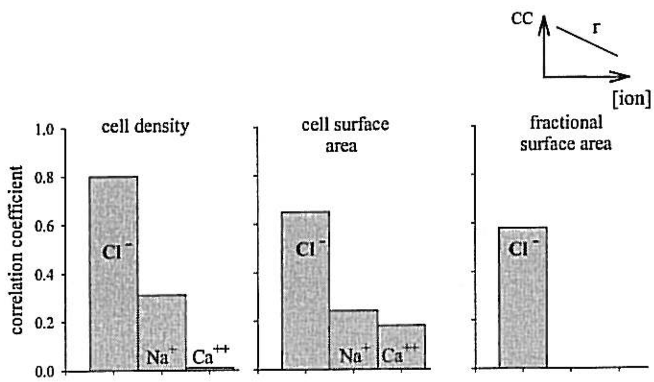

Figure 2: Relationship between chloride cell (CC) morphometry of brown trout and water ionic concentration in remote mountain lakes exhibiting a palette of water ionic concentrations. The relations were only considered to be of some adaptive value when a reduction of a given ion stimulated the CC proliferation (see insert). The correlation coefficient was systematically higher with [Cl]w. It was lower or absent for all other ions.

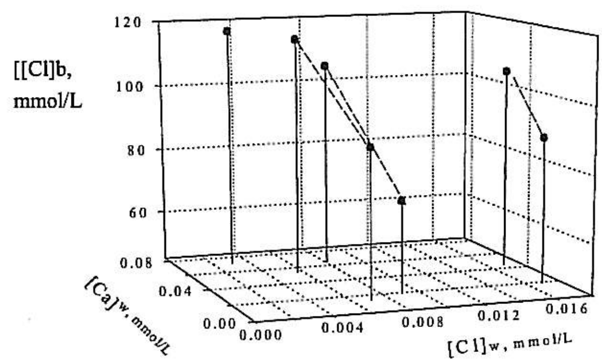

Figure 3: Summary relationship between blood Cl concentration ([Cl]b), water Ca ([Ca]w) and water Cl ([Cl]w) concentrations. A normal [Cl]b can be maintained only in mountain lakes where [Ca]w is high enough (see Figure 1). The stimulation of chloride cell proliferation occurring at low ([Cl]w (see Figure 2) does not allow by itself to compensate for a low [Ca]w.

-Second, they must improve the efficiency of their ionic pumps at the gill level. From laboratory study, it was well known that chloride cells participate to the ionic balance between blood and water. More especially, it was shown that in brown trout a decrease of NaCl in water stimulates their proliferation in low mineralised waters. However, beside this pioneer demonstration, the *in situ* ionic concentration at which this mechanism of adaptation could occur was completely unknown as well as if it was Na, Cl or both Na and Cl that were specifically responsible of this physiological adaptation.

Importantly, note that all data were obtained from fish that were at least 2-4 years old and which were either native of these lakes or stocked as 0+. All animals were caught with gill nets except a series in lake Jorisee (Switzerland).

Plasma ion analysis. In fish blood, the main contributors of osmolarity are the Na and Cl ions. Consequently, natremia ([Na]b) and chloremia ([Cl]b) were measured and compared to reference data obtained in the same fish species living in more mineralised waters (Alsatian plain and Vosges mountains, north-eastern France). Results were analysed as a function of water chemistry data.

The results show that *S. trutta* can maintain a normal blood Na concentration ≥ 110 $mmol \cdot L^{-1}$ in waters where the mineral load is as low as ≈ 4 $mg \cdot L^{-1}$ but that the blood Cl concentration starts to decrease below 8-10 $mg \cdot L^{-1}$. This [Cl]b response was not directly correlated to the concentrations of Na and Cl in the water but dependent on [Ca]w (Figure 1). When [Ca]w is higher than 30-40 $\mu mol \cdot L^{-1}$, *S. trutta* can maintain a normal chloremia even for [Cl]w as low as 3 $\mu mol \cdot L^{-1}$ (see below). This is coherent with literature data on the role of Ca in impermeabilising biological membranes but give new insights into critical limits compatible with brown trout life in remote mountain lakes and/or extremely diluted water solutions. Note that it is in lake Aubé (french Pyrénées) where [Ca]w is only 14-15 $\mu mol \cdot L^{-1}$, and in lake Ovre Neadalsvatn that trouts exhibited the lowest chloremia (70-75 $mmol \cdot L^{-1}$ for [Cl]w = 7-9 $\mu mol \cdot L^{-1}$). Note also, that due to our fish sampling protocol with gill nets, which obviously imposed a severe stress to all fishes, we were unable to say if the low chloremia was the result of the low calcium concentration *per se* or the result of the stress imposed by the test fishing at this low calcium concentration. Nevertheless, the present study demonstrates that for the brown trout *Salmo trutta*, a minimal [Ca]w compatible with a sustainable life is at least 15 $\mu mol \cdot L^{-1}$ (the concentration in lake Aubé) and that [Cl]b can be taken as an indicator of stress in low mineralised waters.

Insights into the adaptation of ion pumping mechanism at the gill level. This study was performed by analysing the fish gill anatomy by scanning microscopy. All fish gills collected in the Molar lakes were prepared in the field for the anatomical analysis in scanning microscopy. A first global analysis integrated with blood data clearly showed first that the proliferation of chloride cells (characteristic of osmoregulatory problems) in trout gill increases when the mineral load decreases. Three parameters were then specifically analysed. The cell density, the cell surface area and the fractional surface area that is the ratio of the cell surface area per unit of secondary lamellae area. The correlation coefficient between these morpho-anatomical characteristics and the water ionic composition were then calculated in an attempt to discriminate between the various ions able to stimulate the proliferation of chloride cells. The relationships were only considered to be of some adaptive value when a decrease of water ionic concentration was associated to a proliferation or an increase of cellular size of the surface aspects of the chloride cells. Figure 2 shows that the only ion which was systematically associated to an increase of chloride cell density, surface and fractional surface was the chloride ion. Based on literature data and the present study, we consequently suggest that in these biotopes, [Cl]w is the single ion which specifically stimulates the chloride cell proliferation. Together with the calcium, they play a key role in the strategy of adaptation of brown trout in low mineralised waters. Remarkably, the largest proliferation of chloride cell was measured on the gills of brown trouts from Gossenkollesee where [Cl]w was only 3 $\mu mol \cdot L^{-1}$ ([Ca]w $\approx$ 80 $\mu mol \cdot L^{-1}$). This value appears thus today as the lowest known water [Cl]w value compatible with fish life.

Note, in addition that although the problem arising from a low [Cl]w can be counterbalanced by a chloride cell proliferation, this physiological adaptation can not replace the deleterious effect of a low [Ca]w on the gill epithelium permeability. Indeed, Figure 3 illustrates that at any [Cl]w ranging from 5 to 17 $\mu mol \cdot L^{-1}$ the chloremia systematically decreased for [Ca]w $\leq$ 20 $\mu mol \cdot L^{-1}$. A high enough [Ca]w, is consequently a prerequisite to allow fish life in these extreme environments.

Film production:
"Looking for artic charr in remote mountain lakes"

The video-movie that we realised in 1998 and whose aim was to present (i) a test fishing performed by MOLAR scientists within the framework of this program and (ii), with the use of an underwater camera, some aspects of the biotope where the artic charr is living is now commercially available. The film (13 min, color, Pal, Secam, NTSC, betacam, etc) has been produced by the CNRS Audio-Visuel and is distributed in french and in english. The French Ministry of Environment sponsored its distribution. During the MOLAR meeting which was held in Arcachon, it has been freely offered to all participants.

IV. List of Publications arising from the project:

Minimal water ion concentration compatible with fish life in mountain lakes. Massabuau et al. Nature (in preparation)

Signature of Partner:

Date: 14 February 1999

Reporting period: From 1th March 1998 to 28 February 1999

Partner: Consejo Superior de Investigaciones Científicas. Department of Environmental Chemistry. Barcelona.

Principal Investigator: Joan O. Grimalt

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I. OBJECTIVES FOR THE REPORTING PERIOD

Completion of field sampling in Øvre Neadalsvatn.

Completion of the analyses of snow, air, water, bulk, wet and dry deposition samples in all lakes.

Completion of the fish analyses.

Cross-correlation of the results from atmospheric, water, precipitation and sediment samples.

Cross-correlation between the results of the fish analyses and the hystological, physiological and enzymatic parameters determined by other groups.

Cross-correlation between the composition of trace organic compounds in air, water and fish.

II OBJECTIVES FOR THE NEXT PERIOD

End of project

III PARTICULAR PROBLEMS. SCHEDULE.

All our tasks in the project were developed without any major problem. All samples were collected and all analyses have been completed as scheduled.

IV MAIN RESULTS ACHIEVED.

Methodology.

C_{18} solid-phase disks have been observed to be useful for the measurement of organochlorine compounds (OC) and polycyclic aromatic hydrocarbons at pg/l in atmospheric precipitation samples with reproducibilities of 5-15% and extraction efficiencies of 80-100%. Quantitation and detection limits of 0.14-3.5 pg/l were achieved from the analysis of 0.25-10 l of water, *e.g.* bulk precipitation or snow. The use of C_{18} disks allows the determination of these organic pollutants in remote areas affording collection and extraction of large numbers of samples with limited instrumentation.

A method for the analysis of trace OC in large numbers of muscle fish samples has been developed. This method provides higher precision than that observed in the most uniform fish populations. Among all sample handling steps, evaporation losses has been observed to constitute the main aspect of recovery decrease. These can be minimized to less than 10% when it is avoided that the extract go to dryness. In any case, the effect of these losses can be compensated by correction by a tetrabromobenzene surrogate.

Sample grounding with sodium sulphate provides significant higher concentrations than freeze-drying. Soxhlet extraction for 18 h is sufficient to draw most OC from the muscle samples, no significant peaks representing measurable concentrations of these compounds have been found by further extraction after this period.

Repeatibility and reproducibility is smaller than the dispersion between fishes of similar length and age from the same lake for all compounds except a-HCH.

From the point of view of instrumentation (gas chromatography coupled to mass spectrometry using chemical ionization in the negative ion mode –GC-NICI MS-), the use of ammonia as reagent gas provides lower limits of detection and quantitation than methane for most OC. This lower limits allow the detection and quantitation of species with three and four chlorine substituents in aromatic rings which are difficult to determine at trace levels when methane is used as reagent gas. The use of ammonia as reagent gas also facilitates the quantitation of the DDT derivatives.

The mass spectra obtained with ammonia and methane correspond to the molecular incorporation of thermal electrons rather than true chemical ionization reactions. Despite the differences in fragmentation patterns associated to these two reagent gases, the use of one or the other does not require changes in the compound-specific ions selected for the selected ion monitoring mode.

In any case, calibration of all OC using straight lines and check for uniform slope values is needed for correct quantitation.

Finally, a method based on HPLC-fluorescence at the excitation/emission wavelength pairs of naphthol (290/335 nm) and pyrenol (345/395 nm) on fish bile samples has been developed. The method has allowed to determine the concentrations of hydroxylated polycyclic aromatic hydrocarbons in fish from the lakes considered in the project. Concentration ranges between 69 and 990 ng/ml bile have been found.

Field studies

High altitude lakes are remote but not pristine environments. All measurements performed on fish, water, air and sediments show that the concentrations of OC and PAH are similar to those found in sites with a moderate degree of contamination which is *a priori* unexpected when considering the long distance of these ecosystems from the pollution sources. The present project has shown that high altitude lakes provide a good case for the study of long-range transport of persistent organic pollutants.

The study of fish concentrations and sediment inventories (430-2800 meters above sea level, 40-67ºN) shows that lake elevation is the major variable determining the accumulation of low volatility OC such as 4,4'-DDE, 4,4'-DDT and penta- to hepta-chlorobiphenyls. These compounds are also significantly correlated with annual average air temperatures. In contrast, volatile OC (sub-cooled liquid vapor pressure > $10^{-2.5}$ Pa) do not exhibit any gradient with elevation. The results obtained in the study illustrate that in temperate regions global distillation of OC involves the selective retention of the low volatility compounds at the coldest areas. This fractionation effect is responsible for the accumulation of high concentrations of potentially harmful compounds in high altitude ecosystems. PAH do not show this trend with temperature.

On the other hand, other aspects such as fish age or trophic status are also relevant for the accumulation OC in fish. However, the accumulation trends derived from these factors are smaller than those observed as consequence of temperature effects.

A correlation between levels of lake sediment PAH, hydroxy PAH in fish and antioxidant hormones in fish (namely ß-carotene and gluthation disulphide) has been found in the high altitude lakes considered in this study. This is the first case of a correlation identified between markers of environmental stress and a lake pollutant. The analysis of OC and metals have allowed to exclude any trend with these antioxidant hormones in the case of these compounds.

The sediment data show that PAH inventories in these high altitude lakes started to increase at the beginning of the century. Conversely, the increase of OC is observed in the seventies.

Atmospheric deposition shows a higher content in persistent organic pollutants in wet samples. The deposition fluxes exhibit rather constant values throughout the year.

V. LIST OF PUBLICATIONS ARISING FROM THE PROJECT

P. Fernandez, R. Vilanova and J.O. Grimalt
PAH distributions in sediments from high mountain lakes.
Pol. Arom. Comp. **9**, 121-128 (1996)

L. Berdie, M. Santiago-Silva, R. Vilanova and J.O. Grimalt*
Retention time repeatability as a function of the injection automatism in the analysis of trace organochlorinated compounds with high-resolution gas chromatography.
J. Chromatogr. A **778**, 23-29 (1997)

R. Vilanova, P. Fernandez and J.O. Grimalt
Atmospheric persistent organic pollutants in high altitude mountain laks. A preliminary study
In: *Sea-air exchange: processes and modelling.*
Edited by J.M. Pacyna, D. Broman and E. Lipiatou. 1998.
Office for official publications of the European Communities. Luxembourg. 1998. pp. 209-215.

G. Carrera, P. Fernandez, R. Vilanova and J.O. Grimalt
Analysis of trace polycyclic aromatic hydrocarbons and organochlorine compounds in atmospheric deposition by solid-phase disk extraction
J. Chromatogr. A **823**, 189-196 (1998)

R. Chaler, R. Vilanova, M. Santiago-Silva, P. Fernandez and J.O. Grimalt
Enhanced sensitivity in the analysis of trace organochlorine compounds by negative ion mass spectrometry using ammonia as reagent gas
J. Chromatogr. A **823**, 73-79 (1998)

L. Berdié and J.O. Grimalt
Assessment of the sample handling procedures of a man power minimized method for the analysis of organochlorine compounds in large numbers of fish samples
J. Chromatogr. A **823**, 373-380 (1998)

E. Escartin and C. Porte
Biomonitoring of PAH pollution in high-altitude mountain lakes through the analysis of fish bile
Environ. Sci. Technol., in press

J.O. Grimalt, L. Berdié, P. Fernandez, R. Vilanova, R. Psenner, R. Hofer, B.O. Rosseland, P.G. Appleby, J. Catalan, J.C. Massabuau and R.W. Battarbee
Selective cold trapping of organochlorine compounds in high altitude lakes
Nature, Submitted for publication

L. Berdie, M. Santiago-Silva, R. Vilanova, P. Fernandez and J.O. Grimalt
Detector linearity in the routine analysis of organochlorinated compounds by GC-ECD and GC-MS
Anal. Chem., Submitted for publication

L. Berdié, J.O. Grimalt, P. Fernandez, R. Vilanova, D. Pastor
Environmental and physiological aspects determining the composition of organochlorine compounds in fish from high altitude lakes
Environ. Sci. Technol., in preparation

J.O. Grimalt, R. Vilanova, Fernandez and R. Lackner
Oxidative stress and polycyclic aromatic hydrocarbon intake in fish from high altitude sites
Environ. Sci. Technol., in preparation

G. Carrera, R. Vilanova, P. Fernandez and J.O. Grimalt
The composition of organochlorine compounds in snow from high altitude sites
Water Res., in preparation

G. Carrera, P. Fernandez, R. Vilanova and J.O. Grimalt
The origin of polycyclic aromatic hydrocarbons in snow from high altitude sites
Water Res., in preparation

G. Carrera, P. Fernandez, R. Vilanova and J.O. Grimalt
Precipitation trends of polycyclic aromatic hydrocarbons in Redo Lake (Pyrenees)
Atmos. Environ., in preparation

G. Carrera, R. Vilanova, P. Fernandez, J.O. Grimalt, M. Ventura, Ll. Camarero and J. Catalan
Atmospheric deposition of organochlorinated compounds in Redo Lake (Pyrenees)
Atmos Environ., in preparation

G. Carrera, P. Fernandez, R. Vilanova and J.O. Grimalt
Precipitation trends of polycyclic aromatic hydrocarbons in Gossenköllesee Lake (Alps)
Atmos. Environ., in preparation

G. Carrera, R. Vilanova, P. Fernandez, J.O. Grimalt, M. Ventura, Ll. Camarero and J. Catalan
Atmospheric deposition of organochlorinated compounds in Redo Lake (Alps)
Atmos Environ., in preparation

R. Vilanova, P. Fernandez and J.O. Grimalt
Sedimentary composition of polycyclic aromatic hydrocarbons in European high mountain lakes
Environ. Sci. Technol., in preparation

P. Fernandez, R. Vilanova and J.O. Grimalt
Markers of combustion processes in European high mountain lakes
Environ. Sci. Technol., in preparation

R. Vilanova, P. Fernandez and J.O. Grimalt
The composition of organochlorine compounds in atmospheric samples from high altitude lakes
Atmos. Environ., in preparation

R. Vilanova, P. Fernandez and J.O. Grimalt
Origin and transformation of airborne polycyclic aromatic hydrocarbons from high mountain lakes
Atmos. Environ., in preparation

R. Vilanova, P. Fernandez and J.O. Grimalt
Organochlorine compounds high mountain lake waters
Water Res., in preparation

P. Fernandez, R. Vilanova and J.O. Grimalt
The partitioning of polycylic aromatic hydrocarbons in waters from high altitude lakes
Water Res., in preparation

P. Fernandez, R. Vilanova and J.O. Grimalt
Sedimentary distributions of polycyclic aromatic hydrocarbons in European high altitude lakes
Environ. Sci. Technol., in preparation

P. Fernandez, R. Vilanova and J.O. Grimalt
Background levels of polycyclic aromatic hydrocarbons before and after industrial development
Nature, in preparation

P. Fernandez, R. Vilanova and J.O. Grimalt
Changes in contamination by polyclic aromatic hydrocarbons in high mountain lakes in the last century
Environ. Sci. Technol., in preparation

R. Vilanova, P. Fernandez, J.O. Grimalt, M. Ventura, Ll. Camarero and J. Catalan
Fluxes and reservoirs of organochlorinated compounds in high mountain lakes. I. Lake Redo (Pyrenees)
Environ. Sci. Technol., in preparation

R. Vilanova, P. Fernandez, J.O. Grimalt, U. Nickus, H. Thies and R. Psenner
Fluxes and reservoirs of organochlorinated compounds in high mountain lakes. II. Lake Gossenköllesee (Alps)
Environ. Sci. Technol., in preparation

R. Vilanova, P. Fernandez, C. Martinez, L. Lien and J.O. Grimalt
Fluxes and reservoirs of organochlorinated compounds in high mountain lakes. III. Lake Øvre Neadalsvatn (Scandinavia)
Environ. Sci. Technol., in preparation

P. Fernandez, R. Vilanova, J.O. Grimalt, M. Ventura, Ll. Camarero and J. Catalan
Deposition fluxes and in-lake distribution of polycyclic aromatic hydrocarbons in high mountain sites. I. Lake Redo (Pyrenees)
Environ. Sci. Technol., in preparation

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Environ. Sci. Technol., in preparation

P. Fernandez, R. Vilanova, C. Martinez, L. Lien and J.O. Grimalt
Deposition fluxes and in-lake distribution of polycyclic aromatic hydrocarbons in high mountain sites. III. Lake Øvre Neadalsvatn (Scandinavia)
Environ. Sci. Technol., in preparation

Signature of partner

date: 28th February 1999

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: 1-3-1998 to 28-2-1999

Partner: Botanical Institute, University of Bergen

Principal Investigator: H.J.B. Birks

Scientific staff: Einar Heegaard
John-Arvid Grytnes

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+ 47 55 58 33 50

Fax: + 47 55 58 96 67

E-Mail: John.Birks@bot.uib.no
Jon.Grytnes@bot.uib.no

I. OBJECTIVES FOR THE REPORTING PERIOD:

- Development of the MOLAR primary data-base using ACCESS software.
- Development of an unambiguous site/variable sampling time coding system and series of data-base tables between Bergen, Oslo and London.
- Statistical analysis of data collected during the AL:PE projects that form the basis of part of MOLAR Work Package 3.
- Storage of MOLAR data after analytical quality control.
- Statistical analysis of MOLAR Work Package 3 data.

II. OBJECTIVES FOR THE NEXT PERIOD:

- The project finishes on 28.2.1999.

PART B

III. ARE THERE ANY PARTICULAR PROBLEMS ? IS YOUR PART OF THE PROJECT ON SCHEDULE ?

- No problem in connection with the data-base design or structure.
- The absence of data from many MOLAR colleagues has created the problem that the data-base design and structure cannot, as yet, be fully tested for WorkPackages 1 and 2.

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS* (use other pages as necessary but preferably no more than 2)

The main statistical work by H.J.B Birks has been on the development of the AL:PE modern diatom-pH calibration data-set, the development of predictive models for lake-water pH using diatoms preserved in lake sediments, and the comparison of diatom pH preferences in high-altitude/high-latitude lakes (AL:PE and MOLAR) and low-altitude (SWAP) lakes. The resulting pH inference model has a root mean square error of prediction (RMSEP) of 0.33 pH units, based on weighted averaging partial least squares. Optima for the major diatom taxa have been estimated by Gaussian logit regression using maximum-likelihood estimation. The results obtained highlight (a) the high quality of the AL:PE diatom data-set as a predictive tool and (b) the uniqueness of high-altitude/high-latitude lakes in terms of light climate, pH optima, and diatom assemblages.

The main statistical work by John-Arvid Grytnes in conjunction with Einar Heegaard, Roy Thompson, and John Birks has involved regression modelling of the biological and sedimentary variables in the MOLAR Work Package 3 lake sediments in relation to the instrumentally-based climate data for each lake. The modelling has involved principal components analysis of the down-core diatom, chrysophyte cyst, chironomid, and cladoceran data, LOESS regression and smoothing of the climate data using different spans, and linear correlation of the responses (biology, pigments, sedimentary parameters) in relation to five different climatic predictors. The results highlight new statistical problems because of sample temporal autocorrelation and the complex relationships between biological and sedimentary parameters and climate in these highly sensitive high mountain lakes.

V. List of Publications arising from the project (include copies):

Cameron, N.G., Birks, H.J.B., Jones, V.J. and 13 others. (1999) Surface-sediment and epilithic diatom pH calibration sets for remote European mountain lake (AL:PE project) and their comparison with the Surface Waters Acidification Programme (SWAP) calibration set. *J. Paleolimnology* (in press).

Birks, H.J.B. (1998) Numerical tools in fine-resolution paleolimnology-progress, potentialities, and problems. *J. Paleolimnology* **20**, 307-332.

Lotter, A.F., Birks, H.J.B., Hofmann, W. & Marchetto, A. (1997) Modern cladocera, chironomid, diatom, and chrysophyte cyst assemblages as quantitative indicators for the reconstruction of environmental conditions in the Alps I. Climate. *J. Paleolimnology* **18**, 395-420.

Lotter, A.F., Birks, H.J.B., Hofmann, W. & Marchetto, A. (1997) Modern cladocera, chironomid, diatom, and chrysophyte cyst assemblages as quantitative indicators for the reconstruction of environmental conditions in the Alps. II. Nutrients. *J. Paleolimnology* **19**, 443-463.

Signature of Partner: HJB. Birks

Date: 28. ii. 99

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: 01.03.98 – 28.02.99

Partner: LFI, Institute of Zoology, University of Bergen

Principal Investigator: Gunnar G. Raddum

Scientific staff: Arne Fjellheim, Øyvind A. Schnell

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I. OBJECTIVES FOR THE REPORTING PERIOD:

Supporting field work

Sorting and handling of samples

Data processing and quality assurance

Reporting and production of manuscripts

II. OBJECTIVES FOR THE NEXT PERIOD:

Tie together results from other Workpackages for overall analyses.

Reporting and production of publications.

PART B

III. Are there any particular problems? Is your part of the project on schedule?

All work on the samples from the sites that we are responsible for is on schedule.

IV. MAIN RESULTS OBTAINED: METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS (use other pages as necessary but preferably no more than 2)

Sorting and processing of qualitative and quantitative invertebrate samples is finished. Species lists and data on seasonal variation have been obtained. The results are now being evaluated and manuscripts prepared.

Important zoogeographical knowledge of different species have been obtained. New information about the biodiversity in remote mountain lakes of Europe has become available. The effects of altitude (as a proxy for climate), latitude, longitude, water quality and other physical and biological variables for the composition of benthic invertebrates have been evaluated. Altitude (indirectly climate) and pH of the water so far seems to be the most important variables determining the fauna composition (Fjellheim *et al.*, in press). Further statistical treatment, combining results from other workpackages, is expected to give more detailed understanding and improved conclusions. Overview of habitat use of different benthic organisms in remote mountain lakes in Europe have been compiled and will be available as a database.

A manual has been prepared with the aim to ease chironomid identification and promote a more uniform approach to taxonomy by the different workers within the project (Schnell, 1998). Also, a proposal for a coding system for European chironomids will be published soon (Schnell *et al.*, 1998).

V. List of Publications arising from the project (include copies):

Fjellheim, A., A. Boggero, G.A. Halvorsen, A.M. Nocentini, G.G. Raddum, M. Rieradevall & Ø.A. Schnell. Distribution of benthic invertebrates in relation to environmental factors. A study of European remote alpine lake ecosystems. (Verh. Int. Verein. Limnol. 27: in press).

Schnell, Ø.A. 1998 a. Guidelines for the identification of chironomid larvae in the MOLAR project. NIVA report SNO 3710-97. 23 pp.

Schnell, Ø.A. 1998 b. The development of the chironomid fauna in sediment cores from five oligotrophic lakes in Europe (Abstract of oral presentation given at the XXVII SIL Congress in Dublin, August 1998).

Schnell, Ø.A., Granados, I. & Rieradevall, M. 1999. Proposal for a standarised coding system for European Chironomidae (Diptera) for use in ecological and paleoecological databases. (To be published as a NIVA report soon).

Signature of Partner:

Gunnar G. Raddum

Date:18.02.99

PART B

Reporting period: from 1-3-1998 to 28-2-1999

Partner: Consiglio Nazionale delle Ricerche – Istituto Italiano di Idrobiologia (CNR-III)

Principal Investigator: A. Lami
Scientific staff: R. Mosello, P. Guilizzoni, M. Manca, A.M. Nocentini, A. Pugnetti, A. Boggero, C. Callieri, R. Bertoni, A. Marchetto, G.A. Tartari, L. Corbella, V. Libera, M. Contesini, R. Bettinetti, P. Comoli.

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Fax:: +39-0323-556 513 e-mail: a.lami@iii.to.cnr.it

I. OBJECTIVES FOR THE REPORTING PERIOD:

- Data collection in the drainage basin of Lake Paione Superiore (LPS) on: meteorological base parameters, amount of precipitation, chemistry of atmospheric deposition, lake chemistry, microbial pelagic food web including bacteria, autotrophic picoplankton, heterotrophic nanoflagellates, ciliates, phytoplankton, zooplankton;
- Sample collection for lake water chemistry analysis on the secondary site, L. Paione Inferiore (LPI);
- Sediment core analysis for pigments and elemental carbon, nitrogen, and sulphur;
- Investigation of macroinvertebrates and co-operation with experts to assess the taxonomical benthic refinement;
- Organisation of workshop on Analytical Quality Control for chemical analyses;
- Participation in specific workshop for method and data harmonisation.

II. MAIN RESULTS OBTAINED: METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS (use other pages as necessary but preferably no more than 2)

Workpackage 1

Collection of volume of precipitation and meteorological data

Since July 1996 an automatic weather station (AWS) has been installed on LPS. This equipment has provided data on temperature, solar radiation, wind direction and speed, amount of precipitation.

With the aim of collecting all the meteorological data relevant to our geographical area, we are also collecting data from other high altitude AWS in co-operation with the Meteorological Service of the Piedmont Region. This will help to construct a fuller set of meteorological information relevant to the work involved in the MOLAR Workpackage 1 and 3, and is being done in collaboration with Dr R. Thompson, Univ. of Edinburgh.

Chemistry of atmospheric deposition

Atmospheric deposition was sampled at the station of Graniga, located at 1080 m a.s.l., in the same valley where lakes Paione Superiore and Inferiore (2269 and 2002 m a.s.l.) are located.
Samplings and chemical analyses were performed weekly. The volume of precipitation during 1998 was 1251 mm. Results show pH values ranging from 3.82 to 6.93, with a median value of

4.70. The main cations are ammonium and hydrogen ion (median values of 50 and 20 $\mu eq\ l^{-1}$), while nitrate and sulphate (48 and 43 $\mu eq\ l^{-1}$) are the main anions.

Lake chemistry

The LPS sampling for 1998 are summarised in Tab. 1. In LPI we took only outflow samples.

Tab. 1 - Summary of the samples collected.

	Chem.	ZOOS	ZOOL	phyto	APP	HPP	HNF	ciliates
4-2-98	*(3)			*(2)	*(2)	*(2)	*(2)	*(2)
18-3-98	*(3)			*(2)	*(2)	*(2)	*(2)	*(2)
6-5-98	*(3)			*(2)	*(2)	*(2)	*(2)	*(2)
8-6-98	*(3)			*(2)	*(2)	*(2)	*(2)	*(2)
13-7-98	*(3)	*(2)	*integr.	*(2)	*(2)	*(2)	*(2)	*(2)
29-7-98	*(3)	*(2)	*integr.	*(2)	*(2)	*(2)	*(2)	*(2)
24-8-98	*(3)	*(2)	*integr.	*(2)	*(2)	*(2)	*(2)	*(2)
16-9-98	*(1)	*(2)	*integr.	*(2)	*(2)	*(2)	*(2)	*(2)
27-10-98	*(2)	*(2)	*integr.	*(2)	*(2)	*(2)	*(2)	*(2)
17-12-98	*(2)			*(2)	*(2)	*(2)	*(2)	*(2)

* indicates that a samples was taken, while number of depths sampled are reported in brackets. See text for the explanation of the code used.

The range of concentration of chemical variables in LPS and LPI is similar to that of the previous years. Values of total ionic concentrations between 122-185 and 192-236 $\mu eq\ l^{-1}$ and of conductivity 8-12 and 11-13 $\mu S\ cm^{-1}$ at 20°C are measured in LPS and the surface values in LPI, respectively. Figure 1 shows the trends, observed over the last 8 years, of pH, alkalinity, sulphate and total inorganic nitrogen (TIN), expressed in $\mu eq\ l^{-1}$, for the two lakes. The main difference lies in their alkalinity values, which range between 0-10 $\mu eq\ l^{-1}$ in LPS (dashed line) and between 20-40 $\mu eq\ l^{-1}$ in LPI (solid line). Therefore, pH is between 5.2-6.3 in LPS, while in LPI the range is 6.1-6.8. Alkalinity and pH values show well-defined seasonal variations. The lowest values are measured at the snowmelt (June-July) when large amounts of pollutants (especially nitrate and sulphate) reach the lakes, and maximum values at the end of the summer and during the snow cover. Minimum summer values of nitrate correspond to maximum phytoplankton uptake. Figure 1 clearly shows a significant increase in pH (particularly in LPS) and a decrease in sulphate and TIN corresponding to the same long-term trends observed in atmospheric depositions.

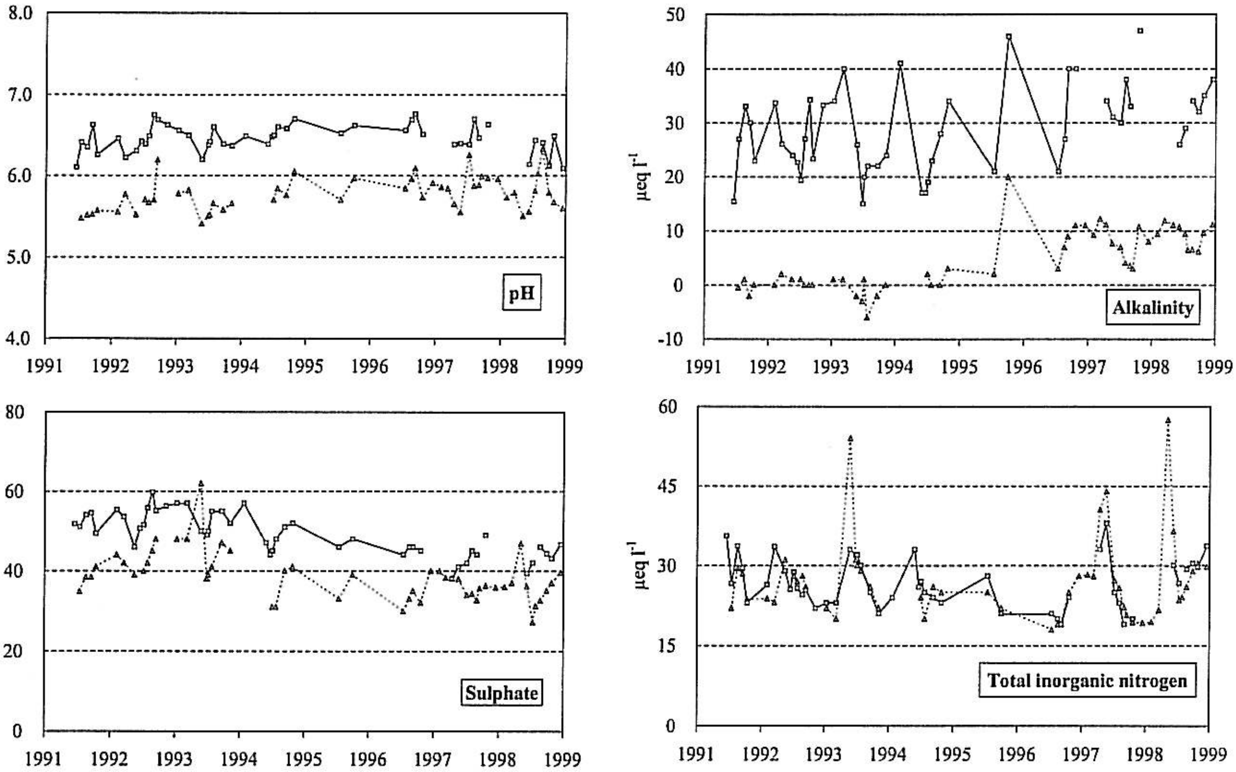

Fig. 1 - Trends of pH, alkalinity, sulphate and total inorganic nitrogen in lakes Paione Superiore (dashed line) and Inferiore (solid line).

Microbial (pelagic) Food Webs - 1st Level

APP, Bacteria, HNF, ciliates and phytoplankton

Ten samplings were performed during 1998 (cf. Tab. 1) to collect micro-organisms present in the Lake Paione food web. As in the previous years the autotrophic picoplankton (APP), bacteria (HPP), heterotrophic nanoflagellates (HNF), ciliates and phytoplankton were identified, counted and their biomass expressed in terms of carbon content (from biovolume measurements). The intercalibration of HNF and bacteria counted using different procedures in C. Budejovice and in Pallanza laboratory was performed. The depths were the same as those chosen in 1997: one meter below the surface and one meter above the bottom.

APP: *Synechococcus* sp. was rarely found, and APP was mainly composed by coccoid cells of 2 µm and eukaryotic algae. The numbers ranged from 0 to 22 cell ml^{-1} in surface and bottom samples. The carbon content was not higher than 0.06 µg C l^{-1}.

HPP: All the different bacterial forms were found in this lake: cocci, rods, vibrions, and in some months the filamentous forms were dominant. In July very large rods were found, so that the carbon and biomass values were high. Under the ice the higher values are found near the bottom where the mean is 0.322 million cell ml^{-1}; conversely, in the ice free period the surface numbers are higher with 0.641 million cell ml^{-1}. Carbon and biomass were, with the sole exception of September, higher at the bottom. Carbon varied from 1.4 to 56 µg C l^{-1}.

HNF: The heterotrophic nanoflagellates found at the two depths were of two sizes: smaller than 3 µm and larger, but no more than 10 µm. Their number and biomass were higher at the bottom than at the surface. The high value of 17 million HNF per liter was reached in July. The carbon value ranged from 0.3 to 43 µg/l.

Ciliates: The ciliate community is represented by Prostomatida, Oligotrichida and Scuticociliatida. The two genera of prostomatida recognized to date are *Urotricha* and *Holophrya.* From protargol preparations at least 3 species of *Urotricha* seem to be present in this lake: *U. furcata, ovata* and *agilis.* Among the oligotrichida, *Halteria* sp. and *Strombidium* sp. are the only organisms found. *Strombidium* sp. organisms were observed in fission. During winter ice-cover the ciliate carbon was very low at both depths but the abundance of prostomatids with *Urotricha* spp. and of the oligotrich *Halteria* reached the value of 2000 ind l^{-1}. Under the ice cover the carbon values were very low; the highest carbon values being measured at the bottom, in summer. The range of the number values was 25-2000 individuals l^{-1} and the carbon varied from 0.01 to 2.3 µg C l^{-1}.

Phytoplankton: In 1998 phytoplankton comprised mainly Chrysophyceae and Dinophyceae. The group of Chlorophyceae was also present with *Chlamydomonas* spp., but with few individuals. The highest number was reached in July (2783 ind ml^{-1}) near the surface. A peak under the ice cover, in the surface sample, due to cf. *Chromulina* sp. was found on February. Many colonies of *Dinobryon sertularia* were found.

In 1998 the mean total carbon concentration in the microbial food web was 25 and 30 µg C l^{-1} near the surface and the bottom respectively. At the two depths, under the ice the concentration was 15 and 10 µg C l^{-1} while in the ice-free season was 34 and 46 µg C l^{-1} with a dominance of the heterotrophic organisms.

Zooplankton

Following the sampling protocol, we collected, on each date both net, integrated samples along the water column, as well as bottle samples at two different depths, i.e. 1 m above the bottom and 1 m below the surface (cf. Tab. 1). We obtained carbon from body length through length/biomass regression equations and through direct measurements of dry weight of replicate live samples.

In Lago Paione Superiore, population density is always negligible in the most superficial layer. This distribution is due to the fact that Crustacea are the most abundant component of the zooplankton community of the lake. The levels of population density attained are noteworthy (on average ca 20 ind l-1); maximum values, usually found in August, vary considerably between the years; up to 50 ind l-1 can be attained. This extreme variability can result from the type of sampling we used (volumetric sampling on a single location), which makes it possible to collect swarms. A large spatial variability (both horizontal and vertical) characterises the distribution of zooplankton in this type of environments. Except for one date, Cladocera, and particularly Daphnia (D. longispina) are the most abundant organisms, especially in September. They usually develop after the peak of Cyclops abyssorum, which occurs in August. The dominance of Crustacea is even clearer in terms of biomass. On average, carbon is around 70 µg l-1, but very high levels can be reached (ca 250 µg l-1) (September, 1998). This value is probably relative to a swarm, being population density in the net sample collected at the same date, not so high. An almost homogeneous distribution of zooplankton along the water column is suggested form the data of September 1996. In fact, that sampling day was particularly cloudy (89% cloud cover).

There is a very good correspondence between the data of carbon biomass obtained directly from dry weight of live samples and those obtained indirectly, by applying LWRE. (length-weight regression equation). The estimates are very good also because they were made on independent samples, where a large variability could be expected. The dominance of Daphnia specimens as well as their richness in lipids in our samples means that food is of good quality. Which are the food sources for Daphnia is an open question. Certainly, it is intriguing the correspondence, already stressed and published (Cammarano & Manca, 1996) between the decline in phytoplankton numbers and the increase in Daphnia population density. This is still evident when we compare the seasonal changes in total POC with those in the standing stock biomass of zooplankton.

Macroinvertebrates

Qualitative "kick samples" were taken during the ice-free period in LPS at 3 littoral, 2 inlets and 2 outlets (100 and 200 m downstream) stations, using a net with a 225 µm mesh aperture. On 10 October, it was not possible to collect any samples from the inlets because they were dry.
The depth level considered was about 50-100 cm and littoral sampling stations were selected taking account of differences in substratum. A complete fieldwork was possible only on 21/7 and 29/9 while on 29/10 the inlets were completely dry; only littoral and outlet samples were taken in this occasion.
The macrobenthos of the littoral community is prevalently composed of Insecta, particularly Diptera Chironomidae, which represent more than 90%. Second as importance are Oligochaeta, while Plecoptera (Nemouridae and Leuctridae), Trichoptera (Limnephilidae and Rhyacophilidae) and Coleoptera (Dytiscidae) are quite well represented. Hydracarina and Turbellaria are less frequent. Other groups, such as Culicidae, Empididae, Limoniidae, Simulidae and Tipulidae, are negligible.

Workpackage 3

Pigment analysis

Eight sediment cores (SAAN1, HAGE2; LEDV4, GKS3, OVNE5, TERI6, REDO1 and CIM1) were collected by site-operator and sent to our Institute for plant pigment, carbon nitrogen and sulphur determinations. The identification and quantification of the specific carotenoids of algae was performed by High Pressure Liquid Chromatography (HPLC) as described by the MOLAR method Manual and ca. 900 samples was measured. The same number of samples was analysed for carbon, nitrogen and sulphur content. The sediment remaining after the pigment extraction was transferred to the laboratory responsible for zooplankton remains analysis. All the data were transferred to the MOLAR database.
In this year, a special meeting among the specialists for the determination of the Chrysophytes cysts was organised in Pallanza by A. Marchetto. The main objective was to refine the cysts taxonomy in order to produce a comparable analysis of the different cores collected in the WP3.
A major part of the activity for this period was the elaboration and evaluation of the result in co-operation with the site-operators involved in the WP3 activity. The more interesting results will be presented as co-ordinated paper into scientific journals: Journal of Paleolimnology and Memorie dell'Istituto Italiano di Idrobiologia.

III. PRESENTATION OF RESULTS

A special volume of the "Memorie dell'Istituto Italiano di Idrobiologia", Straskrabova, Callieri and Fott (Eds.), is in preparation with the aim to collect the papers derived from the studies done in the WP1 on the "pelagic food web", including microbial loop phyto- and zooplankton. During the Workshop held in Pallanza from 11 to 13 November 1998 a content of the volume was prepared; a paper on the lacustrine chemistry was also included.

The main results from the WP3 "Climate variability and ecosystem dynamics at remote mountain lakes" will be collected in the form of scientific papers. These contributions will be published in a special Volume of "Memorie dell'Istituto Italiano di Idrobiologia", edited by A. Lami, A. Lotter, A. Khorola and N. Cameron (Eds.).

IV. LIST OF PUBLICATIONS ARISING FROM THE PROJECT (INCLUDE COPIES):

Signature of Partner:

Date: 1/3.99

Dr. A. Lami

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: **01-03-98 / 28-02-99**

Partner: **Laboratorio Biologico - Provincia Autonoma di Bolzano (I)**

Principal Investigator: **Dr. Bertha Thaler**

Scientific staff: **Danilo Tait, Andrea Scapin**

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Fax: 39 471 951263 E-Mail: Danilo.Tait@provinz.bz.it

I. OBJECTIVES FOR THE REPORTING PERIOD:

- Water chemistry sampling and analyses for Lago di Latte (Milchsee) and Lago Lungo (Langsee)
- Zooplankton and phytoplankton sampling, species identification, enumeration, biovolume calculation and chlorophyll-a analyses for Lago di Latte and Lago Lungo.
- Chemical analyses of precipitation at 3 sites
- Elaboration of the obtained data

II. OBJECTIVES FOR THE NEXT PERIOD:

III. The sampling and analyses have been performed according to the schedule. Data have been delivered.

IV. MAIN RESULTS OBTAINED

Precipitation

The precipitation sampling sites considered in this study are Ritten/Renon, located at 31 Km distance from the lakes at 1780 m altitude, Gfeis (Riffian/Riffiano), located at a distance of 7 Km and at 1340 m altitude and Texel located close to the studied lakes at 2390 m altitude. Atmospheric precipitation samples were collected weekly at Ritten (bulk and wet) and at Riffian (bulk), while collection of bulk samples from the site Texel occurred at irregular intervals between one to three months for a total of eighteen samples taken during the period 04/11/96-09/12/98.

The comparison between the data from these sites shows that both concentration and deposition values recorded at the site close to the studied lakes (Texel) do not differ significantly from the values recorded at the site Ritten using the same bulk sampling. The values measured at Ritten in the wet samples are instead somewhat lower. The site Riffian-Gfeis, which seemed to be a good reference site for the lakes' watershed, although located at a lower altitude, proved to be strongly influenced by bird droppings as the striking difference in the ammonia concentrations shows.

The seasonal pattern of precipitation quantity were similar among the different sites. Atmospheric precipitation in the area is higher during the summer months and is much lower during the winter months. The deposition fluxes show a marked seasonal trend: sulphate, nitrate and ammonia are lower in the winter months, when also the lowest precipitation amounts are recorded. For the site Ritten, the average bulk deposition values during 1996 and 1997 are shown in the table.

	$SO4^{--}$	$NO3^{-}$	$NH4^{+}$	H^{+}	Ca^{++}	Mg^{++}
meq m^{-2} yr^{-1}	26.3	23.8	32.1	5.6	12.6	6.4

Lake chemistry

Lago di Latte (Milchsee) has been sampled seven times during 1996, seven times during 1997 and six times during 1998. Samples have been taken at several depths at the deepest part of the lake. The adjoining lake Lago Lungo (Langsee) has been sampled two times during 1996, three times during 1997 and four times during 1998. Temperature has been measured for the whole water column, while oxygen, pH, conductivity, chlorophyll have been measured at five to nine different depths, where also samples for chemical analyses have been taken. The measured chemical variables are: major ions, nitrate ammonia, reactive soluble P, total P, total dissolved P, total dissolved and total nitrogen, TOC, dissolved reactive silica, and iron. Chlorophyll has been extracted in acetone using sonication and calculated according to Goltermann.

Sulphate weighted average concentrations in the lakes are about twice as high as the average concentration in atmospheric precipitation (30 μeq L^{-1}) showing that some sulphur minerals are present in the watershed. Nitrate concentrations are lower than the concentration found in precipitation because nitrate are partly taken up from the watershed grass vegetation before they enter the lake, and partly by the internal lake production. Although ammonium concentration in precipitation is relevant, its concentration in the two high altitude lakes is negligible. For most solutes a marked concentration gradient was observed from the superficial to the bottom water layers. From the beginning of 1996 to the end of 1998 an general increase of the lake water temperature was registered for Milchsee together with the increase of the pH values, of conductivity, alkalinity, calcium sulphate and silica. On the contrary a decrease of the total organic carbon concentrations, of the inorganic carbon and of total and free carbon dioxide was observed. For Langsee, the much greater volume of the lake and its higher productivity have a masking effect and the modifications of the same parameters are less pronounced.

Lake biology

Zooplankton and phytoplankton samples have been taken at the same depths chosen for chemical analyses. Phytoplankton biomass was estimated by counting (Utermöhl, 1958) and by the mean cell volume. Zooplankton samples were taken at every meter depth, but 3 samples were filtered together in situ through 100 μ mesh and analysed as single specimen. Rotifers were counted in aliquots under a dissecting microscope and crustaceans under a stereomicroscope.

The phytoplankton of Milchsee is essentially composed of Dinophyceae and Chrysophyceae. During 1995 and 1996 small Zygnemaphyceae became dominant. Phytoplankton biomass of the lake Milchsee had in the period 1992-98 a median value of 303 mg m^{-3}. After 1994 the biomass increased over the level typical for high mountain lakes with the strong development of a small species of Zygnemaphyceae, up to a maximum of 1400 mg m^{-3}. After a two year period of predominance of Zygnemaphyceae algae, with high biomass densities even in winter under the ice cover, the phytoplancton productivity decreased again, but maintained summer peaks higher than before. These summer peaks were mainly composed of Dinophyceae (almost exclusively of the species *Peridinium umbonatum var. umbonatum*). Langsee displays a much higher primary production level with a median biomass value of 1379 mg m^{-3} and peaks up to 3200 mg m^{-3}, a very high value for a remote high altitude lake. The predominant species during the eight years of observation was always *Staurodesmus crassus*, a small species of Zygnemaphyceae.

The rotifers abundances were in both lakes quite high and reached the maximum values of 230 Ind.L^{-1} for Milchsee and 500 Ind. L^{-1} for Langsee. In both lakes a sudden decrease of rotifers densities took place in the last 2-3 years with a strong reduction of the previously dominant two species *Keratella hiemalis* and *Polyarthra dolichoptera.* The Cladocera densities are in both lakes small but show a continue light increasing tendency. Beyond *Chydorus sp.* and *Bosmina sp.,* also representatives of the genera Daphnia and Ceriodaphnia were found from 1997 in Milchsee. The only copepod species present in both lakes was, until 1995, *Cyclops abyssorum tatricus*, a species typical for high altitude lakes. Afterwards also diaptomids were found in Milchsee. While cyclopoids reached densities up to 22 Ind.L^{-1} in Langsee, these remained always below 1 Ind.L^{-1} in Milchsee.

Conclusions

The reduction of the acidic atmospheric input to the lakes observed during the past years has produced the expected modifications toward more buffered conditions. Furthermore some other modifications have been observed which are not all linked with the changed acidic input. These modifications are probably dependent from a general increase of the air temperature observed during the last two decades during the Winter and Spring months. These climatic modifications have likely produced an increased weathering which has as a consequence the observed increase of the inlake solutes concentrations. This phenomenon superimposed to other changes like other physical factors, nutritional conditions and biological factors (competition, predation) has probably produced in the last years greater modifications than those to be expected from the decreased acidic input alone.

V. List of Publications arising from the project (include copies):

Thaler, B. and Tait, D. Temporal changes in the chemistry and biology of two high mountain lakes in the Eastern Alps. In: Head Water '98 (Ed.: Tappainer U. et al.), Poster Volume, 191-194,1998.

Tait, D. and Thaler, B. Atmospheric deposition and lake chemistry modifications at a high mountain site in the eastern Alps. In preparation.

Signature of Partner:

Date: 28th February 1999

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: 01/03/98 to 28/02/99

Partner: University of Liverpool, GB (ULIV)

Principal Investigator: Professor P G Appleby

Scientific staff: Dr C M G van den Berg
Professor J A Dearing
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PART B

I. OBJECTIVES FOR THE REPORTING PERIOD:

1. To complete our measurements of fallout radionuclides at each of the main WP2 sites via both rain water measurements and soil cores.
2. To complete the water column sampling by collecting samples from Øvre Neadalsvatn
3. To complete measurements of fallout radionuclides in the water column samples from the main WP2 lakes, including sediment trap material.
4. To complete the metal determinations, and to interpret the data including modelling transport
5. To complete the dating of the sediment cores.
6. To complete the magnetic analyses of the sediment cores.
7. To analyse sediment cores from the WP2 sites for trace metals.
8. To carry out radiometric analyses on biota samples from the WP2 sites.
9. To develope and test models for the transfer of fallout radionuclides and trace metals through the WP2 catchment/lake systems.

II. OBJECTIVES FOR THE NEXT PERIOD:

1. To complete a small number of measurements of fallout radionuclides in soil cores and to finalise estimates of the atmospheric fluxes of ^{210}Pb, ^{137}Cs and ^{7}Be at each site.
2. To finalise calculations of ^{210}Pb and ^{137}Cs transport parameters for the water columns of the main WP2 sites and to evaluate models of the transport of ^{210}Pb and ^{137}Cs to the sediment records.
3. To complete a small number of measurements of ^{210}Pb and ^{137}Cs in fish samples and to evaluate the value of these radionuclides as tracers in biota.
4. To carry out a systematic comparison of radionuclides and trace metals in rainwater, lake water and bottom sediments.
5. To evaluate models of the transport of atmospherically delivered pollutants and the value of radionuclides as tracers for interpreting sediment records.

III. Are there any particular problems ? Is your part of the project on schedule ?

There have been some problems analysing the larger than expected number of samples for radionuclides, though this work is now virtually complete. Uncertainties in total precipitation, particularly during the winter months when it has been mainly in the form of snow, have lead to some difficulty in calculating radionuclide fluxes directly from rainfall. These appear to have been solved, and the methods used have for the most part proved satisfactory. Significant differences have been found between the speciation of radio-lead and stable lead. These are being investigated to determine the cause. The project is on schedule.

PART B

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS*

1. Atmospheric Deposition of Radionuclides

Methods

Radioactive fallout (^{210}Pb and ^{7}Be) has been measured in rainwater samples collected from Gossenkollesee, Redo, Øvre Neadalsvatn, Lochnagar, Jorisee and Starolesnianske. Radionuclides are removed from the sample by coprecipitation with manganese dioxide. The precipitate is separated from the supernatent liquid by filtration, dried and the activities determined by gamma spectrometry. Yields were determined using standard solutions prepared from a certified Amersham ^{210}Pb standard.

Soil cores have been collected from sites adjacent to Gossenkollesee, Redo, Øvre Neadalsvatn, Lochnagar, Jorisee and Starolesnianske. Dried subsamples have been analysed for fallout ^{210}Pb, ^{137}Cs and ^{241}Am by gamma spectrometry to determine the fallout inventories.

Results

Concentrations in rainwater show large fluctuations of timescales of 2-4 weeks, but mean annual values are very uniform on a regional basis and in line with predictions. At sites near the Atlantic seabord (Redo, Øvre Neadalsvatn, Lochnagar) mean annual ^{210}Pb concentrations all lie in the range 66-84 Bq kl^{-1} with variations in flux being largely controlled by variations in rainfall. Concentrations at sites from central Europe (Gossenkollesee, Starolesnianske) are in the range 146-173 Bq kl^{-1}, reflecting the global west/east increase within land masses.

In spite of the anticipated difficulties (limited suitable core sites, the impact of snow cover), the soil core results appear to quite good. From the ^{210}Pb inventories we can calculate the mean flux over c.30 years. At most sites these are comparable with the short-term values from direct measurements, confirming the constant nature of the ^{210}Pb flux. The one exception is Redo where the soil core measurements appear to record the long-term influence of Saharan dust inputs. The data on ^{137}Cs will allow us to reconstruct the record of ^{137}Cs deposition

Discussion

Measurements of the ^{210}Pb flux in Europe (from both soil cores and direct precipitation) show that at a local level there is a strong correlation between fallout and rainfall. Higher fallout levels in Central Europe compared to those in Great Britain reflect the usual west to east increase within continents, presumably due to a build of ^{222}Rn concentrations in the atmosphere as the prevailing winds transport air masses over the land surface. From these results we will be able to make accurate estimates of radionuclide fluxes at most European sites, enhancing their value as tracers.

2. Radionuclides in the Water Column

Methods

Particulate and dissolved ^{210}Pb and ^{137}Cs have been measured in the water columns of Gossenkollesee, Redo and Øvre Neadalsvatn using an INFILTREX II water sampler. The particulate fraction was determined using 1 µm and 0.45 µm filters in series. The filters were dried and weighed to determine the suspended sediment concentrations and analysed for ^{210}Pb and ^{137}Cs by gamma spectrometry. The soluble fraction was determined using exchange columns with appropriate extraction materials. These were removed in four separate sections, dried and analysed for ^{210}Pb and ^{137}Cs, again by gamma spectrometry. Fluxes of ^{210}Pb and ^{137}Cs through the water column have been measured via concentrations on samples collected in sediment traps. Measurements have also been carried out on plankton and fish.

Results and discussion

Although some of the data still needs to be analysed in detail , the main results are now clear. ^{210}Pb concentrations in the water column are ~ 2-5 Bq kL^{-1}, representing a c.40 times dilution of the rain water. There is a clear seasonal influence due to the influence of ice cover, and this is presently being modelled. ^{137}Cs concentrations are in the range ~ 0.5-4 Bq kL^{-1}. Since there has been no atmospheric fallout of ^{137}Cs since 1986, the source must be either catchment runoff or remobilisation.

3. Metal speciation in the water column

Methods

Trace metal concentrations and their speciation have been determined in water column samples from Gossenkollesee, Redo and Øvre Neadalsvatn using anodic and cathdic stripping voltammetry in the Liverpoool University Oceanography laboratory. Analyses have been carried out on both filtered (0.4 µm and 0.1 µm) and unfiltered, samples.

Results and discussion

Concentrations of Pb, Cd, Ni, Co have been determined at all three sites and in all fractions, and are in the ranges: Pb 0.3-1 nM, Cd 0.07-0.2 nM, Ni 1.5-3 nM, Co 0.2-0.6 nM. High Pb concentrations in the surface samples from Redo in summer are attributed to atmospheric inputs. Initial results suggest that these trace metals are mainly in the soluble phase. Enhanced concentrations in some species were recorded at mid-depths, possibly due to biological factors. Systematic comparisons between trace metals and radionuclides are presently being carried out.

4. Sediment Dating

Methods

Cores from Lochnagar (NAG8), Ovre Neadalsvatn (OVNE4&7), Saanajarvi (SJ96/1), Gossenkollesee (GKS2), Jorisee (JORI3), Hagelsee (HAG96-1), Nizne Terianske (TERI7), Jezero Ledvicah (LEDV5), Redo (RCM2), Cimera (CIM97-1) have been analysed for the radionuclides ^{210}Pb and ^{137}Cs by gamma spectrometry. Sediment chronologies have be calculated by ^{210}Pb using an appropriate model and validated where possible by ^{137}Cs and/or ^{241}Am.

Results

Work has been completed and the results submitted to the MOLAR data base.

5. Mineral magnetic analyses

Methods

Cores from all WP3 sites have been analysed for a range of mineral isothermal magnetic properties, including magnetic susceptibility and a range of hysteresis loop parameters. All the data sets have been interpreted in terms of dominant sources and origins of the magnetic minerals, ranging from a strong pollution signal in several of the lakes to detrital and authigenic signals in others.

Results

Work has been completed and the results submitted to the MOLAR data base.

V. List of Publications arising from the project (include copies): None

(A number of papers on atmospheric deposition, the water column and sediment records are in preparation.)

Signature of Partner:

Date: 25/2/99

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: 1. March 1998 to 28. February 1999

Partner: Swiss Federal Institute for Environmental Science and Technology (EAWAG)

Principal Investigator: Dr A.F. Lotter

Scientific staff: Drs G. Goudsmit, W. Hofmann, B. Müller, G. Lemcke, DM Livingstone, C. Ohlendorf, M. Sturm

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I. OBJECTIVES FOR THE REPORTING PERIOD:

During the reporting period the major objectives of the Swiss contribution to the MOLAR WP3 were:

i) the sampling and the measurements of water-column biology, physics and chemistry, and water-column sediment fluxes at Hagelseewli until September 1998
ii) to finish the biological and physical sediment analyses
iii) to continue the measurements of on-site meteorology at Hagelseewli until September 1998
iv) to establish empirical relationships between surface air temperatures and epilimnetic water temperatures in lakes at different altitudes
v) to have a preliminary application of lake models
vi) to check the data quality of the meteorological data from all MOLAR WP3 AWS stations and remove obviously incorrect data
vii) to explore climatic influences on the break-up of lake ice

II. OBJECTIVES FOR THE NEXT PERIOD:

PART B

III. Are there any particular problems ? Is your part of the project on schedule ?

The project is on schedule. However, the following minor problem occurred during the reporting period:

- due to technical problems with the automatic weather station substantial amounts of meteorological data were lost during spring/summer 1998

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS* (use other pages as necessary but preferably no more than 2)

Biostratigraphies such as pollen, diatoms, and chironomids have been finished. The diagrams have been zoned using a combination of optimal zonation with a broken-stick model to assess the significant number of biozones (see Figs. 1-3). The cladoceran analyses showed that the concentration of chydorids as well as of planktonic cladocerans was extremely low.

Thermistor measurements conducted in a Hagelseewli and a series of neighbouring lakes during the summer season showed that the short-term structure of summer lake surface water temperature (LSWT) in a suite of lakes at different altitudes is essentially the same as that of air temperature over a large altitudinal gradient. LSWTs tend to exceed corresponding air temperatures by 3-5 K. They decrease approximately linearly with altitude, allowing an LSWT "lapse rate" to be defined that is slightly greater than that of air temperature. Diel variations in LSWT are large, implying that individual manual water temperature measurements are unlikely to be representative. Local factors such as topographic shading, partial ice cover and meltwater inflows affect LSWTs, but not air temperatures, possibly resulting in severe distortion of the relationship between the two. Hagelseewli gives a particularly good example of this. Several implications for palæolimnological studies directed at palæoclimate reconstruction result. (i) Palæolimnologically reconstructed LSWTs are likely to be significantly higher than the air temperatures prevailing at the altitude of the lake. (ii) Lakes used in palæoclimate reconstruction studies should be selected to minimise local effects distorting the summer air-water temperature relationship. (iii) If at all avoidable, palæolimnological temperature calibration studies should not be based on single manual water temperature measurements. (iv) Consideration should be given to calibrating palæolimnological temperature inference models directly in terms of air temperature rather than water temperature. (v) The primary climate effect on the aquatic biota of high-altitude lakes (above about 2200 - 2500 m a.s.l. in the Alps) may be mediated by ice cover, and therefore be related more to air temperatures prevailing before freeze-up and during thawing than to the temperatures (air or water) prevailing during the open-water period.

An investigation of the timing of break-up of various lakes in the Northern Hemisphere showed that the effects of the North Atlantic Oscillation and other large-scale climatic phenomena can be quite easily detected. Because spring break-up triggers many ecologically important physical, chemical and biological processes, the detection of large-scale climate forcing signals in the timing of break-up implies that the ecology of individual lakes may be linked to climate on a very large scale. This is an important result in view of the dominant role played by ice cover in controlling physical, chemical and biological processes in the MOLAR lakes.

A model was developed to simulate the effect of local topography on solar radiation incident on mountain lakes. This model was applied successfully to Hagelseewli and other MOLAR lakes. Physical modelling of the water column was successful during the open-water phase, but the modelling of ice cover presents problems.

A contribution was made to the reconstruction of air temperatures at MOLAR sites over the last 200 years. The applicability of lapse rates obtained from Alpine meteorological stations to the MOLAR sites in the Alpine region was investigated, based on the measured AWS data from the MOLAR sites. With respect to Hagelseewli, the air temperature was able to be reconstructed back to 1961 based on air temperature measurements at Jungfraujoch, and back to 1755 based on the long Basle air temperature series.

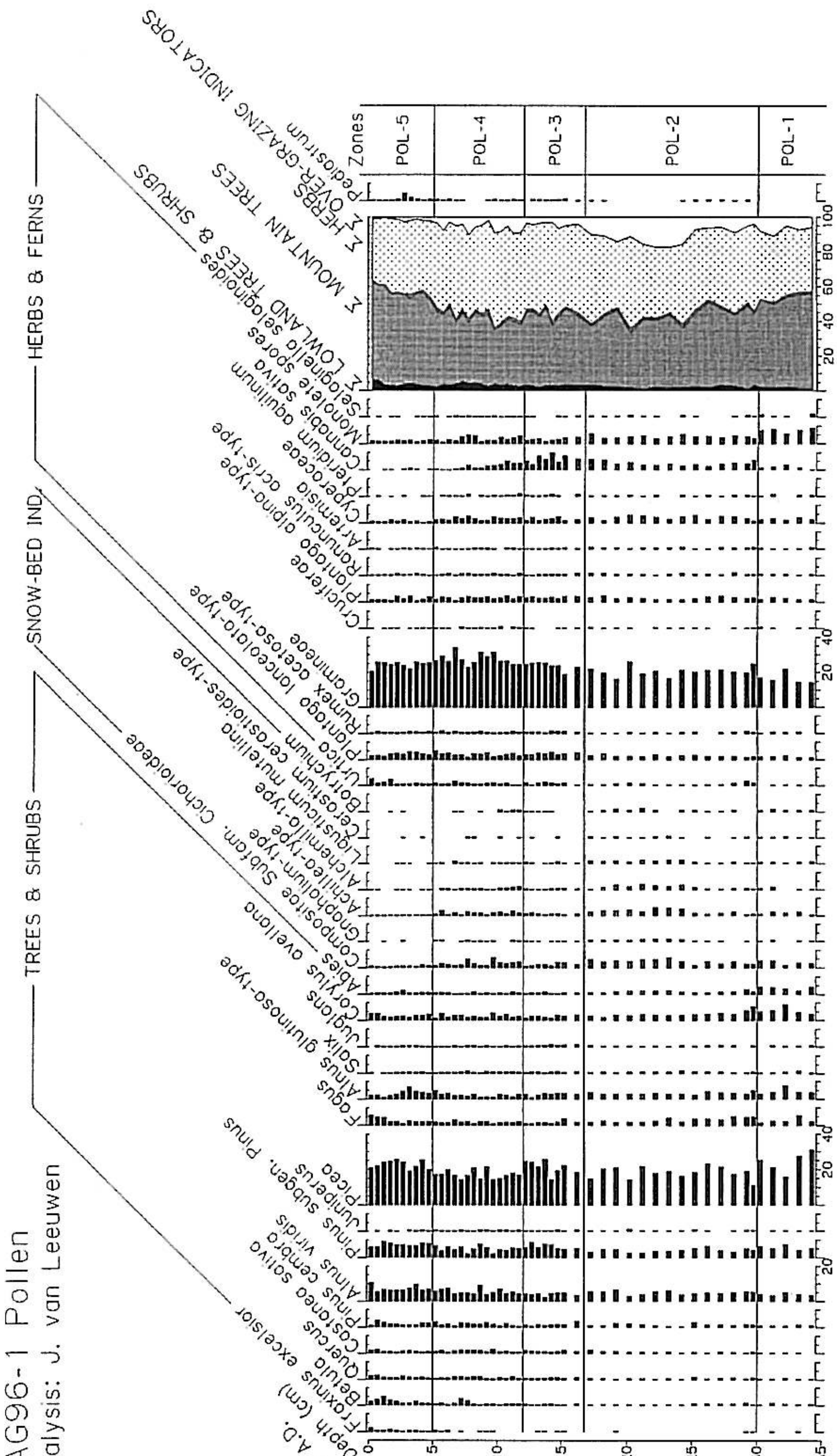

Figure 1. Pollen stratigraphy from Hagelseewli core HAG96-1.

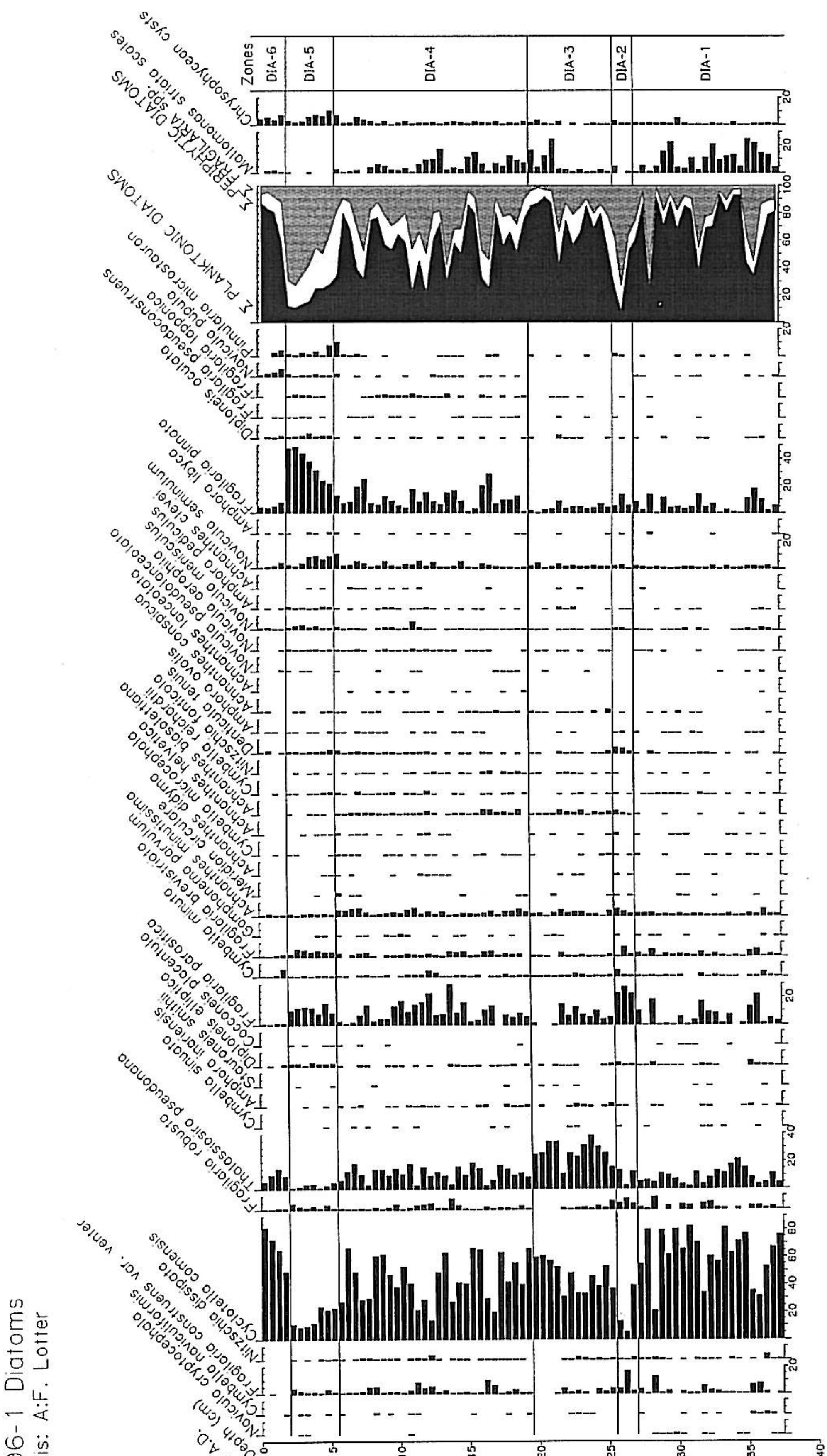

Figure 2. Diatom stratigraphy of Hagelseewli core HAG96-1.

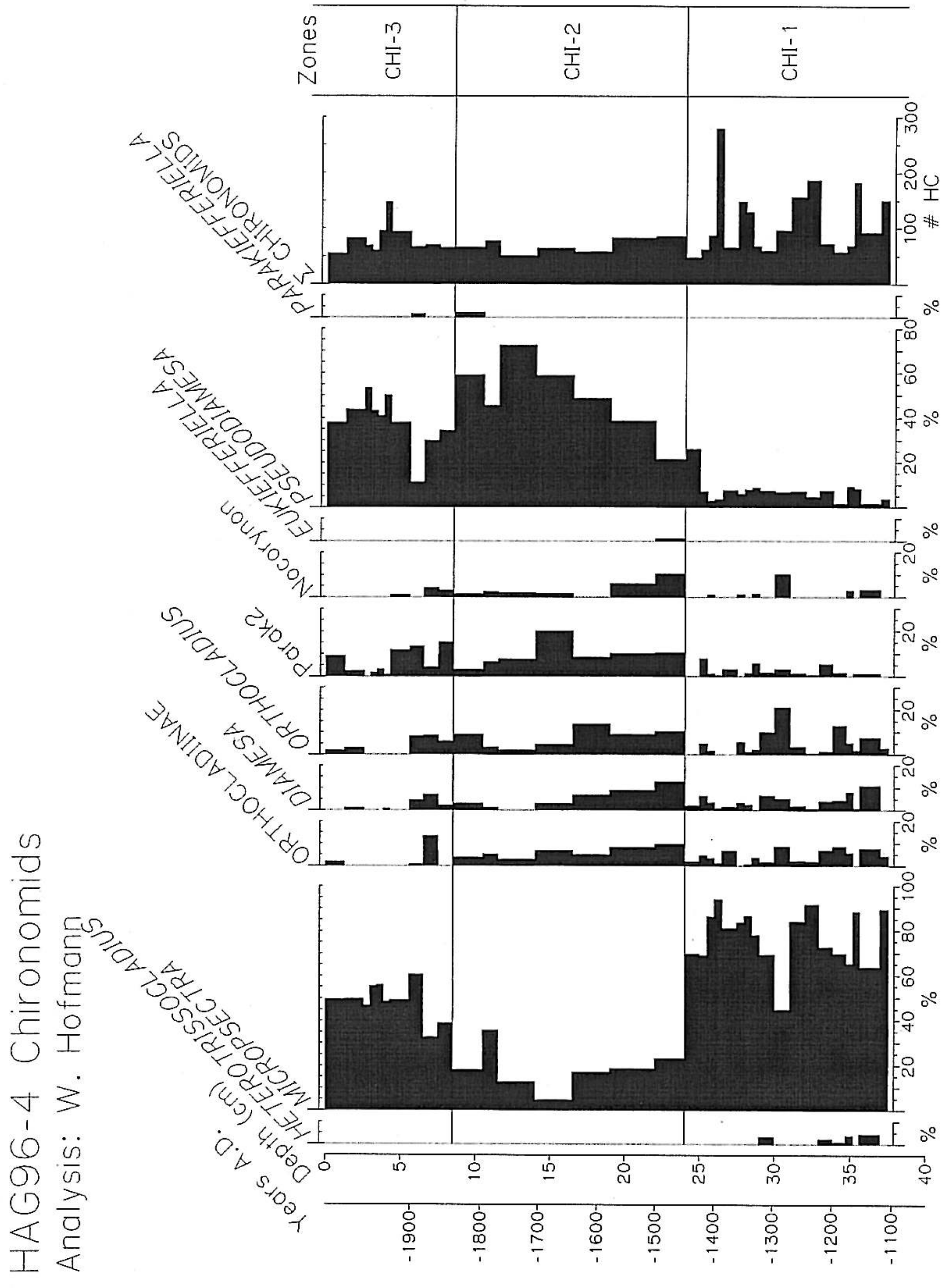

Figure 3. Chironomid stratigraphy of core Hagelseewli HAG96-4, expressed in depths of core HAG96-1.

V. List of Publications arising from the project (include copies):

Agusti-Paraneda, A., R. Thompson and D. M. Livingstone (1999)
Reconstructing climatic variations at high elevation lake sites in Europe during the instrumental period. *Verh. Internat. Verein. Limnol.*, **27** (in press).

Bigler, C. (1998)
Verbreitung von Diatomeen im Oberflächensediment eines alpinen Sees im Berner Oberland (Hagelseewli 2339 m ü. .M.). Diplomarbeit, phil.-nat. Fakultät, Universität Bern. 79 pp.

Goudsmit, G.-H., G. Lemcke, D. M. Livingstone, A. F. Lotter, B. Müller and M. Sturm (1999)
Hagelseewli: a fascinating mountain lake - suitable for palæoclimate studies? *Verh. Internat. Verein. Limnol.*, **27** (in press).

Livingstone, D. M. (1997)
Break-up dates of Alpine lakes as proxy data for local and regional mean surface air temperatures. *Clim. Change*, **37**(2), 407-439.

Livingstone, D. M. (1998)
Das Auftauen des St. Moritzer Sees: Ein Indikator für überregionale Lufttemperatur und globalen Vulkanismus. *EAWAG Jahresbericht 1997*, 41-42.

Livingstone, D. M. (1999)
Large-scale climatic forcing detected in historical observations of lake ice break-up. *Verh. Internat. Verein. Limnol.*, **27** (in press)

Livingstone, D. M. (1999)
Ice break-up on southern Lake Baikal and its relationship to local and regional air temperatures in Siberia and to the North Atlantic Oscillation. *Limnol. Oceanogr.* (submitted)

Livingstone, D. M. and A. F. Lotter (1998)
The relationship between air and water temperatures in lakes of the Swiss Plateau: a case study with palæolimnological implications. *J. Paleolimnol.*, **19**(2), 181-198.

Livingstone, D. M., A. F. Lotter and I. R. Walker (1999)
The decrease in summer surface water temperature with altitude in Swiss Alpine lakes: a comparison with air temperature lapse rates. *Arctic. Alpine Res.* (submitted)

Signature of Partner: Lotter A.

Date: 23-2-99

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: March 1, 1998 - February 28. 1999

Partner: Faculty of Science, Charles University, Prague, Czech Republic

Principal Investigator: Dr. Jan Fott

Scientific staff: Dr. Evzen Stuchlik. Dr. Martin Cerny, Dr. Miroslava Prazakova, Dr. Veronika Sacherova,
Martin Blazo, Otakar Strunecký

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I. OBJECTIVES FOR THE REPORTING PERIOD:

a/ Field work:
Field work at the site 15.1 Starolesnianske Pleso (WP1 and 2, site operator Evzen Stuchlik) and 15.2 Terianske Pleso (WP3). Sampling surface sediment of a set of Tatra lakes. Operating precipitation collectors in the catchment of Starolesnianske Pleso (bulk collectors) and at Skalnate Pleso (WADOS collector, bulk collector, horizontal collector). Sampling soils and snow at Starolesnianske. Pleso.

b/ Laboratory work:
(i) analysing phytoplankton and zooplankton from the sites O.Neadalsvatn, Stavsvatn, Lochnagar, Gossenköllesee, Starolesnianske and Terianske Pleso, analysing phytoplankton only from the site Dlugi Staw, analysing zooplankton only from the sites Hagelsee and Jörisee.
(ii) chemical analyses of lakewater, rainwater, snow and soil from the sites Starolesnianske Pleso, Terianske Pleso and from the weather station Skalnate Pleso.
(iii) analysing remains of Cladocera from the WP3 cores Terianske Pleso and Gossenkollesee and from surface sediments of Tatra lakes.

II. OBJECTIVES FOR THE NEXT PERIOD:

PART B

III. Are there any particular problems ? Is your part of the project on schedule ?

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS* (use other pages as necessary but preferably no more than 2)

Sampling at the Tatra sites (Starolesnianske pleso, Terianske pleso)

Field measurements and sampling for chemical and biological analyses were carried out according to the schedule (Tab. 1). Sampling at the Terianske lake included measurement basic physical and chemical parameters on the vertical profile (temperature, pH, oxygen, conductivity) with use of the Hydrolab probe and taking samples from 10 depths on the vertical. Sampling at the Starolesnianske lake included also taking samples of rainwater in biweekly intervals; this was carried out by our local observer. Other activities are listed at the bottom of the Table 1.

Sediment coring in Tatra lakes above the tree line (in collaboration with the team from the Academy of Sciences, Ceske Budejovice), was continued in September 1998 (33 lakes). The surface sediments have been analysed for remains of Cladocera. The objective is to find relationship of cladoceran abundance to environmental variables and comparison or merging the Tatra data set with a similar set from the Alps.

Tab. 1: Field activities in the year 1998

Sampling term	Lake	sampling &measurements
18.3.1998	NižnéTerianske pleso	profiling & sampling from the vertical (biology and chemistry)
13.5.1998	NižnéTerianske pleso	profiling & sampling from the vertical (biology and chemistry)
18.7.1998	Nižné Terianske pleso	profiling & sampling from the vertical (biology and chemistry)
24.3.1998	Starolesnianske pleso	profiling & sampling from 1m depth (biology and chemistry)
12.5.1998	Starolesnianske pleso	profiling & sampling from 1m depth (biology and chemistry)
17.7.1998	Starolesnianske pleso	profiling & sampling from 1m depth (biology and chemistry)
15.1.1998	Snow – Starolesnianske p.	snow sampling and coring
16.3.1998	Snow – Starolesnianske p.	snow sampling and coring
13.6.1998	Soil – Starolesnianske p.	soil sampling and coring
20.9.-2.10.1998	ICP, sediment	Synoptic sampling, coring 33 lakes

Tab. 2: Sampling schedule for lakewater and for precipitation collectors (Bulk 1 - 3) at the site Starolesnianske pleso and for precipitation collectors (wet only, BULK 4 and horizontal precipitation collector) at the site Skalnaté pleso, 1998.

Sampling	Frequency	Sample type	Analyses	Note
Lakewater	biweekly	spot sample	major ions, nutrients	running monthly from November 1998
BULK 1 precipitation	biweekly	integrated over 1month	major ions, nutrients	still running
BULK 2 precipitation	biweekly	integrated over 1month	radionuklids, metals	until August 1998, still running for amount of prec.
BULK 3 precipitation	biweekly	integrated over 1month	SCPs	until August 1998, still running for amount of prec.
wet only precipitation	weekly	integrated over 1week	major ions, nutrients	running biweekly from November 1998
BULK 4 precipitation	weekly	integrated over 1 month	major ions, nutrients	from January 1998 at Skalnaté pleso
horizontal precipitation	on events		major ions, nutrients	still running

Running a MOLAR precipitation collector at the weather station Skalnate pleso:

The performance of the „wet only and dry only" collector (type WADOS, product of Kronais, Austria) continued at the meteorological station Skalnate pleso, together with the bulk collector and the collector of horizontal precipitation.

Chemical analyses of lakewater, rainwater and snow were carried out in the Prague laboratory as described previously; samples of SCPs, radionuclids, organic micropollutants and metals were sent off and analysed in the respective laboratories abroad. Chemical analyses of soil samples for determination of parameters required by the MAGIC model were performed at the Hydrobiological Institute, Academy of Sciences, Ceské Budejovice and at the Czech Geological Survey, Prague.

Chemical analyses - QA/QC: In 1998 we analysed 3 test samples (from ISPRA and from NIVA), two of them simulating lakewater and one simulating rainwater. The analyses were reasonably successful.

Biological analyses of plankton were based on the determination of species, their abundance, size structure and biomass of phytoplankton and zooplankton.

Evžen Stuchlík organised a WP2 workshop at the Hydrobiological Station of the Charles University (Blatna, January 1999). Later on, experts in MAGIC modelling Richard Wright from NIVA, Oslo and Chris Curtis from UCL, London, stayed at the Hydrobiological station several days calibrating the model for Starolesnianske Pleso.

Remains of Cladocera (and some other invertebrates, microscopical size) fom the WP3 cores Terianske Pleso and Gossenkollesee were analysed and counted, data sent to the Bergen database.

V. List of Publications arising from the project (include copies):

Kopáček J., Stuchlík E., Fott J., Veselý J., Hejzlar J., 1998: Reversibility of acidification of mountain lakes after reduction of nitrogen and sulfur emissions in Central Europe. Limnology & Oceanography.

Jiří Kopáček, Evžen Stuchlík, Věra Straškrabová, Petra Pšenáková, in press: Factors governing nutrient status of mountain lakes in the Tatra Mountains. Freshwat. Biol.

Straskrabova V., Simek K., Macek M., Hartman P, Fott, J., Blazo M., in press.: Pelagic food webs and microbial loop in clear-water mountain lakes sensitive to acidification. Proceedings SIL, Congress in Dublin (1998).

Petra Pšenáková, Evžen Stuchlík, Jan Fott and Veronika Sacherová: in prep. Morphometric parameters of the Starolesnianske lake, the High Tatra Mountains, Slovakia

Jiří Kopáček, Evžen Stuchlík, Jan Fott, in prep.: Water chemistry of lakes in the Tatra Mountains: 1993-94 status.

Jan Fott, Ferdinand Šporka, Peter Bitušík, Martin Blažo, Martin Černý, Martin Hais, Jiří Kopáček, Ilja Krno, Petra Pšenáková, Otakar Strunecký, Evžen Stuchlík, Elena Štefková: in prep.: Spatial distribution and seasonal changes of physical, chemical and biological parameters of Nižné Terianske Lake, High Tatra Mountains, Slovakia.

Evžen Stuchlík, Otakar Strunecký, Jiří Kopáček, Martin Blažo, Jan Fott, Peter Bitušík, Martin Černý, Martin Hais, Ilja Krno, Petra Pšenáková, Ferdinand Šporka, Elena Štefková: in prep.: Response of a small acidified high mountain lake (High Tatra Mountains, Slovakia) to environmental change.

Fott Jan and Prazakova Miroslava., in prep.: A 200 years history of NNzooplankton communities in the high mountain lakes Nizne Terianske Pleso (Tatra) and Gossenkollesee (Alps), as related to environmental change.

Fott J., Blazo M., Stuchlik E., Strunecky O.: Phytoplankton of three high mountain lakes in the Tatra Mountains. - will appear in Mem. Ist. ital. Idrob., Callieri C. ed.

Fott J., Hais M., Stuchlik E., Strunecky O.: Zooplankton of three high mountain lakes in the Tatra Mountains. - will appear in Mem. Ist. ital. Idrob., Callieri C. ed.

Fott Jan, Sporka Ferdinand, Bitusik Peter, Blazo Martin, Cerny Martin, Hais Martin, Kopácek Jiri, Krno Ilja, Psenakova Petra, Strunecky Otakar, Stuchlik Evzen, Stefkova Elena **Straskrabova Vera**, in prep.: Spatial distribution and seasonal changes of physical, chemical and biological parameters of Nižné Terianske Lake, High Tatra Mountains, Slovakia.

Stuchlik Evzen, Strunecky Otakar, Kopacek Jirí, Blazo Martin, Fott Jan, Bitusik Peter, Cerny Martin, Hais Martin, Krno Ilja, Psenakova Petra, Sporka Ferdinand, Stefkova Elena, **Straskrabova Vera**, in prep.: Response of a small acidified high mountain lake (High Tatra Mountains, Slovakia) to environmental change.

Signature of Partner: Jan Fott

Jan Fott

Date: 1.03.99

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: March 1, 1998 to February 28, 1999

Partner: HBI ASCR - Hydrobiological Institute, Academy of Sciences of the Czech Republic

Principal Investigator: Viera Straškrábová

Scientific staff: Josef Hejzlar, Petr Hartman, Jiří Kopáček, Miroslav Macek, Karel Murtinger, Jiří Nedoma, Karel Šimek, Jaroslav Vrba

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I. OBJECTIVES FOR THE REPORTING PERIOD:

- Summarization of microbial food webs results from 1997 at the project meeting in Bled.
- Elaboration of results from 1997 - sediment analyses and microbial biomass.
- Evaluation of the results for microbiology 1st and 2nd level from 1996 and 1997 - intercomparison among lakes and labs, comparison with phytoplankton and zooplankton biomass.
- Additional measurements of several chemical parameters and microbial processes in the lakes from Tatra Mts and in Lago Paione Superiore (Italy).
- Second sampling of sediments from the lakes in Tatra Mts, evaluation of adsorption isoterms of phosphorus.
- Construction of flow-chart models of carbon flow in the pelagic region of mountain lakes.
- Organization of MOLAR and mountain lake ecology session at SIL (International Society for Limnology) Congress in Dublin.
- Organization of workshop on pelagic food webs of MOLAR project in Pallanza
- Publication of results
- Summarization of microbial food webs results from the whole MOLAR project at the project meeting in Arcachon

II. OBJECTIVES FOR THE NEXT PERIOD:

- Complete analyses of sediments from Tatra lakes sampled in 1998
- Final report on pelagic food webs in MOLAR lakes
- Complete database of microbial food web results
- Publication of summarizing results

III. Are there any particular problems ? Is your part of the project on schedule ?

Our part of problem is on schedule. Complete summarization of pelagic food webs results is waiting for complete data on zooplankton from other partners.
Problem is the delay of payments – up to now we obtained only 74% of the value stated in the contract.

PART B

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS* (use other pages as necessary but preferably no more than 2)

METHODOLOGY was the same as in preceding year (according to the project manual)
RESULTS

- chemical analyses Starolesnianské pleso: surface layer till June bi-weekly, then monthly total P, total dissolved P, organic N, nitrate and ammonia N, chemical oxygen demand, total organic C, silica
- chemical analyses Starolesnianské pleso: bulk deposition till June biweekly, then monthly, wet-only deposition weekly whole year forms of N, P, C.
- chemical analyses NižnéTerianské pleso: zonation from 10 layers till August monthly, same parameters like in a)
- chemical analyses Skalnaté pleso: bulk deposition since spring monthly, same parameters like in b). This station will be the long-term reference base.

Results of analyses were sent to coordinators.

- chemical analyses of sediments from 23 Tatra lakes sampled in 1997, layers 0-1, 1-5 and 5-10 cm pH, C, N, P, Na, K, Ca, Mg, Al, Fe, Mn
- sampling of sediments from 8 Tatra lakes during expedition (Kopáček and Kotorová) in autumn 1998, elaboration is in process the same like e)
- microbiological analyses of preserved samples from 1997 (bacterial biomass, species and biomass of ciliates) from three lakes from Tatra Mts, two lakes from Norway, one from Russia, one from Scotland and one from Switzerland, were completed. Data on pelagic biomass were sent to us from other five partners and database is established. Up to now the data on zooplankton have not been completed by two partners.
- measurement of primary production and exudation was done by V. Straškrabová in lago Paione Superiore (first measurements in this lake) with the team from Pallanza (Istituto Italiano di Idrobiologia) in July 1998
- participation and reporting at project conferences in Bled (March 1998, Straškrabová, Kopáček, Macek) and in Arcachon (February 1999 Straškrabová, Kopáček)
- participation at steering committee meetings (Straškrabová) in Bled (March 1998), in Barcelona (September 1998), in Arcachon (February 1999)
- participation in project workshop WP 2 (Kopáček) in Blatná (January 1999)
- organization of special session "Mountain lakes ecology" (including chairing and reviewing papers) at the 26th Congress of SIL (Societas Internationalis Limnologiae = International Association for Limnology) in Dublin with 12 oral and 6 poster contributions, 10 of them were from MOLAR project (one summarizing microbial food web results from 8 MOLAR lakes – Straškrabová et al., accepted to Proceedings)
- organization of project workshop on pelagic food webs (together with Istituto Italiano di Idrobiologia) in November 1998 in Pallanza (Straškrabová, Macek), summarization of results, comparison of methods, discussion o n structure of databases, preparation of special volume of Memorie del Istituto Italiano di Idrobiologia devoted to pelagic food webs

- submitting the oral contribution from project results to International Conference LAKE 1999 (will be in May 1999 in Copenhagen)
- summarization of Tatra lake results from AL:PE II and MOLAR projects concerning nutrients, chlorophyll and bacteria – accepted manuscript to Freshwater Biology

DISCUSSION AND CONCLUSIONS

- 84 glacial lakes in Tatra Mountains (Slovak and Polish), sampled in September 1993 and 1994 were elaborated with respect to their nutritional status (N, P, C, chlorophyll-a, bacteria). Parameters, which might determin nutritional status were tested: elevation, water acidity, catchment vegetation. Concentrations of organic carbon, organic nitrogen, chlorophyll-a and bacterial numbers were tightly correlated with total phosphorus content. Their levels were highest in forest lakes, then decreased in alpine lakes with decreasing amount of catchment vegetation and soil cover, and were the lowest in lakes situated in bare rocks. The above pattern was further modified by lake water acidity. In alpine lakes with pH between 5 and 6, concentration of total P, organic C and chlorophyll were lower than in more or less acid alpine lakes, and zooplankton was absent. Nitrate concentrations followed an inverse trend to total P: lowest values in forest lakes, then increased with increasing amount of catchment vegetation. Not the elevation, but vegetation cover in catchment was crucial factor determining nutrient status.
- Data on biomass of different components of pelagic food webs from 4 North European lakes in a west-east transsect (Lochnagar, Stavstvatn, Øvre Neådalsvatn, Chuna), from 3 Tatra lakes (Starolesnianské and Nižné Terianské pleso, Dlugi Staw) and from 1 lake in the Alps (Gossenköllesee) were summarized (Table 1). In lakes with the highest total biomasses (above 100 $\mu g\ l^{-1}$ C), total organic C concentrations were the highest (1 to 2.3 mg l^{-1}), the biomasses of phytoplankton also were high (Starolesnianské, Chuna and one value in Stavsvatn) and the ratio of autotrophic to heterotrophic microbial biomass was above 10 or more. The lowest pelagic biomass found in Dlugi Staw roughly corresponded to 5% of its total organic C concentration, whereas the highest biomasses found in Starolesnianské and Chuna lakes reached 20% of total organic C. Picocyanobacteria were almost absent in the lakes studied. In both the extreme lakes (Starolesnianské and Dlugi) zooplankton is almost absent and the top trophic link in these lakes were heterotrophic and mixotrphic flagellates and ciliates. No relation of total biomass or their particular components to pH or alkalinity was found.

Table 1. Pelagic biomass, ranges of average column values during one sampling season in $\mu g\ l^{-1}$ C, and ratios: aut/het. micr. - phytoplankton to bacteria+protists, phy/zoo - phytoplankton to zooplankton.

Lake	phytoplankton	bacteria	protists	aut/het.micr.	phy/zoo
Lochnagar	3 - 10	18 – 20	0 - 0.5	0.6 - 0.7	-
Stavsvatn	14 - 195	4 – 20	0 - 0.6	0.9 - 10	0.5 - 0.7
Øv. Neådalsvatn	8 - 13	6 – 12	0.2 - 0.8	0.6 - 1.7	1.2 - 2.6
Chuna	57 - 83	2.5 - 3.3	0.2 - 0.4	18 - 24	1.0 - 1.3
Starolesnianské	334 - 450	11 – 17	0 - 14	13 - 26	334 - 450
Niž. Terianské	17 - 33	6 – 29	0 - 3.1	0.6 - 5.7	2.3 - 5.8
Dlugi Staw	2 - 5	2 – 11	0 - 0.01	0.2 - 2.6	24 - 53
Gossenköllesee	44 - 64	8 – 14	5 - 13	2.2 - 3.4	1.4 - 18

- Primary production, exudation and bacterial utilization of algal products was measured in three lakes (Table 2). Total production (i.e. particular production of phytoplankton, bacterial utilization and dissolved exudates) was more than by one order lower than in lowland lakes and reservoirs, but the percentages of exudation and bacterial utilization were significantly higher (22-87% and 8-36%, respectively). The percentage of extracellular release (including part immediately utilized by bacteria) is increasing with decreasing total production, and the exudation in the ultraoligotrophic lake Dlugi even surpasses particulate production. Both the data in preceding paragraph and the data on exudation and their utilization by bacteria showed that in oligotrophic mountain lakes, the share of bacteria compared to other components increases, both in terms of biomass and in terms of carbon fluxes. It is not yet clear whether the main factor is trophy, alkalinity or acidity, and what is the proportion of allochthonous carbon compared to autochthonous production.

Table 2 Primary production, exudation and bacterial utilization of algal products in mountain lakes.

lake	date	total production $\mu g\ l^{-1}\ h^{-1}$ C	particulate prod. $\mu g\ l^{-1}\ h^{-1}$ C	bact. in partic. %	exudation in tot. %
Starolesnianské	June 17, 97	2.08	0.92	21	55.6
Starolesnianské	June 20, 97	2.4	1.22	8	48.4
Sarolesnianské	Septemb. 3, 97	4.28	3.53	6.8	21.7
Starolesnianské	Septemb. 6, 97	10.98	8.41	7.2	25.4
Dlugi Staw	Septemb. 9, 97	0.1025	0.010	198	86.9
Øvre Neådalsv.	July 20, 97	0.131	0.087	24.8	34.2
Øvre Neådalsv.	July 22, 97	0.128	0.069	29.8	50

V. List of Publications arising from the project (include copies):

Accepted to publication:

Kopáček, J., Stuchlík, E., Straškrabová, V., Pšenáková, P.: Factors governing nutrient status of mountain lakes in the Tatra Mountains. Freshwater Biology. Accepted.

Straškrabová, V., Šimek, K., Macek, M., Hartman, P., Fott, J., Blažo, M.: Pelagic food webs and microbial loop in low alkalinity mountain lakes. Verhandlungen der internationalen Vereinigung für Limnologie (Proceedings of the SIL Congress in Dublin), accepted.

Straškrabová, V., Šimek, K., Nedoma, J.: Importance of pelagic bacteria in lakes and reservoirs of different trophy – implications for long-term monitoring. Proceedings (Extended abstracts) of Lake 99 8th Internat. Conference on the Conservation and Management of Lakes, Copenhagen 1999, accepted.

Signature of Partner: [signature]

Date: February 28, 1999

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: March 1, 1998-February 28, 1999

Partner: IZ SAS - Institute of Zoology, Slovak Academy of Sciences, Bratislava, Slovakia

Principal Investigator: Dr. Ferdinand Šporka

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I. OBJECTIVES FOR THE REPORTING PERIOD:

a/ Field work at the site 15.2 Nizne Terianske lake:
-Water chemistry sampling from ice-cover period
-Operating Automatic Weather Station (AWS) in the Terianske pleso

b/ Laboratory work:
-Finalise analysing diatoms from sediment core
-Finalise analysing chironomids from sediment core

II. OBJECTIVES FOR THE NEXT PERIOD:

Preparing the final report and manuscripts

PART B

III. Are there any particular problems? Is your part of the project on schedule?

No particular problems

Our part of project is in schedule.

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS*
(use other pages as necessary but preferably no more than 2)

Diatoms

26 levels from the Nižné Terianske pleso core "TERI 7" have been analyzed for diatoms and chrysophytes. A total of 97 taxa belonging to 24 genera were found. 23 taxa had abundance greater than 5%. Diatom analysis of the core shows that the assemblages in the upper part of the core are different from the bottom part. In the upper 3 cm there are increases in many diatom taxa, previously absent or rare in the core e.g. *Achnanthes marginulata, A. subatomoides, A. levanderi, A. austriaca v. helvetica, Orthoseira roeseana, Navicula digitulus, N. schmassmannii* and *Stauroneis anceps*. In the bottom part of the core were dominant e.g. *Asterionella formosa, Denticula tenuis* and *Fragilaria capucina.*

Four sediment trap samples have been analysed for diatoms and chrysophytes. 65 diatom taxa were found there with dominant species of *Orthoseira roeseana* and more species of *Achnanthes*.

Epilithic diatoms from Nižné Terianske pleso were taken too. Together 56 taxa were identified from it. Most common species were *Achnanthes minutissima, Cymbella minuta, Denticula tenuis* and *Navicula gallica var. perpusilla.*

Chironomids

From sub-fossil chironomid remains (head capsules) eleven chironomid taxa were identified. The subfossil record was dominated by *Micropsectra radialis* followed by *Procladius* sp., *Diamesa* spp. and *Heterotrissocladius* cf. *marcidus*. Three more or less clear changes in the relationship between the dominant taxa were recognised. The first two ones take place between 19.4 - 18.6 cm and 17.8 and 13.8cm, respectively. They can not be connected with atmospheric pollution and could be rather caused by climatic oscillations.

The top of the core showed generally decreasing of the absolute head capsules number from the 5.0 - 4.8 cm. The irregular occurrence of *Diamesa* and often changes in the relative abundance of *M. radialis* were connected with this event. Diamesa was not found above 2.0 cm. These findings together with subfossil diatom and cladoceran data suggest that high deposition in the Tatra region may have had a effect on communities in the lake despite of the high buffer capacity and stable pH of the lakewater.

AWS

Meteorological data collection from AWS, situated at Nizne Terianske lake collected 10 parameters (wind direction and speed, solar energy, radiation- incident and reflected, pressure, temperature air and water, humidity and precipitation) with problems cause with battery failure. The logging started at May 31 and stopped completely at October 2 but with three breaking, cause maybe cut off any sensors. Maximum air temperatures recorded in 1998 were 20.77°C (August 3) and maximum surface water temperatures were 11.6°C (August 16). The maximum wind speed was 19,24m.s^{-1}, and maximum daily precipitations were 51.6mm (September 14).

V. List of Publications arising from the project (include copies):

Bitušík, P., Kubovčík, V., 1999: Sub-fossil chironomids (Diptera: Chironomidae) from the sediments of the Nizne Terianske pleso (High tatra mts., Slovakia). Preliminary results. - Dipterologica bohemoslovaca, 8 (in press).

Cameron, N. G., Birks, H. J. B., Jones, V.J., Berge, F., Catalan, J., Flower, R.J., Garcia J., Kawecka, B., Koinig, K.A., Marchetto, A., Sánchez-Castillo, P., Schmidt, R., Šiško, M., Solovieva, N., Štefková, E. & Toro, M. Surface-sediment and epilithic diatom pH calibration sets for remote European mountain lakes (AL:PE Project) and their comparison with the Surface Waters Acidification Programme (SWAP) calibration set. JOPL .Accepted for publication.

Signature of Partner:

Date: 24.2.1999

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: January 1998- February 1999

Partner: IFB-PAS

Principal investigator: Joanna Galas
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I. OBJECTIVES FOR THE REPORTING PERIOD:

Completion tasks included in WP1 for the lake Dlugi Staw:

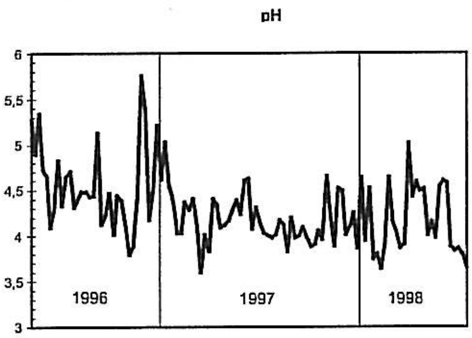
- Deposition sampling and analysis
- Water chemistry sampling and analysis
- Microbial food web (1st level) - ciliates determination, phytoplankton sampling
- Zooplankton sampling and analysis
- Macroinvertebrates sampling and analysis
- Preparing the final publications

II. MAIN RESULTS OBTAINED:

Chemistry of atmospheric deposition

Bulk deposition was sampled weekly in the Meteorology Station situated at Hala Gasienicowa near the lake. Both samples: precipitation and lake water were sent immediately to the Institute for Ecology of Industrial Areas in Katowice for analysis

pH values ranging from 3.64 to 5.01, with a median value of 4.04. Figures 1 presents the trends of pH and S-SO_4, expressed as mg l^{-1}, observed over last 3 years. Progressive decreasing trends for pH values and S-SO_4 concentration is observed.



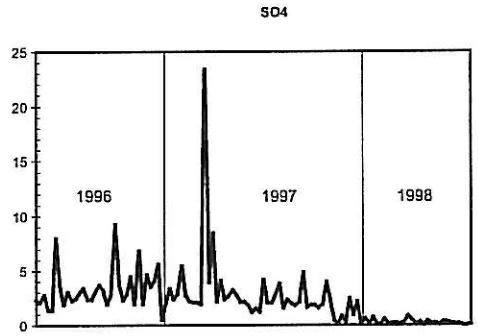


Fig. 1 Trends of pH and SO_4 the precipitation collected from the Hala Gasienicowa.

Water chemistry

Surface water chemistry samples for major ions were taken and analysed according to the sampling protocol of WP1.

Figure 2 presents the changes of pH and S-SO_4 values over last 3 years. \

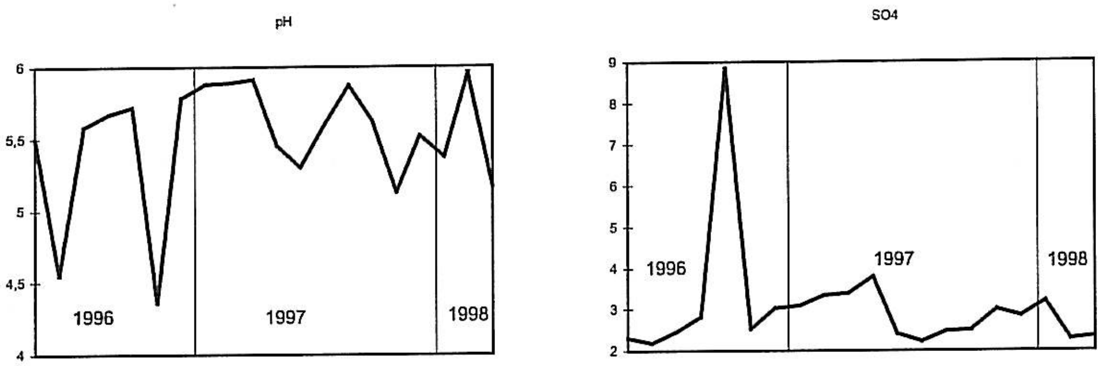


Fig. 2 Trend of pH and SO_4 the water of Dlugi Staw lake

The mean value of pH in 1998 year was 5.39, but its lowest value was during time of snow melting and in September of 1996 and 1997 (below 5.1). Sulphate concentration was stable except one maximum value in 1996 (over 2.65 mg/l).

Lake biology

Ciliates

Phytoplankton and ciliates samples were taken two times during ice free period from the lake bottom (8 m.) and 1 m. below the surface. Phytoplankton samples were send immediately to Prague University, Institute of Hydrobiology.

Bigger density of Ciliates was found in June, both in sample from 1 m. below the surface and 1 m. above bottom. Their amount was comparable with the number found in 1996 and 1997.

Zooplankton

Zooplankton samples (qualitative and quantitative) were taken two times during ice free period (June, July).

Table 1 presents the results of zooplankton found in 1998

1998	17.06		30.07	
	ind/m^3	ind.	Ind/m^3	ind.
Chydorus spaericus	8	2	141	36
Alonella excisa	0	0	35	8
Diacyclops bicuspidatus	0	0	8	3
nauplii cyclopoida	0	0	0	14

Zooplankton community consists of only few species, of which the Cladocera *Chydorus spheaericus* and *Alonella excisa* were most abundant (especially in July sample). *Chydorus spheaericus* was the dominant species over last three years (Table 2)

Table 2. Averege number of zooplankton species in the Dlugi Staw lake

Dlugi Staw	**1996** in/m^3	**1997** in/m^3	**1998** in/m^3
Chydorus sphaericus	36	253	83
Alonella excisa	36	172	19
Acanthocyclops vernalis		47	

Diacyclops bicuspidatus	1	4

Macroinvertebrates

Macroinvertebrates samples (from profundal and littoral) were taken also in the same time as zooplankton samples.

In the Dlugi Staw 6 taxonomic groups were found (Table 3). Fauna in the profundal samples were very poor in June and July, represented only by Nematoda, two oligochaetes taxa and three Chironomidae species. The density of macroinvertebrates was very low: 1200 n/m^2 in June and 600 n/m^2 in July, comparing with over 10 000 n/m^2 in 1996 and 8 000 n/m^2 in 1997 (annual average). Very low density of macrofauna was caused mainly by very low number of Nematodes which were the first dominant in 1996 and 1997. In compare with first and second years of project the *Cernosvitoviella tatrensis* was still not found in profundal zone, while *Micropsectra coracina* appeared in June sample but in very low density.

In the littoral zone Oligochaeta were represented by 6 species and this group dominated, as it was stated in the previous years. Especially in July higher number of *Cernosvitoviella tatrensis* (both young and mature specimens) was found.

Table 3. Macroinvertebrates in Dlugi Staw

Dlugi Staw	**June** profundal n m^{-2}	kick	**July** profundal nm^{-2}	kick
NEMATODA	597			3
OLIGOCHAETA				
Stylodrilus sp.	199			
Cognettia spp.		18		30
C. sphagnetorum		15		16
C. glandulosa		2		1
C. lapponica		1		6
Cernosvitoviella spp.		10		71
Cernosv. Tatrensis		8		49
Cernosv. Atrata		0,3		
Marionina argentea		0,3		0,3
Enchytraeidae juv.		1	199	
APHANONEURA				0,3
Aeolosoma sp.		0,3		
TRICHOPTERA		0,3		
DIPTERA				0,3
Micropsectra coracina	199			
Tanytarsus lobatifrons	199			
Tanytarsini sp. (juv.)				0,3
Limoniidae (Pedicia sp.)		1		
Limnophyes sp.		3		
Smittia sp.		1		
Heterotrissocladius marcidus			398	
Chaetocladius gr. vitellinus		0,3		
amphibiotic form		1		
COLEOPTERA		1		
TOTAL	1194	63,5	597	177

List of Publications arising from the project:

Invertebrate communites of high mountains lakes (Tatra Mountains) as acid pollution indicator. A. Kownacki, J. Galas., E. Dumnicka *Hydrobiology,* submitted.

Bacteria, phyto-and zooplankton in high mountain lakes under heavy nitrogen loading: Tatra Mountains (Slovak and Polish) Straskrabova, V., Simek, K., Macek, M., Hartman, P., Kopacek, J., Nedoma, J., Vrba, J., Fott, J., Blazo, M., Stuchlik, E. and Galas, J.

Signature of Partner: Joanna Galas

Date: 27.02.1999

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: March 1 1998 - February 28 1999

Partner: National Institute for Biology
Laboratory for freshwater and terrestrial ecosystems research (NIB)

Principal Investigator: Anton Brancelj

Scientific staff: Alenka Gaberščik, Olga Berčič-Urbanc, Milijan Šiško, Gregor Muri, Andreja Jerebic

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I. OBJECTIVES FOR THE REPORTING PERIOD:

1.) Water column sampling
2.) Sampling of contemporary diatoms and Cladocera in littoral zone
4.) Contemporary zooplankton and phytoplankton (diatoms)
5.) Sediment traps (SCP, diatoms and cladocerans remains)
6.) Sediment core diatoms and cladocera from lake Ledvica
7.) Sediment core cladocera from lake Redo
8.) Meteorological data collection

II. OBJECTIVES FOR THE NEXT PERIOD:

Project is finished. Preparation of publications in national and international journals.

III. Are there any particular problems ? Is your part of the project on schedule ?

All planned activities were finished according to the schedule. Field work should be finished in the mid of summer but we prolong the sampling (water chemistry) and measurement (meteorology) till end of autumn. We will leave automatic weather station (AWS) in operation for the next two years. In AWS we have some problems with solar sensor but it was repaired. Due to improper manipulation of data logger we lost data for one month (in May). Some problems arose also due to freezing of wind direction sensor that lasted few days.

As in 1997 we had problems with considerable oscillation of water level also in 1998. There was extremely low water level in July and extremely high in the next month. Difference was more than 2,5 m. As a result we could not collect proper benthos samples.

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS* (use other pages as necessary but preferably no more than 2)

Water column sampling

In 1998 we sampled water column from March till November. We sampled it seven times. In March the lake was covered with c. 80 cm thick ice. Above the ice there was c. 20 cm of powdered snow. In May there was still c. 50 % of the lake under ice cover. Characteristic for summer period was intensive rainfall resulting in raised water level in the lake.

Comparing previous two years (1996 and 1997) some chemical parameters in the water column have considerably increased concentrations. The most extreme raises we observed in sulphate ion (maximum up to 7 mg l^{-1} in 1998 compared with maximum 3 mg l^{-1} in 1997) and total nitrogen. Total nitrogen has decreased from Sept. 1996 till Sept. 1997 and increased again from Nov. 1997 to Nov 1998 - increase from 11 mg l^{-1} to 17 mg l^{-1}. The increase could be observed also in sodium (from 0,5 mg l^{-1} in January 1998 to >3,5 mg l^{-1} in November 19987)

Values for total phosphorus concentrations in 1998 were similar to those in 1997 Exception was in November, when a peak of TP concentration rose up to 0,9 mg l^{-1}. Values of pH, conductivity and Chl a concentrations were similar to those in 1996 and 1997.

pH, conductivity, alkalinity, nitrate and calcium concentrations oscillated considerably from one sampling date to another but there have no tendency to change within the last three years. Opposite to them, concentrations of sodium, sulphate ion and total nitrogen have a tendency of increase and slight decrease of total organic carbon, chloride ion and magnesium could be observed in the mentioned period.

Sampling of contemporary diatoms and Cladocera in littoral zone

In 1998 sampling of biota in the littoral zone was difficult due to intensive water level oscillations - up to 2,5 m. .No representative semi-quantitative samples could be obtained there. Qualitative analyses of both groups get the same species composition as in previous years. Analyses of diatoms from the transect collected in Sept. 1996 show that the most common diatom species is *Acnanthes minutissima,* occupying the interval from surface to the depth of 12,5 m. Eighteen diatom species were identified in transect samples which were relatively abundant. There is a clear difference between epilithic community (occupying interval between 0 and 10 m -rocky bottom) and epithelic community (between 12,5 and 15 m of depth - soft bottom).

Contemporary zooplankton and phytoplankton (diatoms)

Phytoplankton in lake Jezero v Ledvicah was present all the time in very low concentration (expressed as $\mu g\ l^{-1}$ of Chl), with maximum concentration of 0,55 $\mu g\ l^{-1}$ (as mean volume weighted value). Comparing to 1997 Chl values were lower for almost 50 %. There were no diatoms in the plankton. Zooplankton was represented by three taxa (*Arctodiaptomus alpinus*, *Cyclops abysssorum tartricus* and *Daphnia longispina*). In zooplankton was observed also the decrease of biomass comparing it with previous years. Maximum value of a standing crop of zooplankton biomass in 1998 was 0.11 $g\ m^{-3}$ (0.19 $g\ m^{-3}$ in 1997).

Sediment traps (SCP, diatoms and cladocerans remains)

Sediment traps were emptied at the same dates as water column samples were collected. There was no diatoms in the trap and number of remains of *Daphnia* increased in autumn period only. Number of SCP, being very abundant in 1997 (up to 2500 particles per square cm), dropped to c. 600 particles cm^{-2} in 1998.

Sediment core diatoms and cladocera from the lake Ledvica

In total 40 diatom taxa and 4 cladoceran taxa were found in the sediment core from the lake. There is no changes in species distribution along the 40 cm long sediment core but there are qunatitative changes. Particularly in upper-most part of the core number of remains of both groups increase. There is no particular correlation in number of remains between groups. Several analyses of the sediment from the lake indicate that top-most 16 cm were effected by some external event. As the most probable one there is an earthquake that hit the lake twice (in 1942 and 1976). From 1942 onward (corresponding to the depth of 12 cm in the sediment) number of Diatom remains increases but those of Cladocera start to oscillate. In the top 2,5 cm of the sediment number of Diatom remains is increasing and has the highest value per unit regarding the whole core. In Cladocera the situation is opposite - their number decrease and values are low comparing other part of the core. In Cladocera in the upper 12 cm of the core is a co-dominance of *Chydorus sphaericus* and *Alona affinis*, whilst bellow the depth of 12 cm remains of *A. affinis* are rare.

Sediment core Cladocera from the lake Redo

Analyses of Cladocera remains from the lake Redo are finished. In total 7 species are determined. *Megafenestra aurita, Daphnia pulicara, Chydorus sphaericus* and *Alona affinis* are the most dominant species in the Redo sediment.. *M. aurita* is common in the top-most 10 cm of the sediment. Interval between 10 and 20 cm of the depth is characterised with remains of *A. affinis* and *C. sphaericus*. *D. pulicaria* has bimodal distribution being the most common in the top-most 5 cm and bellow 15 cm.

Meteorological data collection

Meteorological station run in 1998 without serious problems, except in May when we lost data for one month period. Data were collected from the data logger in approx. 2 month intervals. In October they were transferred to EAWG (D. Livinngstone) for evaluation and further analyses.

In 1998 there was a tendency of increasing of summer temperature comparing those with previous years (maximum summer: 24.5 °C in Aug. 1998; 20.2 °C in Sept. 1997; mean summer 12.8 °C in Aug. 1998 and 11.6 °C in Aug. 1997) and decreasing of minimum winter temperature (-14.5 °C in Feb. 1998; -11.7 °C in Feb. 1997). Amount of precipitation (rain only) was the same in both years with maximum of 512 mm in Nov. 1997 and 532 mm in Oct 1998.

V. List of Publications arising from the project (include copies):

URBANC-BERČIČ, Olga, BRANCELJ, Anton, ŠIŠKO, Milijan. Carbonaceous particles from sediment traps in mountain lakes of the Triglav National Park, Slovenia. V: International conference on Water quality management in national parks and other protected areas : second announcement : under the auspice of the croatian goverment : Primošten, 20-23 may 1998.

GABERŠČIK, Alenka, URBANC-BERČIČ, Olga, BRANCELJ, Anton, ŠIŠKO, Milijan. Seasonal dynamic of main trophic parameters in three alpine lakes in the Triglav national park (Slovenia). V: Abstracts. Kinneret: Kinneret Limnological Laboratory, 1998.

MAZEJ, Zdenka, GABERŠČIK, Alenka. Macrophytes in different types of lakes: species composition and species vitality. V: MONTEIRO, Ana (ed.) VASCONCELOS, Teresa (ed.), CATARINO, Luis (ed.). Management and ecology of aquatic weeds : proceedings of the 10th EWRS international symposium on aquatic weeds, Lisbon 21-25 September 1998. Lisbon: European Weed Research Society, 1998.

Signature of Partner:

Dr. Anton BRANCELJ

Date: March 1 1999

PART B

DETAILED REPORT OF THE PARTNER 22

Reporting period: 1.03.98 - 28.02.99

Partner: Institute of North Industrial Ecology Problems of Kola Science Centre

Principal Investigator: Prof. Tatyana Moiseenko

Scientific staff: Dr. Lubov Kudravtseva (analytical works, hydrochemistry), Dr. Vladimir Dauvalter (sedimentology), Dr. Anatoly Lukin, Julia Sharova (ichthyology), Dr. Boris Ilyashuk (invertebrate), Dr. Ludmila Kagan (diatoms), Dr. Oksana Vandysh (zooplankton), Andrey Sharov (phytoplankton), Sergey Sandimirov (meteorology, hydrology), Elena Ilyashuk (chironomids).

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I. OBJECTIVES FOR THE REPORTING PERIOD:
Intensive monitoring of lake - Chuna side under the program WP -1. Research of a chemical composition of atmospheric precipitation, water chemistry, condition of biological communities - phyto -, zooplankton, fishes in north-east of Europe.

II. OBJECTIVES FOR THE NEXT PERIOD:
Generalization of results and reporting. Estimation of influence of atmospheric transmission on water quality of lakes of northern Europe and their biodiversity. Geochemical and paleoecologycal reconstruction of climate changes and environment in north of Europe.

III. Are there any particular problems ? Is your part of the project on schedule ?

IV. MAIN RESULTS OBTAINED

The combination of conditions of high arctic latitude with altitude causes the importance Chuna-site for the European project - understanding of pollutants transmission and early exchanges in ecosystems. Methodology of research within the framework of manual on WP -1.

Chemistry of deposits. In 1998 the pH of deposits in Chuna site vary from 4.87 to 4.99 in a winter period and 4.12-5.72 in a summer period. The dominant anion is sulphate: 0.37-0.87 mg/l in snow samples and 0.9-4.1 mg/l in rain. The concentration of nitrate in deposits much below and changes from 0.036 up to 0.230 mgN/l. Thus, the main parameters of deposits from Chuna site in 1998 insignificantly differ from deposits 1997.

Water chemistry. The pH of Chuna lake waters changes in an interval 5.97-6.39, alkalinity in summer period 1998 changes from 15 to 21 μeqv/l. The dominant cation is Ca (0.8-1mg/l), the dominant anion is SO_4 (1.4-2.03 mg/l). These parameters correspond noticed in 1996-1997.

The definition Ni, Cu, Mn, Sr, Al, Fe was carried out by Graphite Atomic Absorption Spectroscopy. The contents of Ni = 0.5-3.4 μg/l, Cu = 0.3-1.6 μg/l, Cd = 0.05-0.1 μg/l. The high level of Ni and Cu was noticed in a surface layer in June after a snowmelt time. It can be as a result of watershed inputs, where these elements get due to activity of the enterprise. The contents Al in water of Chuna lake changed from 4 up to 60 μg/l, Fe - from 2 up to 14 μg/l. The content of Cr = 0.008-0.01μg/l, Pb = 0.013-0.017μg/l (were determined by ICP MS).

Phytoplankton. The phytoplankton samples were taken in the beginning of summer (9th July) and beginning of autumn (5th September). The diversity of the phytoplankton was sufficiently low, number of species was 5-9 in the different samples (Fig. 1). The composition of phytoplankton at 9th July was typical for this season. The value of plankton algae more in hypolimnion (278 mm^3/m^3) in compare with epilimnion (46 mm^3/m^3). The dominated algae were *Cryptomonas marsonnii*, *Peridinium aciculiferum*, *Cosmarium sp.* and *Stephanodiscus alpinus* (9th July). In the samples of September the diatom algae were absent. The samples were dominated by green algae *Elacatotrix gelatinosa* and *Oocystis sp.* (5th September). The total volume of phytoplankton was 47 mm^3/m^3.

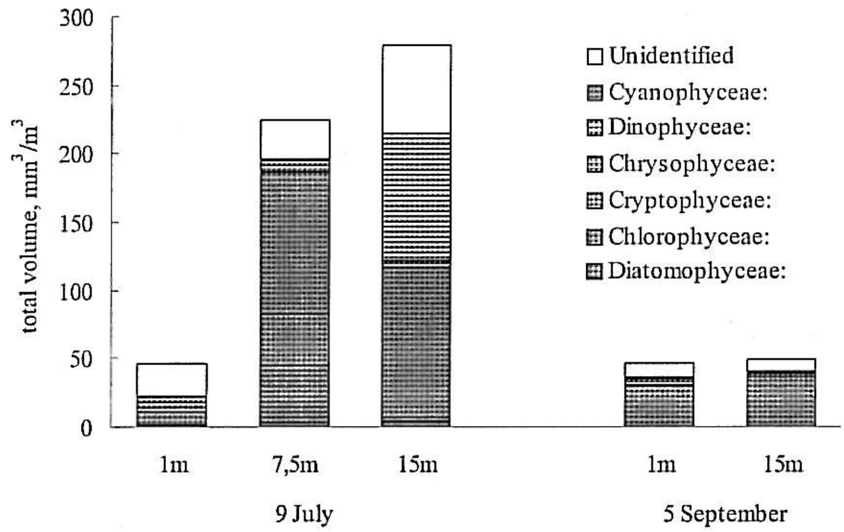

Fig. 1. Phytoplankton composition of the Cuna lake in 1998.

Zooplankton. Zooplankton species composition, number of individuals in sample, number of individuals × 10^3 m^{-3} and biomass (mg wet weight m^{-3}) in Chuna lake during study period are given in Table 1.

Table 1. Zooplankton taxa recorded from samples in the reported period

	N in sample	N ind × 10^3 m^{-3}	B mg w. w. m^{-3}	N in sample	N ind × 10^3 m^{-3}	B mg w. w. m^{-3}
Sampling date	09.07.	09.07.	09.07	05.09	05.09	05.09
Depth, m	0-14	0-14	0-14	0-14	0-14	0-14
Rotatoria	30	0.07	0	17	0.04	0
Kellicottia longispina	30	0.07	0	17	0.04	0
Cladocera	7052	16.01	701.1	259	0.58	26
Alonopsis elongata	1	0.002	0.1	2	0.004	0.2
Bosmina obtusirostris	466	1.06	23.80	150	0.34	9.9
Bythotrephes longimanus	-	-	-	2	0.004	3.7
Holopedium gibberum	6585	14.95	677.2	105	0.24	12.2
Copepoda	1755	3.98	316.3	2081	4.72	292.1
Cyclops scutifer	1380	3.13	284.8	731	1.66	132.1
Eudiaptomus gracilis	375	0.85	31.5	1350	3.06	160
Total	**8837**	**20.06**	**1017.4**	**2357**	**5.34**	**318.1**

In the current study 1998 a total of 7 zooplankton species (Rotatoria - 1, Cladocera - 4, Copepoda - 2) were recorded in the investigated lake (Table 1). The dominant and common species have been: in July *Bosmina obtusirostris*, *Holopedium gibberum*, *Cyclops scutifer*, in September - *Cyclops scutifer* and *Eudiaptomus gracilis*. Highest abundance (20.06 ind × 10^3 m^{-3}) and biomass (1017.4 mg w.w. m^{-3}) during period of observations 1996-1998 was recorded in July 9th 1998. Cladocera prevailed in July 9th (>79% of total abundance and 69% of total biomass). Cyclopoida (31% of total abundance and 41% of total biomass) and Calanoida (57% of total abundance and 50% of total biomass) were a dominant groups in September (Fig. 2).

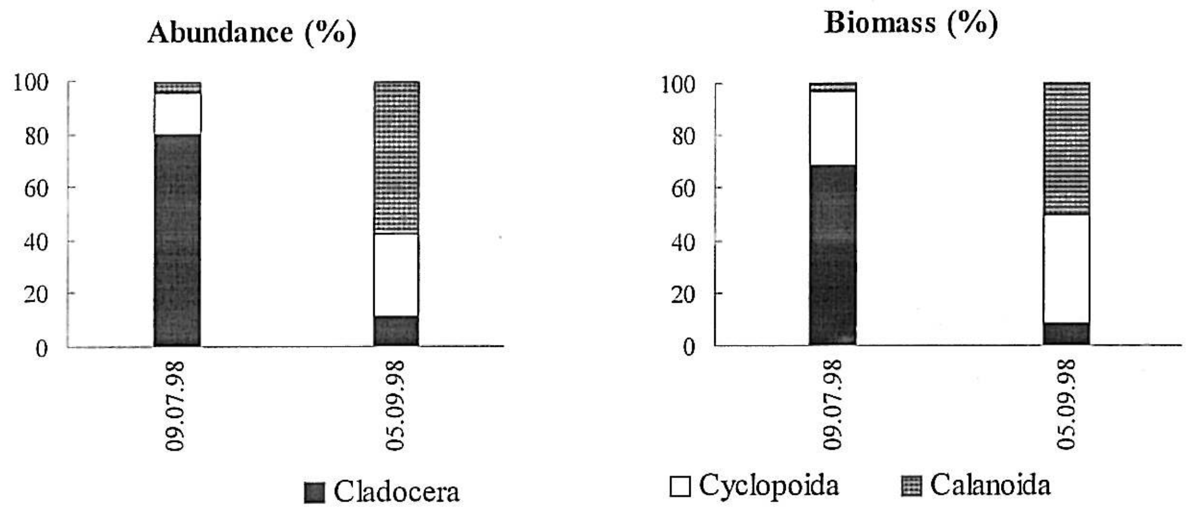

Fig. 2. Relative mean of basic groups of zooplankton in total abundance (%) and in total biomass (%) in monitored lake in 1998

Abundance (ind × 10^3 m^{-3}) and biomass (mg w.w. m^{-3}) calculations showed differences between months. It is obvious that changes in zooplankton community structure associated mainly with a

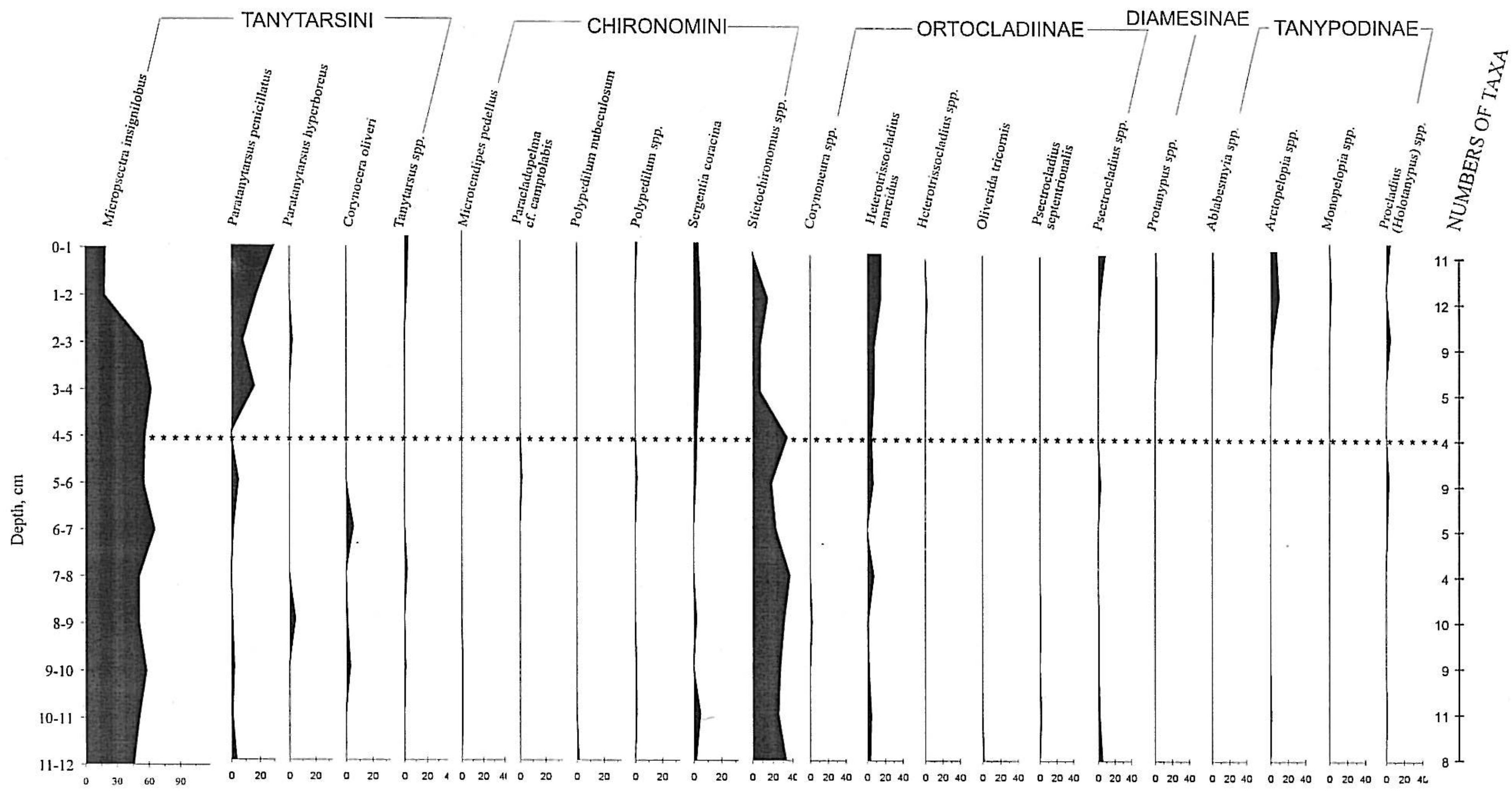

Fig. 3. Stratigraphical profiles of the relative abundance (%) of chironomid taxa in core from the Chuna lake. Asterisk line - beginning of pollution by heavy metals and beginning of anthropogenic acidification according to the reconstruction of past pH from fossil diatoms (from Moiseenko et al., 1997).

seasonal variations of relative abundance of planktonic crustacean (*Bosmina obtusirostris*, *Holopedium gibberum*, *Cyclops scutifer*, *Eudiaptomus gracilis*).

Species of broad ecological requirements, which are capable to survive under low pH and low temperature (*Holopedium gibberum*, *Bosmina obtusirostris*, *Eudiaptomus gracilis*) were found.

Invertebrates. A total of 27 taxa were recorded in the Chuna lake from kick and grab samples during 1998. A total of 11 species of chironomids were identified in samples from different zones of the Chuna lake.

The acidification value of the Chuna Lake was characterized as mesoacidic using the acidification index by Raddum et al. (1988) and Fjellheim and Raddum (1990). The mean acidification index was higher in September (0.40) than in August (0.33).

Subfossil chironomid remains were analyzed in 12 samples from sediment core (12 cm). A total of 618 chironomid head capsules and 22 taxa were found. The four most important species (in order of abundance) were *Micropsectra insignilobus*, *Stictochironomus spp.*, *Paratanytarsus penicillatus* and *Heterotrissocladius marcidus* (Fig. 3). The declines in *M. insignilobus*, *Stictochironomus spp.* and abrupt increases in *P. penicillatus* and *H. marcidus* were noted in sediments dated to recent decades. The diatom stratigraphy and chemical sediment analysis from the Chuna lake indicated gradual acidification and pollution by heavy metals of the lake during the past decades (Moiseenko et al., 1997). The declines in Micropsectra-species and the increases in other Tanytarsina are consistent with the other acidification studies (Walker et al., 1985; Dermott et al., 1986; Schnell, Willassen, 1996; Guilizzoni et. al., 1996).

Fish. In 1998 the population of brown trout consisted of 50 individuals. The amount of age groups had increased in population. Fish of 5 (4+) age prevailed. The population was presented by brown trout from age of 2 (1+) years old up to age of 7 (6+) years old, while in 1997 fish at the age of 1+ and 6+ were absent. The catch was dominated by female in ratio 1:2.3. The analysis of growth rate of brown trout showed up decrease one in 1998 in compare with 1996-1997 when the growth rate was considerably better. Age and length distribution are presented in Fig. 4 a, b.

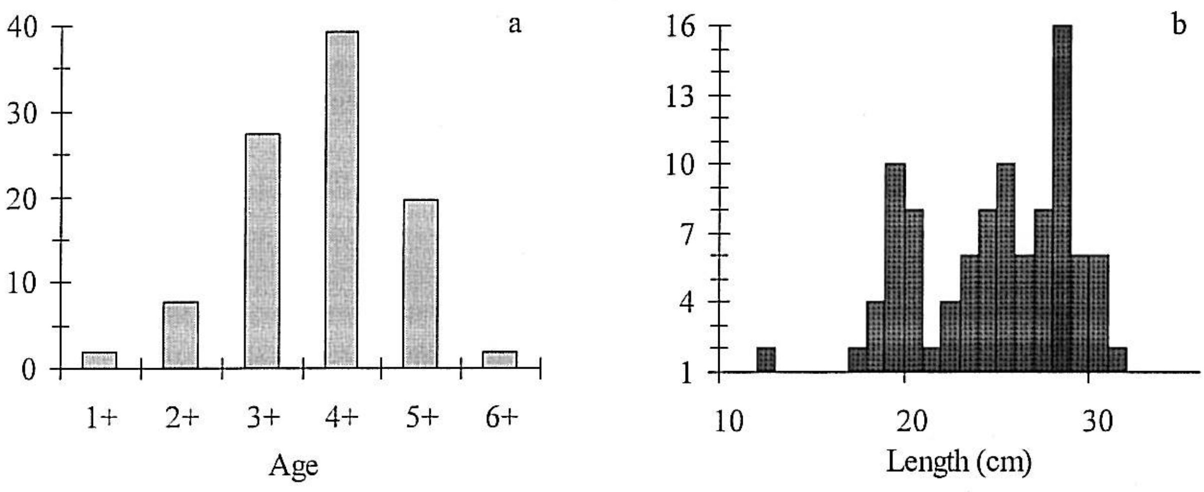

Fig.4. Distribution (%) of age (a) and length (b) of brown trout (*Salmo trutta L.*) in Chuna Lake in 1998.

DISCUSSION and CONCLUSIONS

The results of monitoring in 1998 have shown, that a condition of the Chuna lake ecosystem for three years it is enough stable.

Despite of variability of climatic conditions in these years, distinct trends is not revealed. Precipitation of anthropogeneous sulphur - 0.3 g/m^2 year, pH of deposits - 4.1-5.7.

Seasonal fluctuation of water composition are typical as of all northern lakes. In the spring in snowmelt period (May - June) pH values of water are lowest, and the sulphate contents raise. It specifies, that the major factor of acidification is the sulphate influx from the watersheds. Dynamics of nutrient elements is laid to the typical scheme: increase them in freeze-up period and decrease in vegetation period.

In the summer species dominated - algae *Cryptomonas marsonnii*, *Peridinium aciculiferum*, *Cosmarium sp.* and *Stephanodiscus alpinus*.

Number and biomass of zooplankton in comparison with other arctic lakes are high - up to 20.06 ind $\times 10^3$ m^{-3} and 1017.4 mg w.w. m^{-3}, respectively. The maximum was in period of opened water. The dominant and common species of zooplankton have been: in July *Bosmina obtusirostris*, *Holopedium gibberum*, *Cyclops scutifer*, in September - *Cyclops scutifer* and *Eudiaptomus gracilis*.

The received monitoring data testify to relative stability of lake in relation to short-term variations of climate and environment.

The more interesting information is received on the basis of the paleoecological data. In 1997 the analysis of geochemical composition and diatoms of sediment core, in 1998 Chironomids composition in the sediment core was completed. The significant changes of all three components are noticed from the layer 4-5 cm, appropriate to industrial development of the European North. According to results of diatoms research, the changes in the layer 8-9 cm connected with industrial activity of the Central Europe are revealed.

V. List of publications arising from the project (include copies):

Moiseenko T.I., Dauvalter V.A., Kagan L.Ya. 1997. Mountain lakes as indicator of air pollution. Water Resources, V. 24, No. 5. - P. 556-564.

Moiseenko T.I., Dauvalter V., Kagan L.Y. Mountain lakes of Russian Subarctic as air pollution markers // Issues in Environmental Pollution, Denver, Colorado, USA, 23-26 August, 1998. - Denver, Colorado, USA, 1998. - Abstract 3.04.

Signature of Partner:

Date: 28th February 1999

PART B

DETAILED REPORT OF THE INDIVIDUAL PARTNERS

Reporting period: 11.2.98 - 28.2.99

Partner: Laboratorio Studi Ambientali (LSA), Sezione Protezione Aria e Acqua, Dipartimento del Territorio, Cantone Ticino, Switzerland (23)

Principal Investigator: Dr. Alberto Barbieri

Scientific staff: Marco Simona, Mauro Veronesi, Giovanni Kappenberger, Manuela Simoni Vassalli and Paola Lanfranchi Da Rold

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I. OBJECTIVES FOR THE REPORTING PERIOD:

- Conclusion of sampling campaign on Laghetto inferiore (LI) and Laghetto superiore (LS): two samplings
- Collection and analysis of wet, dry and aerosol depositions
- Data storage and elaboration, focusing on some phenomena, such as stability of water column, mass fluxes of chemical parameters and phytoplankton stratification

II. OBJECTIVES FOR THE NEXT PERIOD:

- Prosecution of collection and analysis of wet, dry and aerosol depositions
- Survey sampling on LI and LS (during summer and ice cover period)

III. Are there any particular problems ? Is your part of the project on schedule ?

- A new wet deposition sampler has been installed on November 1998. We are now in a comparison phase with the old rain sampler

PART B

IV. MAIN RESULTS OBTAINED: *METHODOLOGY, RESULTS, DISCUSSION, CONCLUSIONS*

METHODOLOGY

Our weather station is installed at Robiei, located 7.25 km SW to LI, at 1891 m a.s.l.. Temperature, vapor pressure, relative humidity, solar radiation, wind direction and speed data are recorded every 10 minutes. Atmospheric deposition are collected weekly between May and October 1997 with a wet-only sampler. During autumn and winter seasons (January-April and November-December 1997) snowy precipitation has been estimated with a snow core. The snow core has been divided into fractions corresponding to the most important precipitation events, on the basis of their stratification characteristics (thickness, density and equivalent water content).
Since November 1998 a new wet-only collector (Eigenbrodt NSA 181/KHE) has been installed at Robiei station. This device can work under severe meteorological conditions (outside temperature between -20 and 40°C, occurrence of strong winds) and has therefore been successfully employed also in arctic regions.

Lake water samples were taken from the lake at the point of maximum depth (33m), on the whole water column. At the moment of sampling measurements were made of temperature, pH, dissolved oxygen and conductivity, at 0.5 m intervals, with an Idronaut multiparametric probe (mod. Ocean seven 316). Samples for chemical analysis were taken from the whole water column at 5 m intervals. At these depths the dissolved oxygen concentration was also measured, using Winkler's method (1888).

RESULTS and DISCUSSION

Water column stability

During our campaign (July 1996-July 1998) homothermic periods have been observed (see Fig. 1), but they lasted only for a short time. However, frost and thawing periods didn't induce deep mixing within the lake, because a weak vertical saline gradient, typical for the LI, was maintained during the observation period. Therefore, the density structure of LI is quite stable and shows only temporary weakening.
However, in June 1997 an intense precipitation event (more than 500 mm) took place at the end of the thawing period when the lake was in homethermy, causing the partial mixing of the lake and a partial water dilution, which reduced the mean ion concentration from 210 to 170 $\mu eq\ l^{-1}$. This fact shows that the mixing of LI is possible only after strong rainy events during the short homothermic periods.

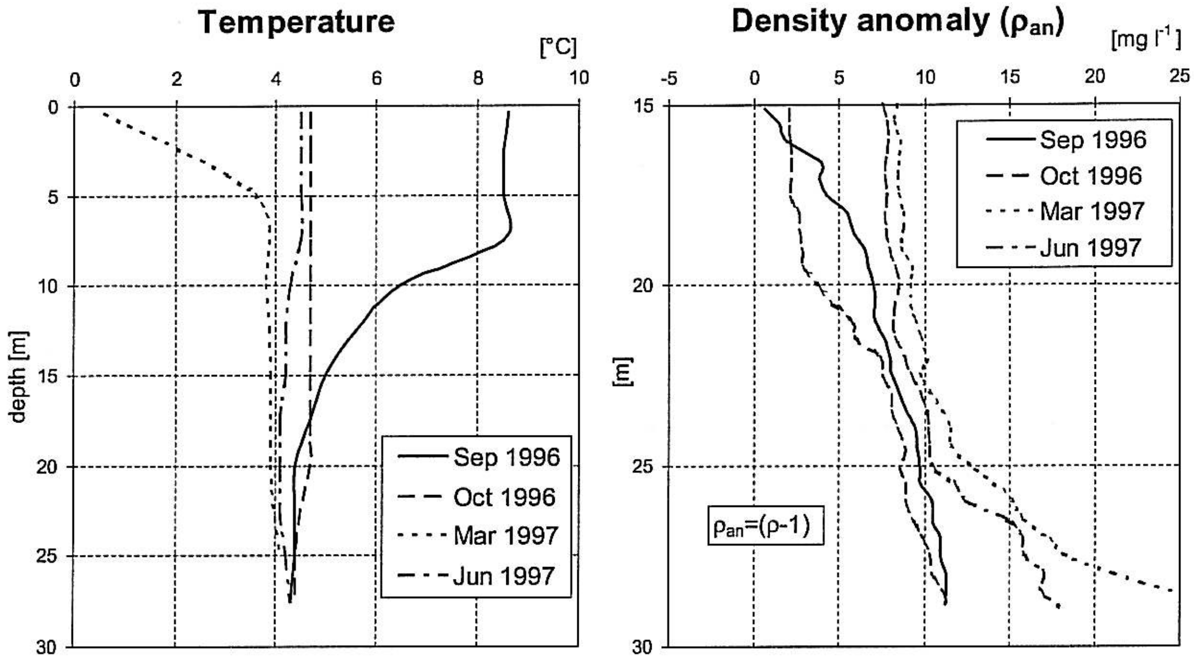
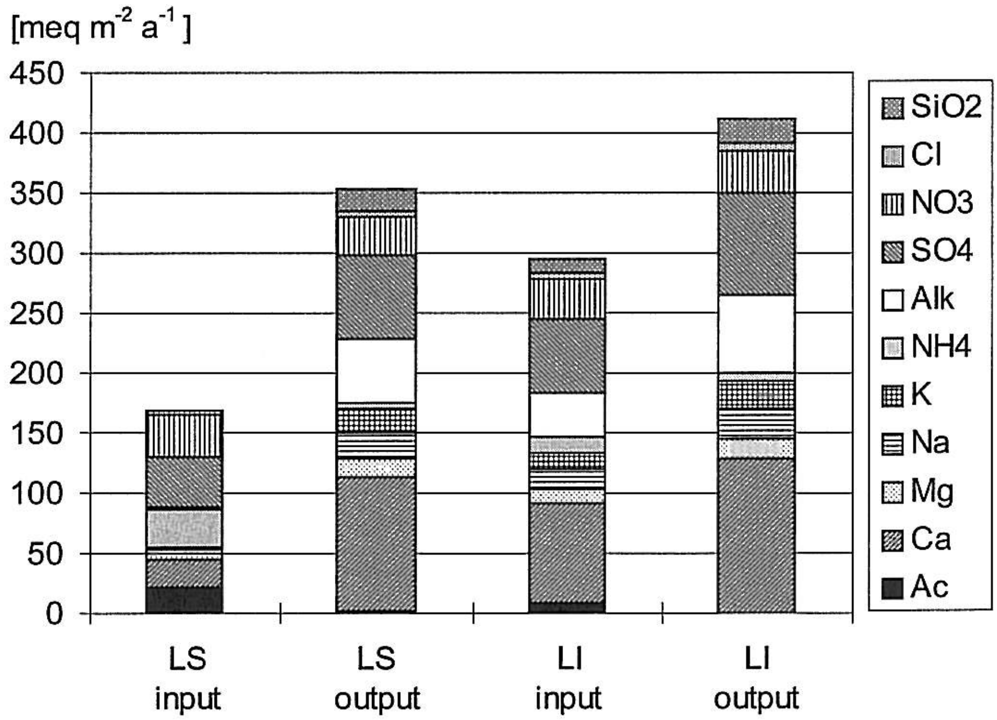


Fig. 1: Seasonal evolution of temperature and density anomaly profiles in LI.

Mass balance

Starting from atmospheric loads and from input values from the above located LS, as well as considering both input and output into and from LI, it is possible to calculate areal mass fluxes for all the considered ions (Fig. 2). In particular it is possible to quantify weathering intensity which are responsible for the concentration increase of several parameters, noticeable at LI's outlet.



PART B

Phytoplankton stratification

To verify the vertical distribution of the phytoplankton population, during the September 1996 sampling, a series of samples was taken every 2.5 m of the depth of the water column, and on each of these the principal taxa were counted (Fig. 3).
The density value curves reveal a sharp vertical division into zones of the single taxa, which reach their maximum development at different depths. The surface layers (0-7.5 m) contain abundant armored Dinophyceae (*Peridinium elpatiewskji*), while the unarmored Dinophyceae (*Gymnodinium*) show a peak at 22.5 m; the Chrysophyceae (*Dinobryon, Mallomonas*) are concentrated around 10 m depth, the Conjugatophyceae (*Arthrodesmus, Gonatozygon*) around 20m, and the Chlorophyceae around 25m. The Cryptophyceae show a clear tendency to develop in the deep layers: practically absent in the top 10 m, they increase progressively below 12.5 m with *Rhodomonas*, respectively below 17.5 m with *Cryptomonas*.
This tendency for phytoplankton species to establish themselves in the deep layers, aided by the great transparency of the water, is confirmed by the relationship between algal biomass and chlorophyll *a* along the vertical profile and also by the trend of the chlorophyll *a* profiles measured in the course of the survey.

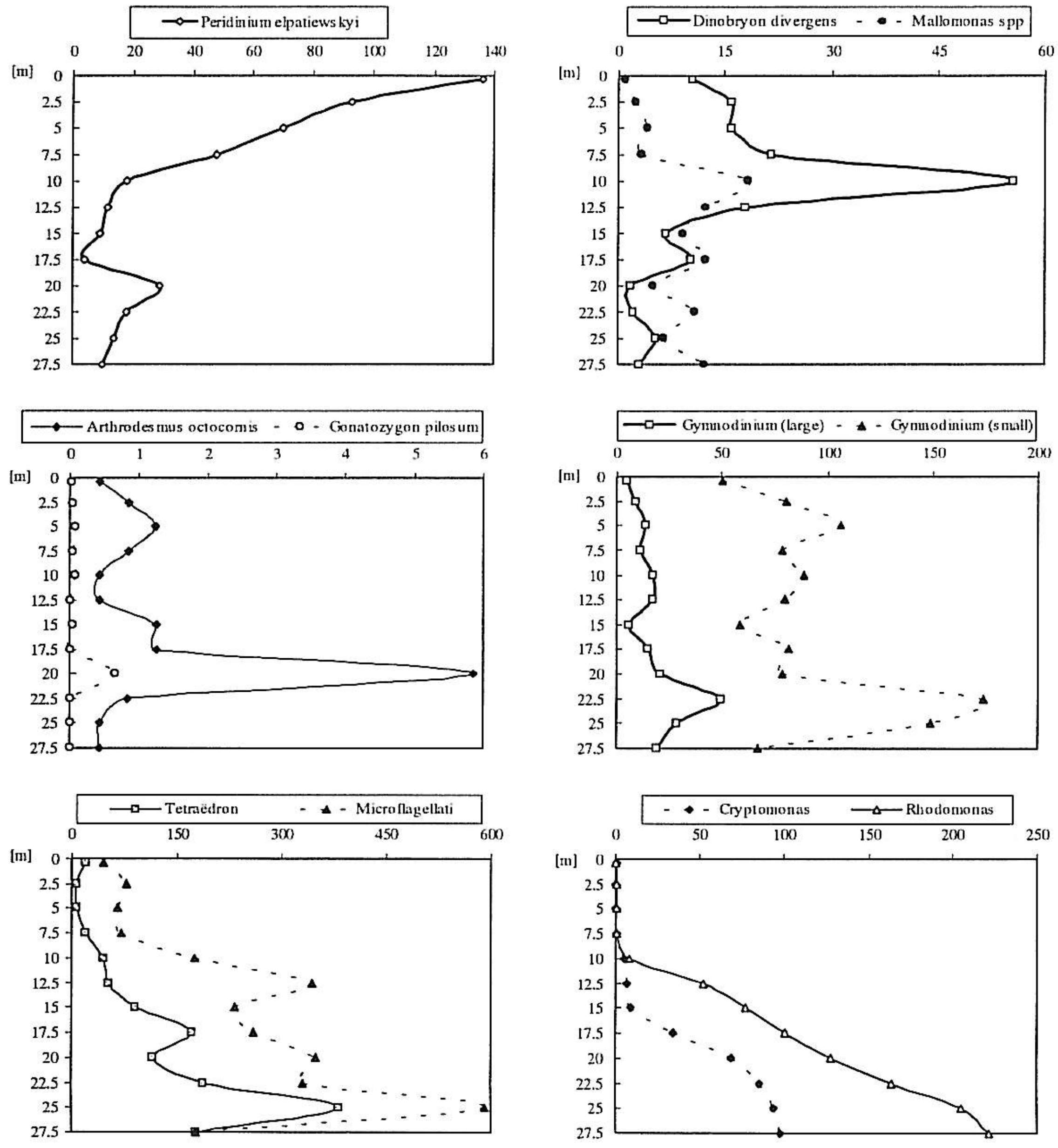


Fig. 3: Stratification of algal groups within the water column of LI.

V. List of Publications arising from the project (include copies):

- Barbieri. A. and R.Mosello
  Recent evolution in chemistry and mass budget of a high altitude lake in southern Alps (LI, Switzerland)

- Barbieri. A, M. Veronesi, M. Simona, S. Malusardi and V. Straskrabova.
  Limnological survey in eight high mountain lakes located in Lago Maggiore watershed (Switzerland)

- Simona M., A. Barbieri, M. Veronesi, S. Malusardi and V. Straskrabova.
  Seasonal dynamics of plankton in a mountain lake in southern Alps (LI, Switzerland)

- Barbieri A., M. Simona and R. Mosello. Chemical trend, recent evolution in mass budget and seasonal dynamics of a high altitude lake in southern Alps (Laghetto inferiore, Switzerland).
  The abstract has been accepted for presentation at the LAKE 99 Conference: Sustainable Lake Management. Copenhagen, 17-21 May 1999.

Signature of Partner:

Date: 16.2.99