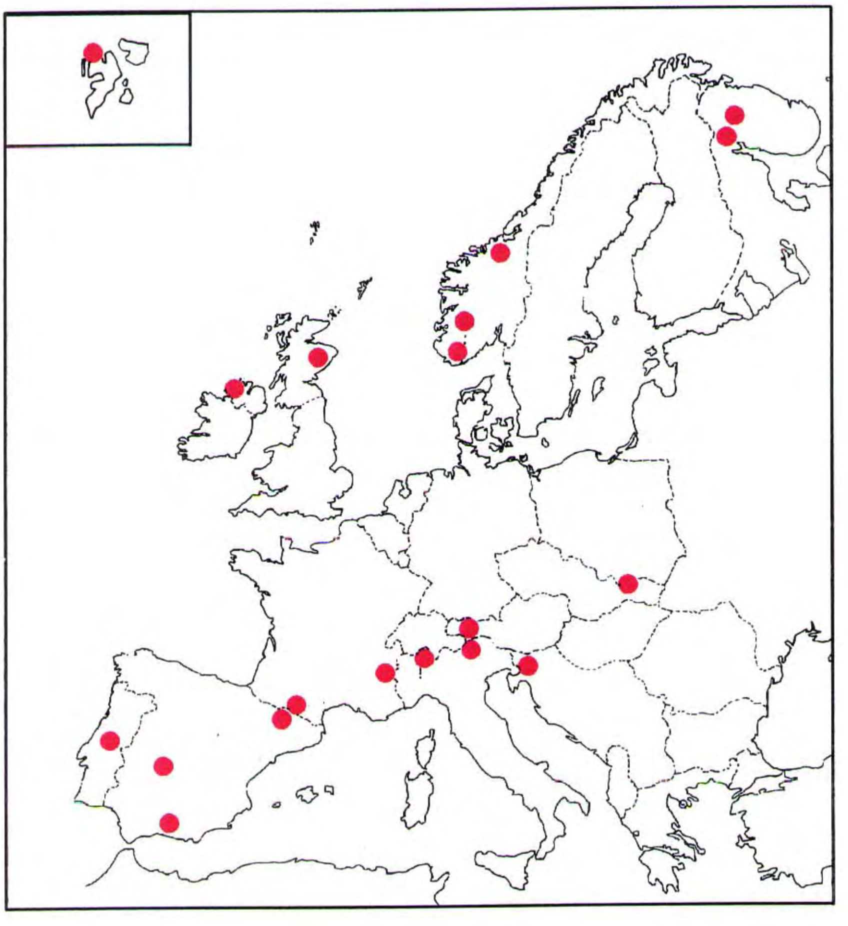
Acidification of Mountain Lakes: Palaeolimnology and Ecology

AL:PE

AL:PE - Acidification of Mountain Lakes: Palaeolimnology and Ecology

Part 2 - Utvidelse.
Sluttrapport til Norges forskningsråd.



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NIVA - RAPPORT

Norsk institutt for vannforskning NIVA

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Ekstrakt:

AL:PE prosjektet ble startet for å vurdere status for alpine eller arktiske innsjøer, kjemisk og biologisk kombinert med analyse av sedimentkjerner. Arbeidet er utført i sjøer med varierende forurensningsbelastning, og resultatene kan brukes til å evaluere hastighet, retning og biologiske effekter av endringer i miljøet. AL:PE prosjektet representerer også den første omfattende studie av alpine innsjøer på et europeisk nivå. Prosjektet er finansiert gjennom EUs forskningsprogram kombinert med midler fra deltakerlandene. NIVA har, i tillegg til 50 % finansiering fra EU, fått støtte fra Norges Forskningsråd gjennom TVLF. AL:PE prosjektet er nå under endelig sluttrapportering etter nesten 5 års aktivitet. Rapporten her gir en kort oversikt over arbeid og resultater for AL:PE prosjektet og besrkriver i mer detalj arbeidet støttet av TVLF i 1995.

4 emneord, norske

1. Høyfjellsjøer
2. Vannkjemi
3. Biologi
4. Europeisk samarbeid

4 emneord, engelske

1. High mountain lakes
2. Water chemistry
3. Biology
4. European co-operation

Prosjektleder

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AL:PE Acidification of mountain Lakes: Palaeolimnology and Ecology. Part 2 - Utvidelse
Sluttrapport til Norges forskningsråd

0. Innholdsfortegnelse

1. Bakgrunn

AL:PE er en forkortelse for "Acidification of Mountain Lakes: Palaeolimnology and Ecology. Remote Mountain Lakes as Indicators of Air Pollution and Climate Change". Prosjektet er et multinasjonalt samarbeid som vokste i omfang og antall deltagere i løpet av prosjektperioden. AL:PE 2 er et prosjektsamarbeid mellom institusjoner fra 11 land, Norge, Storbritannia, Italia, Frankrike, Spania, Østerrike, Den Tsjekkiske Republikk, Slovakia, Slovenia, Russland og Polen. Prosjektet er finansiert gjennom EUs forskningsprogram kombinert med midler fra deltakerlandene. NIVA har, i tillegg til 50 % finansiering fra EU, fått støtte fra Norges Forskningsråd gjennom TVLF.

Alpine og arktiske områder i Europa representerer det mest uberørte vi har, men er likevel truet av sur nedbør og langtransportert forurensning. Disse områdene med tilhørende innsjøer danner spesielt følsomme økosystemer. De har korte isfrie perioder, tynt jordmonn, små og gjerne steile nedbørfelt og korte oppholdstider for vannet. Den høye følsomheten gjør dem til meget gode indikatorer på forurensning og eventuelle klima- eller miljøendringer.

Alpine og arktiske innsjøer, er i prosjektet definert som områder høyt over havet eller langt fra ekvator, beliggende over eller nord for den lokale tregrensen. Innsjøene ligger fjernt fra kilder som gir lokal påvirkning, som endringer i bruken av landområdet eller forurenset avløpsvann. Dette øker muligheten til å registrere effekter av endringer i luftkvalitet og klima.

AL:PE prosjektet ble startet for å vurdere status for alpine eller arktiske innsjøer, kjemisk og biologisk kombinert med analyse av sedimentkjerner. Arbeidet er utført i sjøer med varierende forurensningsbelastning, og resultatene kan brukes til å evaluere hastighet, retning og biologiske effekter av endringer i miljøet. AL:PE prosjektet representerer også den første omfattende studie av alpine innsjøer på et europeisk nivå.

Den første delen av prosjektet, AL:PE 1 startet i april 1991 og ble avsluttet i 1993 etter 2 års innsats. Resultatene er rapportert i EUs rapportserie Ecosystems Research Report Vol. 9. (Wathne *et al.* 1995). Den andre delen, AL:PE 2, som startet i 1993, ble formelt avsluttet i juni 1995. AL:PE 2 bygger på resultatene fra AL:PE 1, og representerer en utvidelse av den første delen både geografisk og faglig.

AL:PE prosjektet er nå under endelig sluttrapportering etter nesten 5 års aktivitet, og etter at EU godkjente det første utkastet til rapport i juli 1995. Sluttrapporten er snart ferdig omarbeidet på en slik måte at den gir en oversiktlig presentasjon av prosjektet og resultatene vi har oppnådd.

2. Hovedmål og organisering

Hovedmålet for hele AL:PE prosjektet var å øke kunnskapen om avsidesliggende høyfjellsjøers struktur og økologi, og deres respons på forskjellige nivå av forurensning.

Kort formulert, var målet for AL:PE 1 å studere avsidesliggende høyfjellsjøers økosystem og deres respons på sur nedbør. I AL:PE 2 var målet og arbeidsområdet utvidet til også å omfatte studier av respons, spredning og effekter av potensielt toksiske komponenter som tungmetaller og organiske mikroforurensninger, slik at prosjektet totalt omfatter studier av forsuringskomponenter og et bredt spekter av langtransporterte luftforurensninger. Utfra de data vi registrerte, ønsket vi også å lokalisere de minst forurensede områdene i Europa for å identifisere referanseområder for fremtidige studier av klimaendringer.

I originalprosjektet er målene formulert som følger:

The main project aims for AL:PE 1 are :

- *to establish an understanding of the ecosystems of high mountain lakes*
- *to use a relevant subgroup of these lakes as early response indicators of increasing or decreasing atmospheric pollution.*

The main project aims for AL:PE 2 are:

- *continue AL:PE 1 to understand the ecosystems of remote mountain lakes and the response of these lakes to varying levels of acid deposition.*
- *enlarge the project from assessing acidity to assessing a wider range of long range transported air pollution components (including total phosphorus, persistent organics and trace metals).*
- *identify unpolluted remote lakes within Europe that can be used as reference sites for studies of climatic change.*

Additional objectives are to:

- *establish links between existing lake chemistry databases in EC countries, Austria, Switzerland, the Czech and Slovak Republic, Poland and Norway.*
- *identify critical S and N loads and recommend target loads for remote mountain areas.*
- *use biological data to establish guidelines for good monitoring and guidance practices.*
- *develop and refine statistical methods for analysing biological data in relation to environmental data to provide a basis for predicting future biological responses to modelled chemical changes.*
- *establish baseline conditions for the long term evaluation of climatic change and its effects.*
- *establish links with other scientists in this field in the world, especially the developing world, aiming at future co-operation and exchange of knowledge.*

Prosjektet har arbeidet med analyser innen kjemi, biologi og palaeolimnologi, og ble bygget opp rundt 6 fagområder som omfatter innsjøsedimenter og diatomeer, fisk, bunndyr, zooplankton, vannkjemi og statistisk analyse og modellering. Hvert av fagområdene har sin ansvarlige koordinator. De 6 fagansvarlige koordinatorene danner en styringskomite for prosjektet, og er ansvarlige også for kvalitetskontroll og nødvendig interkalibrering mellom deltakerne. Administrativ koordinator for prosjektet er University College London, Environmental Change Research Centre (UCL-ECRC), UK, mens faglig ansvar ligger hos NIVA som vitenskapelig koordinator. En oversikt over organisering og ansvar er vist nedenfor:

Administrative Programme Centre:	UCL-ECRC/ Simon T. Patrick and Richard W. Battarbee
Scientific Programme Centre:	NIVA/ Bente M. Wathne and Merete Johannessen
<u>Subject area</u>	<u>Co-ordinated by</u>
- Lake sediments and diatoms	UCL-ECRC/ Nigel Cameron and Richard W. Battarbee
- Fish	NIVA / Bjørn Olav Rosseland
- Invertebrates	UIB-ZM/ Gunnar Raddum
- Zooplankton	CU-DH/ Jan Fott
- Water Chemistry	CNR-III and NIVA/ Rosario Mosello and Bente M. Wathne
-Statistical analysis and modelling	UIB-BI/ John Birks

2.1 Konkrete målsetninger for arbeidet ved NIVA 1995

AL:PE 2 prosjektet har en hovedmålsetning som har vært styrende for detaljplanlegning og gjennomføring av arbeidet siden prosjektet startet i januar 1993. I tråd med hovedmålsetningen ble det satt opp konkrete målsetninger for det prosjektarbeidet som skulle gjennomføres siste halvår av prosjektets levetid, første halvår 1995. Følgende delmål ble formulert:

- Koordinere avslutningen av det vannkjemiske programmet for hele AL:PE 2 prosjektet
- Rapportere resultater for det vannkjemiske arbeidet i alle deltakerland
- Koordinere avslutningen av fiskeprogrammet for hele AL:PE 2 prosjektet
- Rapportere resultater fra fiskeprogrammet fra alle deltakerland
- Koordinere arbeidet med sluttrapporten for hele AL:PE 2 prosjektet

Prosjektstøtten fra TVLF har vært et viktig bidrag til dette arbeidet.

3. Lokaliteter og arbeidsprogram

Alpine eller arktiske innsjøer finner vi i flere steder i Europa, fra Svalbard og norske høyfjell i nordområdene gjennom Alpene og Pyreneene til fjellområder i Spania og Portugal i sør, fra

Irland og de Skotske Cairngorms i vest til det Russiske Kola, Slovenia og Tatrafjellene i øst. Disse områdene mottar forskjellige mengder av langtransportert luftforurensning, som vi må anta har påvirket dem i varierende grad. I AL:PE 1 ble innsjøer valgt på bakgrunn av følgende kriterier:

- Innsjøene skal ligge over eller nord for tregrensen, slik at skog og skogsdrift ikke påvirker miljøet og vannkvaliteten.

- Nedbørfeltet skal være så upåvirket av menneskelig aktivitet som mulig, slik at endringer i vannkvaliteten bare skyldes lufttransportert forurensning, naturen selv eller klimavariasjoner

- Innsjøene skal være følsomme for forsuring, med lav konsentrasjon av basekationer og en kalsiumkonsentrasjon fortrinnsvis lavere enn 50 µekv/l, og alltid lavere enn 100 µekv/l.

I AL:PE 2 programmet ble kravet til forsuringsfølsomhet lempet litt på for å kunne innlemme noen områder med en geologi som gir høyere konsentrasjoner av basekationer, men som ellers er av stor interesse på grunn av uberørthet (Slovenia og Sør-Spania). Innsjøene er vist på kartet i figur 1.

Lokalitetene som er undersøkt ligger i områder i Norge (inkludert Svalbard), Storbritannia (Skottland), Irland, Italia, Frankrike, Spania, Portugal, Østerrike, Den Tsjekkiske Republikk, Slovakia, Slovenia, Russland (Kola) og Polen. Referanseinnsjø for hele AL:PE prosjektet er Øvre Neådalsvatn som ligger i nærheten av Kårvatn, bakgrunnsstasjon for det norske overvåkingsprogrammet for langtransporterte forurensninger. Øvre Neådalsvatn er meget følsom for forsuring, og ligger i et av Europas reneste områder. Områdene som ble inkludert i AL:PE 2 er områder beliggende på/i Svalbard, Portugal, Spania og Irland med lite langtransportert forurensing, og områder med større forurensningsbelastning som innsjøer i Østerrike og Tatrafjellene. Også en innsjø med spesielt høy kalsiumkonsentrasjon i en nasjonalpark i Slovenia er tatt med.

Innsjøene er undersøkt med et omfattende program innen de forskjellige fagområdene:

Vannkjemi:	analyser av hovedioner (pH, konduktivitet, Ca^2, Mg^+, Na^+, K^+, Cl^-, SO_4^{2-},NO_3-N, F, alkalinitet, TOC, RAL, ILAL, Tot P) og tungmetaller (Pb, Hg, Cd)sammen med tålegrenser og overskridelser av tålegrenser.
Invertebrater:	analyser av bunndyr, zooplankton, diatomeer
Fisk:	analyser av fiskebestand, tungmetaller (Pb, Hg, Cd) i kjøtt og lever og organiske mikroforurensninger (PAH, PCB) i kjøtt og fettvev
Sedimenter:	analyser av diatomeer med rekonstruksjon av pH, chironomider, cladocera,organiske mikroforurensninger (PAH, PCB), tungmetaller (Pb, Hg, Cd) og karbonpartikler

Så langt mulig er analysene utført av de lokale laboratorier, og ansvaret for interkalibrering, kvalitetskontroll og harmonisering av metoder ligger hos de ansvarlige for hvert fagområde. Alle resultater er etterhvert overført til botanisk institutt ved UiB hvor de bearbeides ved hjelp av statistisk analyse og empirisk modellering.

Figure 1. The AL:PE 2 sites.

LOCATION OF AL:PE 2 SITES

1.	ØVRE NEÅDALSVATN	11.	SCHWARTZSEE OB SÖLDEN
2	STAVSVATN	12.1	LAGO AGUILO
3.	LILLE HOVVATN	12.2	LAGO REDO
4.1	LOCHNAGAR	13.	LA CALDERA
4.2	SANDY LOCH	14.	LAGOA ESCURA
4.3.	LOCH NAN EUN	15.1	STAROLESNIANSKE PLESO
5.1.	LAGO PAIONE SUPERIORE	15.2	TERIANSKE PLESO
5.2.	LAGO PAIONE INFERIORE	15.3	DLUGI STAW
6.1.	LAGO LUNGO	15.4	ZIELONY STAW
6.2	LAGO DI LATTE	16.	LAGUNA CIMERA
7.3	LAC BLANC	17.	CHUNA
7.4.	LAC NOIR	18.	CHIBINI
8.	ÉTANG d'AUBÉ	19.	ZGORNJE KRISKO JEZERO
9.	ARRESJØEN		
10.	LOUGH MAAM		

4. Resultater og konklusjon

4.1 Sammendrag fra hovedprosjektet

Når sjøene blir sammenlignet viser det seg at de har en rekke likhetstrekk på alle fagområdene hvor vi arbeider. Det gjelder vannkjemi, palaeolimnologi, invertebrater og fisk. Vi kan derfor forvente en lik respons fra de biologiske samfunn på det fysisk-kjemiske miljøet i disse områdene. Kvalitetskontroll og standardiserte arbeidsmetoder bidrar til å sikre at resultatene er sammenlignbare og av høy kvalitet. En punktvis oppsummering av resultatene gir:

- Følsomme områder med høy deposisjon av svovel er forsuret, og en forurensningsgradient fra Nord- og Vest- mot Sentral- og Øst-Europa registreres. Deposisjon av sure komponenter, karbonpartikler (produkter fra fossilt brennstoff), tungmetaller og organiske mikroforurensninger er høyest i sentrale deler av Europa, som Tatrafjellene og Alpene. I Tatrafjellene ser vi også de største overskridelsene av tålegrenser for forsuring. Mer perifere områder, som Svalbard, det norske Nordvestlandet, den Iberiske halvøy, og vestlige Irland er langt mindre påvirket.

- Kontaminering med karbonpartikler, tungmetaller og organiske mikroforurensninger viser samme forurensningsmønster som vannforsuring, og selv i de mest avsides og reneste områdene er det mulig å påvise kontaminering fra langtransportert forurensning.

- Disse minst påvirkede områdene viser foreløpig ubetydelige biologiske endringer, og er derfor godt egnet som referanser for studier av forurensning og klimavariasjoner.

- Det ble også funnet økende relativ betydning av nitrogen i forhold til svovel som forsuringskomponent inn mot sentrale deler av Europa. Ultraoligotrofe vannsystemer reagerer raskt på små endringer i næringstilførsel (nitrat), og oppnår økt trofigrad (basert på analyser av klorofyll, ephippier og fjærmygg) etter begynnende forsuring.

- Det er påvist stor variasjon i invertebratsamfunnet avhengig av surhetstilstand.

- Resultater fra Svalbard og Portugal viser forhøyede konsentrasjoner av Hg både i vann og fisk som gir grunn til videre oppfølging.

- Konsentrasjonen av organiske mikroforurensninger i fisk følger konsentrasjonen i sedimentene. Konsentrasjonen av noen forbindelser, særlig plantevernmiddelet HCB (heksaklorbenzen), viser i likhet med Hg høye verdier på Svalbard.

- Prosjektgruppen bak AL:PE representere i dag et aktivt konsortium av forskere i Europa og har til rådighet en stadig voksende miljødatabase av høy kvalitet. Dette gir grunnlag for videre forskning og kan benyttes som basis for studier av fremtidige miljøendringer.

AL:PE har allerede dannet grunnlag for et nytt EU-støttet forskningsprosjekt kalt MOLAR. Kontrakten med EU er undertegnet av samarbeidspartnere, og den offisiell startdato er 1. mars 1996. Prosjektet vil gå over tre år og omfatter tre delprosjekter med arbeidsområder innen forsuring, forurensningsflux og klimavariasjoner i alpine eller arktiske sjøer.

Det arbeidet som er utført i prosjektet er av stor betydning i seg selv, men sikrer og viderefører også Norges posisjon som ledende i internasjonal miljøforskning. Arbeidet innen prosjektet er utført etter samme metoder i alle deltakerlandene og etter en standard vi mener er forsvarlig. Utveksling av erfaring over landegrensene er også nødvendig for en god faglig utvikling for de norske deltakerne innen alle arbeidsområdene for prosjektet. Standardisering av arbeidsmetoder og interkalibrering styrt gjennom prosjektet vil også gi bedre muligheter for etablering av enhetlige metoder og sammenligning av resultater på et europeisk nivå.

4.2 Resultater og konklusjon for arbeidet ved NIVA i 1995

De spesifiserte målene for AL:PE 2 arbeidet ved NIVA (se pkt. 1.1) i 1995, og som det her skal sluttrapporteres for, omfatter arbeidet med å koordinere og rapportere avslutningen av det vannkjemiske programmet og fiskeprogrammet for hele AL:PE 2 prosjektet. I tillegg å koordinere arbeidet med sluttrapporten for hele AL:PE 2.

Den første utgaven av sluttrapporten ble godkjent av EU i juli 1995, og den endelige utgaven av rapporten er snart ferdig bearbeidet. De to delrapportene for vannkjemi og fisk er vist i vedlegg B og C til denne rapporten. Arbeidet slik det ble avtalt for prosjektet er derfor gjennomført etter planen.

Vedlegg A. Litteraturliste for AL:PE prosjektet

Publications and reports from the AL:PE project

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Vedlegg B. Water chemistry and Critical loads calculations for the AL:PE 2 lakes

AL:PE 2 - Acidification of Mountain Lakes: Palaeolimnology and Ecology. Remote Mountain Lakes as Indicators of Air Pollution and Climate Change

AL:PE 2 report for the period January 1993-June 1995.

Water chemistry and Critical loads calculations for the AL:PE 2 lakes

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2.1. Introduction - Water sampling and analysis

Water chemistry from earlier sampling was one of the criteria for the first selection of the remote mountain lakes for the AL:PE 1 project. There were also a criterion set with regard to acid sensitivity, and to fulfil that criterion, sites with lakewater calcium of 50 µeq/l (1 mg/l) or less, were required. For AL:PE 2 this criterion was somewhat modified, due to a wish of working sites with a broader biological spectrum combined with the wish to identify unpolluted sites in Europe suited for studies of climate change. The selection of lakes took place after careful consideration of all known information about them. A detailed description of each of the sites is given in Appendix 1.

Sampling and analysis for water chemistry was also required in the monitoring programme of the lakes, and planning of the field work was done at an early stage each year before the sampling season. The purpose of the joint planning was to combine the water chemistry sampling programme with the other sampling programmes of AL:PE in an optimal way, and to assure the comparability of chemical data obtained from the different laboratories.

2.2. Methods

2.2.1 Analytical methods

Water sampling followed the protocol agreed under the AL:PE 1 project (Wathne *et al.* 1995). The samples were taken from the outlet of the lake, and one water sample was taken at the same time as the samples for benthic invertebrates were collected. The minimum number of samples required was one yearly sample in the late autumn (at the turnover time for the lake), taken as a representative annual mean sample for the physical-chemical parameters in the lake (Henriksen *et al.* 1988). Most of the lakes were sampled more frequently than the minimum.

The samples were analysed by standard procedures for analysis of low ionic strength waters. The analytical programme includes the following components: pH, conductivity, calcium (Ca^{2+}), magnesium (Mg^{+}), sodium (Na^{+}), potassium (K^{+}), chloride (Cl^{-}), sulphate (SO_4^{2-}), nitrate (NO_3-N), fluoride (F), alkalinity, total organic carbon (TOC), reactive aluminium (RAL) and non-labile aluminium (ILAL), all the same as for ALPE 1. In addition, and new for AL:PE 2, was analysis of total phosphorus (Tot P) and the trace metals lead (Pb), mercury (Hg), and cadmium (Cd). The trace metals are the same as analysed for fish.

The analytical work for the most of the components was done at national laboratories in co-operation with the chemical centres in Italy (CNR-III) and Norway (NIVA), but one autumn sample was sent to NIVA for analysis of Al-speciation, Hg, Cd and Pb from all sites. The sample bottles were mailed from NIVA to the different participants on agreed and due time before the autumn sampling. The following bottles were sent:

- For Hg	250 ml glass bottle specially washed, preserving agent added (NaCl)
- For Cd + Pb	60 ml plastic bottle specially washed for heavy metal analysis
- For RAL, ILAL	500 ml plastic bottle specially washed samples of very low total ionic strength

The procedure was adopted to secure that all results of these low metal concentrations should be comparable.

Table 2.1. Major analytical methods used in Italy and Norway.

	Italy	Norway
pH, electrometry	X	X
Conductivity, electrometry	X	X
Alkalinity, electrometry	X	X
Gran. titration		
Nitrate, ion chromatography	X	
photom. autoanalyser		X
Ammonium, photom. autoanal.	X	X
Total nitrogen, photom. autoanal.	X	X
Chloride, ion chromatography	X	X
photom. autoanalyse		
Sulphate, ion chromatography	X	X
autoanalyser		
Calcium, ICP-OES		X
ion chromatography	X	
Magnesium, ICP-OES		X
ion chromatography	X	
Sodium, ICP-OES		
atomic emiss. spectr.		X
ion chromatography	X	
Potassium, FAAS		X
ICP-OES		
ion chromatography	X	
Fluoride, ion selec. electrode		X
Aluminium, GFAAS	X	X
Aluminium speciation		X
Total/Dissolved organic carbon		
$Na_2S_2O_8$/UV oxidation		X
Total phosphorus, UV/$Na_2S_2O_8$ digestion and photom. autoanal.	X	X
Lead, GFAAS		X
Cadmium, GFAAS		X
Mercury, Cold vapour AAS		X

The analytical methods used in co-ordinating countries for chemistry, Norway and Italy, are summarised in Table 2.1

All the analytical results have been processed using databases in Italy and Norway.

2.2.2 Analytical quality control

The analytical quality and the comparability of the chemical results obtained by the laboratories involved in the research were tested by yearly intercomparison exercises, carried out in 1991 and 1992 for AL:PE 1 and followed in 1993 and 1994 for AL:PE 2. The quality control programme of two exercises in AL:PE 1 and two exercises in AL:PE 2, was carried out by the CNR Istituto Italiano di Idrobiologia, Pallanza, Italy (CNR-III), and the Environment Institute of the European Joint Research Center, Ispra, Italy. The results are described in more details in Appendix 3 by Mosello, Marchetto, Muntau and Serrini.

Also NIVA has been running annual laboratory intercalibration exercises, in the framework of the International Cooperative Programme on Assessment and Monitoring of Rivers and Lakes (ICP Waters) under the UN Convention on Long-Range Transboundary Air Pollution. This has become a routine control of normal laboratory practice in the participating laboratories. The Youden method (two sample approach) is used to assess laboratory performance. Annual reports show how target accuracies are met for most ions in natural waters (Hovind, 1991 1992, 1993, 1994). The following analytical variables have been tested in the last four exercises:

9105 - pH, conductivity, alkalinity, nitrate + nitrite, chloride, sulphate, calcium, magnesium, sodium, potassium, and total organic carbon
9206 - pH, conductivity, alkalinity, nitrate + nitrite, chloride, sulphate, calcium, magnesium, sodium, potassium, aluminium, and dissolved organic carbon
9307 - pH, conductivity, alkalinity, nitrate + nitrite, chloride, sulphate, calcium, magnesium, sodium, potassium, total aluminium, reactive and non-labile aluminium, dissolved organic carbon, and chemical oxygen demand
9408 - pH, conductivity, alkalinity, nitrate + nitrite, chloride, sulphate, calcium, magnesium, sodium, potassium, total aluminium, dissolved organic carbon, and chemical oxygen demand

The participant AL:PE laboratories in the exercises carried out by the CNR-III and the Environment Institute of the European Joint Research Center, and /or NIVA were:

Norwegian Institute for Water Research, Oslo, (NO)
Laboratorio Biologico Provinciale, Laives, (IT)
CNR Istituto Italiano di Idrobiologia, Pallanza, (IT)
Freshwater Fisheries Laboratory, Faskally, Scotland (GB)
Department of Hydrobiology, Charles University, Praha (CS)
Czech Geological Survey, Praha (CS)
Hydrobiological Institute, Academy Sciences, Ceské Budéjovice (CS)
Institute of Zoology, University of Innsbruck (A)
Department of Ecology, University of Barcelona (ES)
Department of Ecology, Universidad Autonoma Madrid (ES)
Instituto del Agua, University of Granada (ES)
Institute of Biology, Department of Freshwater Ecology, Ljubljana (SLO)
Institute of Ecology Problems, Kola Science Centre, Apatity (SU)
Institute of Ecology Industrial Areas, Katowice (PL)
Centro Ciencias Medioambientales, Madrid (ES)
Centre National de la Recherche Scientifique, Arcachon (FR)

2.2.3 Validation of results

Data validation was given special interest. Confidence in comparability between sites and countries was a basis for our work, and all participants needed to feel secure about the data presented, and relay completely on the reported results from others. In addition to the subjective check of the results thorugh looking for outliers and continuity where there are time series, the control was performed according to the following:

1. ionic balance
2. comparison between measured and calculated conducitvity

In particular the ionic balance is performed by a data programme made in two versions, the first including all ions, the second also including Al, NH_4 and TOC. The first set of equations are the following:

Sum anions : SAN = ECl + ENO_3 + ESO_4 + ALK-E

Sum cations : SKAT = ECa + EMg + ENa + EK + EH+

Difference cations/anions : DIFF = SKAT - SAN

Difference in % : D-PRO = DIFF*100/SKAT

E combined with the chemical component means that the component is given on an equivalent basis. For samples where analysis of Al, NH_4 and TOC are present, the second set of equations is used:

Sum anions : SAN2 = SAN + AN-

Sum cations : SKAT 2 = SKAT2 + ELAL + ENH_4

Difference cations/anions : DIFF2 = SKAT2 - SAN2

Difference in % : D-PRO2 = DIFF2*100/SKAT2

AN- is calculated from the TOC value taking into account week organic acids. The equation used is:

AN- = 4.7 - 6.87 * exp(-.332* TOC)

The equation is based on empirical data from Norwegian sites. Tests have shown good agreement with analytical results. Other equations (Oliver *et al.* 1983) taking into consideration the pH-dependent dissociation of organic matter might also be used with minor differences.

In order to check the ionic balance, all of the necessary variables for calculating the sums of cations and anions must be analysed. For good analytical results, the difference in % between sum cations and anions should be <= 10%. To present the results from the ionic balance cheque in a clearly set out way, the sum of anions and cations are plotted against each other. For a perfect balance all results should be placed along the 1:1 line.

A further check of the ionic balance is made by comparing the measured conductivity to the conductivity calculated from the measured ions. Also a check of non marine Na (Na*) may indicate possible problems in Cl-analysis.

2.2.4 Calculating method for critical load of acidity to surface waters

Critical loads are used to express how much loading of a given pollutant natural environments can stand without being significantly harmed or changed.

Critical loads of airborne sulphur and nitrogen are a function of the amount of strong acid loading that result in changes of the chemical conditions of surface waters. These chemical changes may cause damage to biological indicators like freshwater fish and invertebrates. The chemical changes of surface waters are described as ANC (Acid Neutralising Capacity). ANC is used here as the difference in the sum of concentrations of base cations (calcium, magnesium, sodium and potassium) and the sum of anions of strong acids (sulphate, nitrate and chloride). Empirical links have been worked out between ANC and biological indicators. The critical value for biological damage is termed ANC_{limit}, and for freshwater organisms in Scandinavia the ANC_{limit} is set to 20 µeq/l (Lien *et al.* 1996).

Critical load (CL) and exceedance of critical load for sulphur (CL_{exS}), and sulphur plus nitrogen (CL_{exS+N}) are calculated according to the formulas:

$$CL = ([BC]^*_0 - [ANC_{limit}])\,Q - BC^*_d$$

$$CL_{exS} = SO_4{}^*_d - BC^*_d - CL$$

$$CL_{exS+N} = SO_4{}^*_d + NO_{3\,le} - BC^*_d - CL$$

$[BC]^*_0$ is the pre-acidification concentration of non - marine base cations in the surface water.
ANC_{limit} is the critical biological value (limit) for acid neutralising capacity of the water. 20 µeq/l is an acceptable ANC_{limit} for fish and invertebrates.
Q is the run-off from the catchment.
BC^*_d is the annual non - marine deposition of base cations.
$SO_4{}^*_d$ is the annual non - marine deposition of sulphate in the catchment.
$NO_{3\,le}$ is the annual leaching of nitrate from the catchment into the surface water.

For the AL:PE lakes critical load was estimated using an ANC_{limit} = 20 µeq/l. The deposition of base cations (BC^*_d) was set to 30 keq/km^2/year. The exceedance of critical loads was calculated for sulphur separately (CL_{exS}) and for sulphur plus nitrate together (CL_{exS+N}). Deposition of sulphur was used according to informations given from each AL:PE sites. Where no information was available, data from EMEP (Co-operative Programme for Monitoring and Evaluation of the Long Range Transmission of Air Pollutants in Europe) was used.

2.3. Results

All the analytical results for the water samples taken within the AL:PE 2 project (during 1993 and 1994) are listed in Appendix 2. In table 2.2 mean values for each of the lakes are listed and grouped together after regions. In the following part of the report the water chemistry results are described in more detail for each of the lakes, again grouped after regions in Europe.

Svalbard

Arresjøen (9)

Arresjøen at Svalbard (Spitsbergen), is new in AL:PE 2. Arresjøen is situated beyond the timberline (79^o 40' N, 10^o 45'E), and is the northernmost site in the project. This arctic area has an extremely sensitive environment, and was especially chosen with the intention to prepare for studies of possible climate change. The calcium concentrations is low (Ca^{2+} 35 μeq/l), with seasalt ions being the main ions in the lake water, as the lake is situated close to the sea. In 1993 the mean pH of two samples was 5.81. SO_4^{2-} (32 μeq/l) and NO_3-N (close to 0) concentrations are low, and on the same level as for the AL:PE reference lake Øvre Neådalsvatn. Hg concentrations are elevated, again compared to the reference lake. Due to extraordinary weather conditions the sampling trip to Arresjøen, was impossible to carry through in the short ice free periode 1994, and the water chemistry results unfortunately are non-existing.

Kola, Russia

Chuna (17)

Chuna has pH values between 6.2 and 6.7 for 1993 and 1994, and the Ca^{2+} concentration is low (60 - 61 μeq/l). The geology of the Chuna tundra is gabbro with very low content of alkaline elements and not easily mobilised Ca^{2+} and Mg^{+}, resulting in low buffering capacity. Ni (< 1 μg/l) and SO_4^{2-} (42 - 47 μeq/l) concentrations reflect the negligible local effect to the atmospheric pollution of the local smelter. NO_3-N concentrations are fairly low (4 - 12 μeq/l). A small elevation of Hg, Pb, and Cd compared to the reference lake concentrations is found.

Chibini (18)

In Chibiny there are alkaline granites characterised by Na, K and Al geochemical association that favours reasonably quick neutralisation of acid precipitation. Chibini has followlingly a higher buffer capacity than Chuna, and pH values of 7.1 - 7.4. SO_4^{2-} concentrations are 55 - 58 μeq/l and representative for the area (Moiseenko, 1991, Moiseenko et al. 1994, 1995). NO_3-N concentrations are on the same level as central Europe (9 - 17 μeq/l).

Region summary - Kola

The results show that despite being close to the Severonickel smelter, local emissions affect only slightly the high mountain sites in Kola. Heavily polluted air masses do not raise high enough in the atmosphere to affect these lakes in the same way as registered for the lakes situated less than 200 m a.s.l. (Moiseenko, 1991). The water quality of the lakes are consistent with the average value for the region (SO_4^{2-} < 80 μeq/l). Thus the Chuna and Chibini reflects a real situation representative for airborne emissions for the whole Kola region which show higher concentrations of air-borne pollutants than the reference site. The acid sensitive Chuna mountains show sings of proceeding lake acidification. In Chibini the good buffer capacity protects the area against acidification (Moiseenko, 1994).

Norway

Øvre Neådalsvatn (1)

Øvre Neådalsvatn, situated in the part of Norway least affected by long-range transported air pollution, is chosen as the reference lake for the AL:PE project. Øvre Neådalsvatn is a large lake, with an area of 50 ha, lying above the tree line and remote from human activity. The underlying geology is of gneiss and the lakewater has a low Ca^{2+} concentration (Ca^{2+} 8-57 µeq/l). The area is naturally pristine, with little influence of acid rain and long-range transported air pollution. It fulfils the strongest AL:PE acid sensitivity criteria (criteria from AL:PE 1, see chapter 2.1), and is susceptible to acid deposition. The impression of a pristine and sensitive area is also reflected in the water chemistry, characterised by extremely low ionic strength. The main ions in the water are the seasalt ions, and all measured pH values lie between 5.9 and 6.45. Due to an other project in the same area, Øvre Neådalsvatn was sampled regularly through 1993 (n=10) and 1994 (n=28) for most of the parameters of interest also for this project. The mean pH for the 1993 samples was 6.16, and for 1994 the mean pH was 6.17. SO_4^{2-} and NO_3-N values are low. Mean values for 1993 and 1994 are 14 µeq/l and 18 µeq/l for SO_4^{2-} and ~1 µeq/l (10 - 21µg/l) for NO_3-N respectively. Background SO_4^{2-} values are estimated to 14 µeq/l (Henriksen *et al.*, 1988), while background nitrate should be close to 0 or 5 µeq/l as a maximum (Grennfelt & Thörnelöf, 1992). So the measured values confirms our reference site as pristine. In the area surrounding Øvre Nådalvatn is also a background station for the Norwegian Montoring Programme for Long-Range Transported Air Pollution (SFT 1994). Acid episodes in this area have been reported due to the influence of seasalts (SFT 1990).

Stavsvatn (2)

The second Norwegian site, Stavsvatn, is a large lake with an area of 40 ha, lying just above the tree line and with little human disturbance in the catchment. The underlying geology is of granite and the lakewater has a low Ca^{2+} concentration (40-50 µeq/l). Stavsvatn fulfils the strongest sensitivity AL:PE project criteria for a main site, and is susceptible to acid deposition. The lake is affected by acid rain, and the influence of acid deposition is seen from the relatively high contribution of SO_4^{2-} (concentrations of 37 and 33 µeq/l for 1993 and 1994) to the total amount of ions in the water samples. NO_3-N concentrations are ~3 µeq/l. The pH values for 1993 and 1994 respectively was 5.94 and 6.00.

Lille Hovvatn (3)

The third and southernmost Norwegian site, Lille Hovvatn, is an additional site and has a reduced total investigation programme. The lake is situated just below the tree line, and open forest of spruce, pine and birch is interspersed with peaty areas in the catchment. The granitic geology results in low lakewater Ca^{2+} (17-26 µeq/l). The water chemistry for Lille Hovvatn shows that the lake is strongly acidified, with all measured pH values for the years 1993 and 1994 below 5. The mean pH for 1993 and 1994 respectively, was 4.65 and 4.69. SO_4^{2-} makes a large contribution to the total amount of major ions. (SO_4^{*2-} concentrations of 58 µeq/l and 64 µeq/l for 1993 and 1994). Nitrate concentrations are high to be a Norwegian site, but not high compared to central Europe (NO_3-N concentrations of 11 µeq/l and 12 µeq/l for 1993 and 1994). The short distance to the sea is reflected in the seasalt concentrations, which also have a large contribution to the major ion total. Heavy metal analysis show an elevated Pb value compared to the reference site.

Region summary - Norway

In Norway the three sites studied in the AL:PE 2 project, are to a different extent affected by long-range transported air pollution and acid deposition. The northernmost, Øvre Neådalsvatn serves as a reference lake for the whole AL:PE study, is naturally pristine and acid sensitive. The water chemistry is characterised by extremely low ionic strength. Moving along the "pollution gradient", the next Norwegian lake Stavsvatn, is also sensitive and susceptible to acid deposition. This lake is affected by long-range transported air pollution, and the influence of acid deposition is seen from the relatively high contribution of SO_4^{2-}. The southernmost Norwegian lake Lille Hovvatn is an additional site in the AL:PE programme and is strongly acidified. Buffering capacity in the area is low, and all measured pH values for the years 1993 and 1994 are below 5. Both SO_4^{2-} and NO_3-N concentrations are higher than the values measured in Stavsvatn. Also the measured Pb concentration is elevated compared to the reference site.

British Isles

Lochnagar (4.1)

Three of the AL:PE lakes in the United Kingdom are located within a small area in Aberdeenshire, N. E. Scotland. The primary site in the area is Lochnagar, a corrie lake lying above the tree line, having a small catchment with minimal anthropogenic disturbance. The granitic geology and resulting low lakewater Ca^{2+} concentration (Ca^{2+} 25-48 μeq/l) indicate that this lake is susceptible to acid deposition, a sensitive site fulfilling the strongest AL:PE project sensitivity criteria. Mean pH values for 1993 and 1994 respectively was 5.32 and 5.25. Due to the relatively short distance to the sea, the seasalts are dominant ions, but there is a marked contribution from SO_4^{2-} (mean values for 1993 and 1994 are 58 μeq/l and 57 μeq/l). NO_3-N concentrations are 18 μeq/l and 22 μeq/l as mean values for 1993 and 1994. Heavy metal analysis show an especially high Pb value, but also Cd is high compared to the reference site.

Sandy Loch (4.2)

Sandy Loch is one of the two additional lakes in the same region as Lochnagar. It is also a corrie lake lying above the tree line. The granitic geology and resulting low lakewater Ca^{2+} concentration (Ca^{2+} 30-51 μeq/l) indicate that this lake is susceptible to acid deposition, a sensitive site fulfilling the strongest AL:PE project sensitivity criteria. Mean pH value for 1993 was 6.09 and in 1994 the registered value was 5.05. Seasalts and SO_4 (54 μeq/l and 53 μeq/l as mean values for 1993 and 1994) are dominant ions. NO_3-N concentration is 8 μeq/l as mean value both for 1993 and 1994. The sample analysed for heavy metals show a concentration of Hg higher than the at the reference site.

Loch Nan Eun (4.2)

The third lake in the Lochnagar region is Loch Nan Eun. This lake, lies above the tree line, is susceptible to acid deposition and has low Ca^{2+} values (20 μeq/l). Loch Nan Eun is acidified, and all pH values were below 5.5. Mean pH value for the 1993 samples was 5.40, and the 1994 value was 5.05. Seasalts and SO_4^{2-} (48 μeq/l and 49 μeq/l as mean values for 1993 and 1994) were dominant ions. NO_3-N concentrations are 9 μeq/l and 19 μeq/l as mean values for 1993 and 1994. Both Pb and Cd show elevated values compared to the reference lake values.

Lough Maam (10)

Lough Maam is situated in Donegal, north-west Ireland at an altitude of 436 m. The catchment is granite and is mainly covered by blanket peat. Like the Svalbard site, Lough Maam was especially chosen bearing in mind the future studies of possible climate change. The lake is acidified, with mean pH value for 1993 of 4.96. Also here the seasalt are dominating ions due to the short distance to the sea. Marine influence is also seen on the sulphate concentrations. The SO_4^{2-} concentration is 61 μeq/l, but the seasalt corrected sulphate (SO_4^{*2-}) concentration of 20 μeq/l is low, and of the same magnitude as in the reference site. The water chemistry results for 1994 from Lough Maam unfortunately was lost due to EDB problems at the local laboratory where some data were destroyed. The sample analysed for Hg show a small elevation compared to the reference site.

Region summary - British Isles

The AL:PE lakes in Scotland, situated in the same watershed, are all sensitive to acidification with water of low buffering capacity. In all three lakes there is a marked contribution from SO_4^{2-}, but also seasalt concentrations are high, as the distance to the sea is relatively short. The NO_3-N concentrations are on the medium level compared to central Europe. Heavy metal analysis show elevated values for Pb, Cd and Hg in the area compared to the reference site.

The site in north-west Ireland is also acidified, but here the SO_4^{*2-} (seasalt corrected SO_4^{2-}) is as low as for the reference site, and Na^+ and Cl^- are the dominating ions. The sample analysed for Hg show a small elevation compared to the reference site.

Iberia

La Caldera (13)

La Caldera in Sierra Nevada shows high values for Ca^{2+}, (and alkalinity) and pH. The lake has a high buffering capacity protecting against acidificaiton. Also total nitrogen (and the relation TN/TP) is high, but SO_4^{2-} is relatively low (19 µeq/l and 27 µeq/l as mean values for 1993 and 1994). The observed decrease of pH and nitrate along the ice-free period is a dominant (and persistent) feature of the lake (Carrillo, 1989) and the increase in the concentration for most of the other parameters, linked to the seasonal variation, are probably related to the total mineral concentration due to an extreme water volume reduction by infiltration processes. Pb and Cd values are elevated, and also a small elevation of Hg is registered when results are compared to the reference lake.

Lagoa Escura (14)

Lagoa Escura in Sierra de Estrela is an acidified lake (pH 5.3, alkalinity 16 µeq/l). The lake has a higher content of Mg^+ (18 µeq/l and 23 µeq/l) than Ca^{2+} (12µeq/l) and SO_4^{2-} (22 µeq/l and 14 µeq/l) when comparing mean values for 1993 and 1994. This suggests that the acidity can come from natural oxidation of minerals containing sulphides. Also the SO_4^{2-} concentration is of the same magnitude as for the reference site. The water chemistry results for Lagoa Escura in 1994 were consistent with data gathered in 1993, with only minor differences that can be attributed either to analytical accuracy or to a slightly low interannual variability. Lagoa Escura was at the border of acidification, showing null acid neutralising capacity and pH according to that value (pH 5.3-5.5). Nitrate concentration was below detection levels. Lagoa Escura was slightly more productive than the Pyreneen lakes, as was shown by its consistently higher total phosphorus value. Lower altitude and more frequented catchment are probably sufficient to explain this fact. Marine influence was highly apparent in L. Escura with Cl^- being 5-fold higher than in the Spanish Pyrenean lakes. According to those levels of Cl^-, it can be assumed that practically all Na^+ was from marine origin, and that catchment provided scarce concentrations of Ca^{2+}, Mg^+ and SO_4^{2-}, in proportions that did not lead to a positive alkalinity. Therefore, L. Escura, and lakes in Serra d'Estrela in general are highly sensitive to acidification. A slightly acid deposition can lead to a net acidification of their waters. The highest Hg value recorded in the project was found in Escura, when the heavy metal sample was analysed.

Laguna Cimera (16)

Laguna Cimera is situated in Central Spain, in Gredos Mountains, and was not originally in the AL:PE project. The results from this lake was brought into the project through cooperation, and financed through a Spanish national programme. The catchment is granitic and has rocks and debris with small alpine meadows. The water shows low buffering capacity with low Ca^{2+} concentrations (mean values for Ca^{2+} for 1993 and 1994 were 14 µeq/l and 9 µeq/l). Mean pH values for 1993 and 1994 were 5,97 and 5,69 respectively. SO_4^{2-} (11 μeq/l and- 17 μeq/l as mean values for 1993 and 1994) concentrations are very low and about the same as in the reference lake Øvre Neådalsvatn.

Region summary - Iberia

The three lakes scattered over the Iberia peninsula show some differences in their water chemistry, but seems generally less affected by long-range transported air pollution than central Europe. Both SO_4^{2-} and NO_3^- concentrations are low compared to more central mountain sites. La Caldera has high buffering capacity and are not expected to suffer from acidification problems. Laguna Cimera seems to be almost as unaffected and pristine as the reference lake with respect to pollution. Lagoa Escura is an acidified lake but the water chemistry suggests that the acidity can come from natural oxidation of minerals containing sulphides. With respect to heavy metals, La Caldera show elevated values for all three measured components, Pb, Cd, and Hg, and Escura show an especially high Hg concentration.

Pyrenees

Étang d'Aubé (8)

Étang d'Aubé is a corrie lake lying well above the tree line, and with minimal anthropogenic disturbance in the catchment. The granitic geology and resulting low lakewater Ca^{2+} concentration (24 - 32 μeq/l) would suggest that this lake is susceptible to acid depostion. The pH values for the yearly samples in 1993 and 1994 were 6.06 and 6.11 respectively. SO_4^{2-} concentrations are low, and almost at the same level as the reference lake Ø. Neådalsvatn. NO_3-N concentrations are more close to a medium range. (Values for 1993 and 1994 are 26 μeq/l and 17 μeq/l for SO_4^{2-} and 9 μeq/l and 16 μeq/l for NO_3-N.) The Hg value is elevated compared to the reference lake.

Lago Aguiló (12.1)

Aguiló is located in the Bassiers batholith in the Spanish Pyrenees. Aguiló is acid sensitive but not acidified (1993 and 1994 show pH 5.8 - 6.10, Ca^{2+} 22 μeq/l - 18 μeq/l and alkalinity 11 μeq/l - 18 μeq/l). The lake water concentrations are generally low for all compounds, as Cl^-, SO_4^{2-} and NO_3-N^- (SO_4^{2-} concentrations are 15 μeq/l and 13 μeq/l and NO_3-N 3 μeq/l and 2 μeq/l). Total phosphorus (TP) in Aguiló is 5 μg/l, and TOC is 0.59 mgC/l. The the acidity loading through deposition is higher in the Pyrenees than in Iberia, as reflected in the higher nitrogen content in those lakes. Higher nitrate levels in Pyrenean lakes may suggest an on-going acidification process that until now have been compensated by catchment and in-lake alkalinity production, and dust deposition. Its future evolution is difficult to foresee, and merits a more detailed study including direct deposition measurement and catchment and lake chemical modelling. The Hg value for Aguiló is elevated compared to the reference lake.

Estany Redó (12.2)

Redó has pH of 6.3 and 6.69 for 1993 and 1994 respectively. Redó is located on Maladeta batholith, which has a higher weathering rate and contains the largest number of lakes in the Pyrenees. SO_4^{2-} and NO_3-N concentrations are in the low to medium range.Yyearly mean values for 1993 and 1994 are 31 and 23 μeq/l for SO_4^{2-} and 14 and 11 μeq/l for NO_3-N. Total phosphorus (TP) is 9 μg/l, and TOC is 0.63 mg/l.

Region summary - Pyrenees

None of the Pyreneen lakes are acidified. On the Spanish side Lago Aguiló and Estany Redó show some differences in the chemical composition. In this sense, they are representative of the lakes of the two different granodiorite batholiths where they are located, as it was shown in a previous extensive study on the chemistry of the Pyrenean lakes. Maladeta batholith, where Redó is located and which contains the larger number of lakes in the Pyrenees, has a higher weathering rate than Bassiers batholith where Aguiló is located. Water in this latter lake is also more diluted, even in compounds not related with rock weathering, such as Cl^- and NO_3-N^-. Compared to Lagoa Escura in Sierra da Estrela, central Iberia, which was at the border of acidification, the differences are likely to result from weathering properties of the basin bedrock rather than from differences in the acidity loading through deposition. The latter seem to be higher in the Pyrenees as reflected in the higher nitrogen content in those lakes. Higher NO_3-N levels in Pyrenean lakes compared to the Iberian may suggest an on-going acidification process that until now have been compensated by catchment and in-lake alkalinity production, and dust deposition. Its future evolution is difficult to foresee, and merits a more detailed study including direct deposition measurement and catchment and lake chemical modelling. The Hg values both for Étang d'Aubé and Aguiló (French and Spanish side) is elevated compared to the reference lake.

Alps

Lago Paione Superiore (5.1)

Paione Superiore is a small lake (86 ha), lying above the tree line in the Western Italian Alps, with no human disturbance in the catchment. The underlying geology is of gneiss and the lakewater has a low Ca^{2+} concentration (36-51 μeq/l). The alkalinity is close to zero, and the lake has a mean 1993 and 1994 pH of 5.64 and 5.84 respectively. Paione Superiore fulfils the strongest AL:PE 1 project sensitivity criteria and is susceptible to acid deposition. The dominant anions are SO_4^{2-} and NO_3-N. (Mean values for 1993 and 1994 are 46 μeq/l and 36 μeq/l for SO_4^{2-} and 25 μeq/l and 21 μeq/l for NO_3-N.) The heavy metal analysis show elevated concentrations for Pb, Cd and Hg.

Lago Paione Inferiore (5.2)

Close to the Paione Superiore, in the same watershed, Paione Inferiore is situated at a lower altitude. The water chemistry shows relatively high Ca^{2+} values (67-88 μeq/l), higher than Paione Superiore, resulting in higher buffering capacity and resistance to acidification. This is also reflected in the higher pH values for Paione Inferiore, mean values for 1993 and 1994 were 6.43 and 6.53 respectively (alkalinity values of 25 - 27 μeq/l). The dominating anions are SO_4^{2-} and NO_3-N (mean values for 1993 and 1994 are 53 μeq/l and 49 μeq/l for SO_4^{2-} and 27 μeq/l and 26 μeq/l for NO_3-N.) Cd and Hg concentrations are elevated compared to the reference lake values.

Lago Lungo (6.1)

Lago Lungo is a medium sized lake (20 ha) in the group of AL:PE lakes with underlying geology of gneiss. It is located in the Eastern Italian Alps. The lakewater has a rather higher Ca^{2+} concentration (65 - 108 μeq/l) compared to the other AL:PE primary sites. The mean 1993 and 1994 pH values were 6.43 and 6.17 respectively (alkalinity values 27 - 30 μeq/l). The dominant anions in the lakewater were SO_4^{2-} and NO_3-N (mean values for 1993 and 1994 are 70 μeq/l and 60 μeq/l for SO_4^{2-} and 14 μeq/l and 16 μeq/l for NO_3-N). The chemistry of Lago Lungo indicates that the site has a some, but low buffering capacity giving resistance to acidification. Cd concentration is elevated compared to the reference lake.

Lago di Latte (6.2)

Lago di Latte (Milchsee) is a small corrie lake, lying above the tree line in the Eastern Italian Alps, with minimal human disturbance in the catchment. The underlying geology is of gneiss and the lakewater has a higher Ca^{2+} concentration (Ca^{2+} 92 - 108 μeq/l) than the main group of AL:PE 1 primary sites investigated. The 1993 and 1994 mean pH values were 6.60 - 6.35 (alkalinity values 51-53 μeq/l). Lago di Latte fulfils some AL:PE project criteria in that it is a remote and undisturbed site, however lakewater chemistry suggests that the site has some buffering capacity and would be unlikely to show the most marked response to acid deposition. (Mean values for 1993 and 1994 are 23 μeq/l and 22 μeq/l for SO_4^{2-} and 59 μeq/l and 56 μeq/l for NO_3-N.) Also for Lago di Latte was the Cd value elevated compared to the reference lake.

Lac Blanc (7.3)

Lac Blanc is a small lake situated above the tree line in the French Alps. The Ca^{2+} concentration of the lake is 75 - 150 µeq/l, indicating that the lake water has some buffering capacity and not likely to give the most marked response to acid deposition. Mean pH for 1993 was 6.88, and one sample from 1994 gave as result pH of 7.02. SO_4^{2-} and NO_3-N concentrations are in the medium range compared to the other AL:PE lakes (mean values for 1993 and 1994 are 15 µeq/l and 27 µeq/l for SO_4^{2-} and 10 µeq/l and 14 µeq/l for NO_3-N).

Lac Noir (7.4)

Lac Noir is a small lake situated above the tree line in the same area as Lac Blanc. Compared to the other AL:PE sites, the Ca^{2+} concentration of the lake is 125 - 170 µeq/l, indicating as for Lac Blanc, that the lake water has good buffering capacity. Mean pH for 1993 was 7.08, and one sample from 1994 gave as result pH of 7.09. (Mean values for 1993 and 1994 are 24 and 67 µeq/l for SO_4^{2-} and 9 µeq/l and 11 µeq/l for NO_3-N.) Tot P (31 µg/l) is high compared to the other AL:PE lakes, and also high compared to Lac Blanc (3 - 6 µg/l) in the same area. The Tot-P values are indicating some local influence. The Pb value is elevated compared to the reference lake.

Schwarzsee ob Sölden (11)

Schwarzsee ob Sölden (SOS), a new lake in AL:PE 2, is situated at 2799 m a.s.l. in the Austrian Oetztaler Alps, is a softwater lake with low alkalinity (<10 meq/l) in surface waters. However, it has considerable acid neutralising capacity in the hypolimnion which generally becomes anoxic during winter stratification. SOS is, according to our knowledge, the highest fish-bearing lake in the Alps with information on the fish status for several decades. The Ca^{2+} concentration is low (42 - 75 µeq/l), and mean pH values for 1993 and 1994 are 5.56 and 5.60 respectively. Water chemistry samples have been taken monthly for SOS. The SO_4^{2-} concentrations (mean values for 1993 and 1994 of 70 µeq/l and 86 µeq/l) are among the highest registered in the AL:PE project, and also the Hg concentration seem high (68 ng/l) compared to the reference lake.). NO_3-N concentrations are 13 µeq/l and 11 µeq/l as mean values for 1993 and 1994.

Zgornje Krisko Jezero (19)

Zgornje Krisko Jezero is situated in Triglav National Park in the Julian Alps (NW Slovenia) at an altitude of 2150 m a.s.l. In the AL:PE group this lake is special because it is situated in limestone deposits and therefore also has high Ca^{2+} values (660 - 744 µeq/l), and it was included into the AL:PE 2 project through the PECO programme as a reference lake for the study of effects of climate change. pH values are naturally high (7.66 - 7.86), and also SO_4^{2-} concentrations show high values (146 µeq/l and 100 µeq/l as mean values for 1993 and 1994). NO_3-N (8 µeq/l and 10 µeq/l as mean values for 1993 and 1994) concentrations are in the lower area compared to central Europe. A small elevation of Hg compared to the reference lake concentration is found.

Region summary - Alps

The Alps, being centrally placed in Europe, are markedly exposed to long-range transported air pollution, but differences are registered within the area. When comparing the lakes analysed in this project, the acid sensitivity is highest in the western Italian Alps and the Austrian lake Schwarzsee ob Sölden (SOS). SO_4^{2-} concentrations are highest in the eastern part of the Italian Alps together with Schwarzsee ob Sölden. The Slovenian site is rather special in the AL:PE group, because of the high Ca^{2+} and SO_4^{2-} concentrations due to the bedrock in the area. NO_3-N concentrations in the Italian Alps area are among the highest measured in the project, in fact the values measured in the western Italian Alps are the 2nd highest after the lakes in the Tatra Mountains. The Tot-P values are generally low for the whole area, except for Lac Noir where the high Tot-P values are indicating some local influence. The heavy metals concentration in the area as a whole show higher values than those of the reference site.

Tatra Mountains

Starolesnianske pleso (15.1)

Starolesnianske pleso is a strongly acidified lake situated at 2000 m a.s.l. in High Tatra Mountains. The vegetation cover is alpine meadow and bare rocks. Ca^{2+} concentrations are low (39 - 29 μeq/l), resulting in low buffer capacity. Mean pH vales for 1993 and 1994 were 4.80 and 4.69 respectively. SO_4^{2-} concentrations are high (74 μeq/l and 52 μeq/l mean values for 1993 and 1994). NO_3-N concentrations are in the medium range compared to the other European lakes, but low compared to the other Tatra lakes (mean values for 1993 and 1994 of 12 μeq/l and 11 μeq/l). Especially Pb and Hg, but also Cd show high concentrations in Starolesnianske pleso.

Terianske pleso (15.2)

Terianske pleso is situated close to the Starolesnianske pleso in the Slovak Tatra Mountains. Ca^{2+} concentrations are higher than for Starolesnianske pleso (159 μeq/l - 143 μeq/l), resulting in some buffer capacity and higher pH values. Mean pH vales for 1993 and 1994 were 6.86 and 6.40 respectively. Also here the SO_4^{2-} concentrations are high (68 μeq/l and 55 μeq/l as mean values for 1993 and 1994). NO_3-N concentrations (mean vales for 1993 and 1994 of 39 μeq/l and 31 μeq/l) are especially high and in the same range as the Polish Tatra lakes. A small elevation of Cd is registered when the value is compared to the reference lake.

Dlugi Staw (15.3)

Dlugi Staw is situated at 1783 m a.s.l. on granitic bedrock. The Ca^{2+} concentration is 73 - 173 μeq/l. Despite the following buffering capacity, the lake is acidified. Mean pH values for 1993 and 1994 were 5.96 and 5.95. Both for 1993 and 1994 the two Polish lakes have been sampled biweekly through the year due to other project work in a Polish Norwegian cooperative programme. Both SO_4^{2-} and NO_3-N concentration in this area are high. Mean values for 1993 and 1994 are 77 and 74 μeq/l for SO_4^{2-} and 56 and 51 μeq/l for NO_3-N, respectively. Cd is somewhat elevated and Hg show a very high value in the one sample taken for the heavy metal analysis from Dlugi Staw.

Zielony Staw (15.4)

Zielony Staw Gasienicowy, is situated at 1617 m a.s.l. in the same watershed as Dlugi Staw, and also on granitic bedrock. The vegetation cover is slide rock, dwarf pine and alpine meadows. The Ca^{2+} values are higher than for Dlugi Staw (125 μeq/l - 197 μeq/l), giving buffering acpacity, and the mean pH is also higher. For 1993 and 1994 the mean pH values are 6.61 and 6.57 respectively. The nitrate values are high with mean values for 1993 and 1994 of 35 and 51 μeq/l. SO_4^{2-} concentrations are 76 μeq/l and 72 μeq/l as mean values for 1993 and 1994. Also for Zielony Staw high concentrations of Hg and Cd compared to the reference lake, were found.

Region summary - Tatra Mountains

The Tatra Mountains seem to be the region most heavily exposed to air pollution of all the regions in the project. The four lakes in the Tatra Mountains all show high SO_4^{2-} concentrations, and with the exception of Starolesnianske pleso they also show very high NO_3^- concentrations. In fact they show the highest NO_3^-concentrations measured in the project. The area as a total shows elevated values also for the heavy metals Hg, Cd and Pb. The Polsih side of the mountains seem to be highest exposed for air pollution, with the highest concentration of SO_4^{2-}, NO_3^- and Total nitrogen (TN).

Table 2.2. Water chemistry mean values for the AL:PE 2 lakes grouped together after regions.

Lake n°	Site/lake	Mean	pH	Cond	Cond	NH4	Ca	Mg	Na	K	Alk	SO4	SO4*	NO3	Cl	F	TN
		period		µS/cm 20°C	mS/m 25°C	(µgN/l)	(mg/l)	(mg/l)	(mg/l)	(mg/l)	(µeq /l)	(mg/l)	(mg/l)	(µgN/l)	(mg/l)	(µg/l)	(µgN/l)
9	Arresjøen	1993	5,81	37,55	3,76	5	0,71	0,59	4,76	0,24	24	1,55	0,40	<1	8,25	<0.1	94
17	Chuna	93-94	6,50	16,05	1,61	19	1,32	0,23	0,78	0,13	49	2,13	1,99	110	1,03		245
18	Chibini	93-94	7,18	29,60	2,96	5	0,88	0,10	4,52	1,15	183	2,72	2,61	177	0,76		190
1	Ø. Neådalsvatn	91-94	6,26	8,30	0,83	5	0,46	0,11	0,80	0,14	23	0,72	0,58	10	0,99	<0,1	64
2	Stavsvatn	91-94	5,96	9,94	0,99	11	0,86	0,12	0,53	0,09	21	1,81	1,72	40	0,68	0,74	111
3	L. Hovvatn	91-94	4,63	27,22	2,72	51	0,45	0,19	1,56	0,11		2,98	2,36	140	2,70	<0,1	110
4.1	Lochnagar	91-94	5,38	22,32	2,23	56	0,65	0,39	2,12	0,23	9	2,86	2,42	229	3,13	20,00	400
4.2	Sandy Loch	91-94	5,77	18,80	1,96	60	0,87	0,32	2,06	0,19	26	2,64	2,30	122	2,41	<0,1	390
4.3	L. Nan Eun	91-94	5,23	14,54	11,33		0,63	0,34	2,49	0,17	5	2,35	1,80	213	3,95		
10	L. Maam	1993	4,96	59,50	5,95		0,81	0,76	7,84	0,37	7	2,93	0,98	46	13,89	<0,1	285
13	La Caldera	93-94	7,69	29,18	2,92	62	4,77	0,47	0,35	0,14	114	1,20	1,06	45	0,95		263
14	L. Escura	93-94	5,36	12,15	1,22	7	0,25	0,25	0,69	0,14	1	0,86	0,69	1	1,20		
16	Laguna Cimera	93-94	5,83	5,85	0,59		0,44	0,14	0,59	0,04	21	0,68	0,64	141	0,33		116
8	Etang d'Aube	91-94	6,10	8,51	0,85	44	0,65	0,07	0,48	0,21	22	1,16	1,09	154	0,49		415
12.1	L. Aguilo	93-94	5,95	5,90	0,59	7	0,41	0,14	0,20	0,07	15	0,68	0,65	36	0,21		
12.2	L. Redo	93-94	6,51	12,05	1,21	11	1,46	0,16	0,22	0,08	43	1,30	1,27	175	0,23		
5.1	L.Paione S.	91-94	5,67	9,81	0,98	46	0,89	0,09	0,21	0,26	3	1,96	1,94	326	0,13		402
5.2	L.Paione Inf.	91-94	6,45	13,03	1,30	8	1,55	0,15	0,31	0,34	27	2,50	2,48	378	0,14		417
6.1	Lago Lungo	91-94	6,34	13,49	1,38	38	1,58	0,18	0,35	0,27	32	3,17	3,15	239	0,16		346
6.2	Lago di Latte	92-94	6,47	14,65	1,51	33	1,83	0,15	0,36	0,35	49	2,76	2,74	332	0,13		415
7.3	L.Blanc	92-94	7,15	15,79	1,58	15	2,39	0,22	0,29	0,35	138	1,16	1,14	175	0,10	135,00	227
7.4	L.Noir	92-94	7,17	21,14	2,12	4	2,90	0,42	0,32	0,19	113	2,93	2,92	139	0,15	44,00	183
11	Schwarzsee ob S.	93-94	5,58	14,47	1,45	17	1,19	0,25	0,33	0,13	4	3,75	3,73	166	0,10	4,79	
19	Krisko jezero	93-94	7,73	93,03	9,30	17	14,95	0,80	0,83	0,29	647	5,90	5,90	126	0,20	0,10	483
15.1	Starolesnianske pl.	93-94	4,74	14,75	1,46	27	0,68	0,08	0,09	0,09		3,04	3,02	412	0,14	0,01	372
15.2	Terianske pleso	93-94	6,63	19,98	2,01	7	3,03	0,10	0,33	0,14	65	2,96	2,93	488	0,18	0,02	556
15.3	Dlugi Staw	93-94	5,97	20,17	2,02	14	2,38	0,13	0,37	0,14	8	3,65	3,65	746	0,27	<0,1	794
15.4	Zieloni Staw	93-94	6,60	12,61	1,16	27	2,86	0,18	0,43	0,17	62	3,59	3,54	541	0,27	<0,1	619

2.4. Overall comparison between sites and discussions

2.4.1 Quality control

All the AL:PE lakes have been sampled at least once a year for water chemistry. Most of the lakes have been sampled more often than annually, although they are not easily reachable. Results of the analytical quality controls (AQC), as described in section 2.2.3, are shown in figure 2.1a and 2.1b, where the sum of anions and cations are plotted in comparison with the 1:1 line.

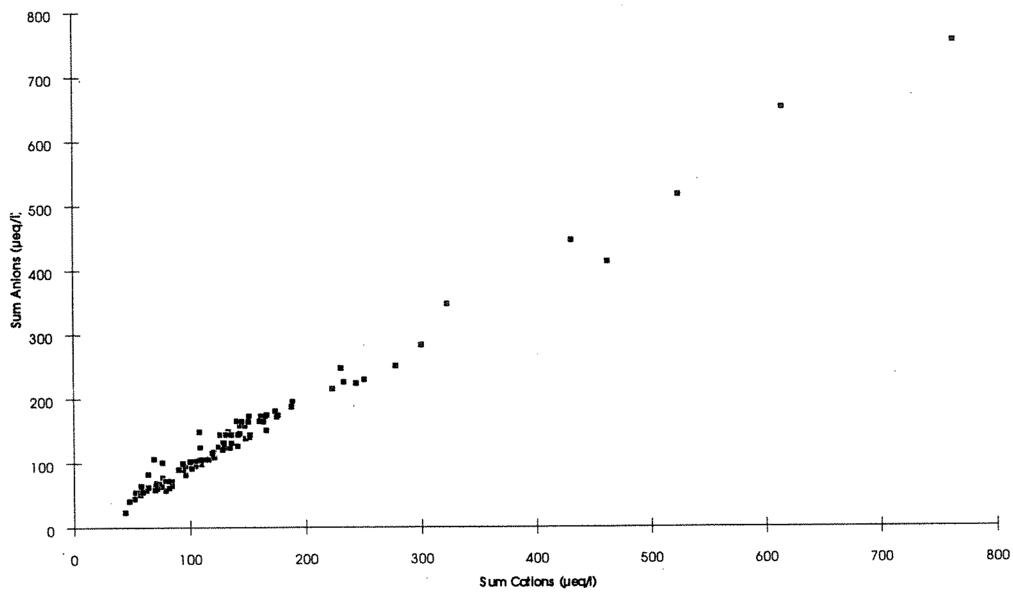


Figure 2.1a. Sum of cations plotted against anions for the 1993 data.

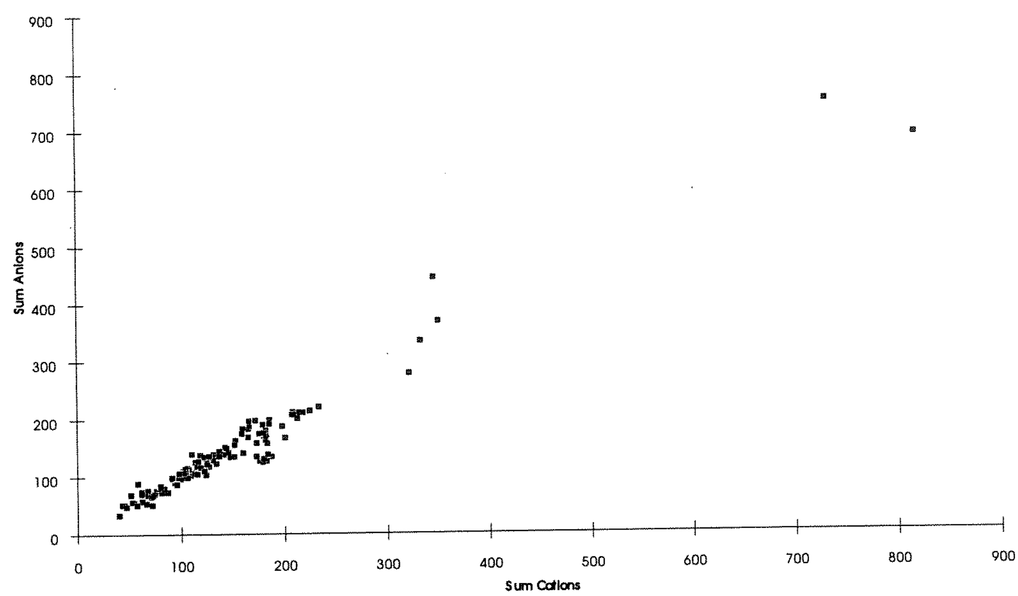


Figure 2.1b. Sum of cations plotted against anions for the 1994 data.

Also the AQC based on the comparison of measured and calculated conductivity (Fig. 2.2a and b) gives satisfactory results.

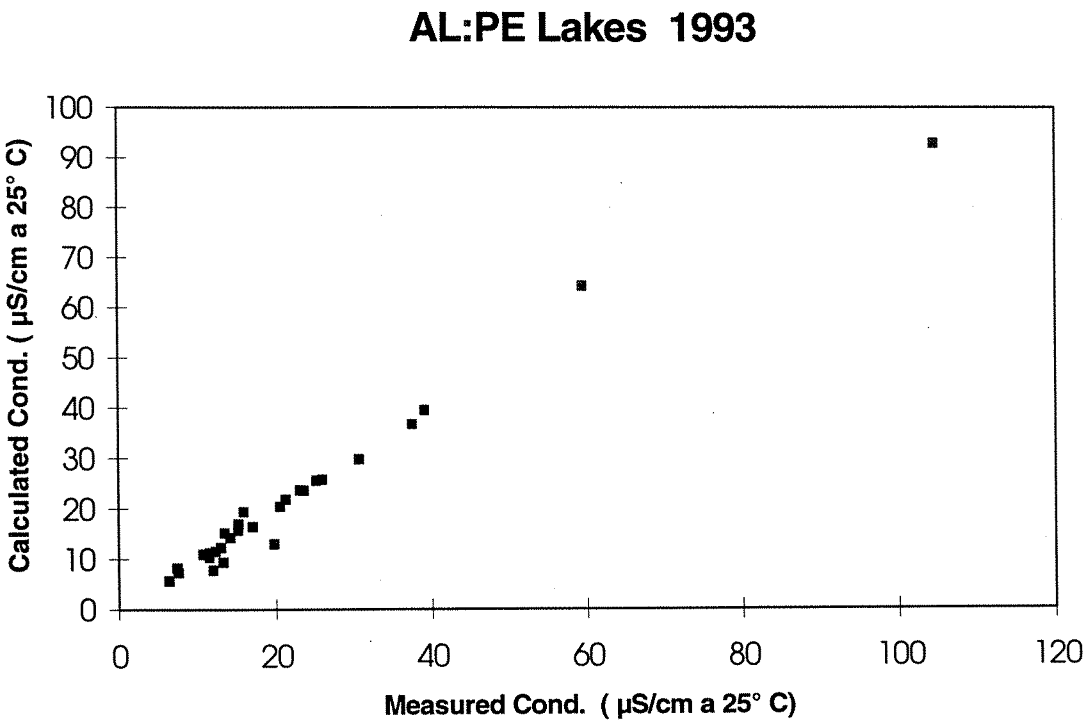


Figure 2.2a. Comparison between measured and calculated conductivity for the 1993 mean values.

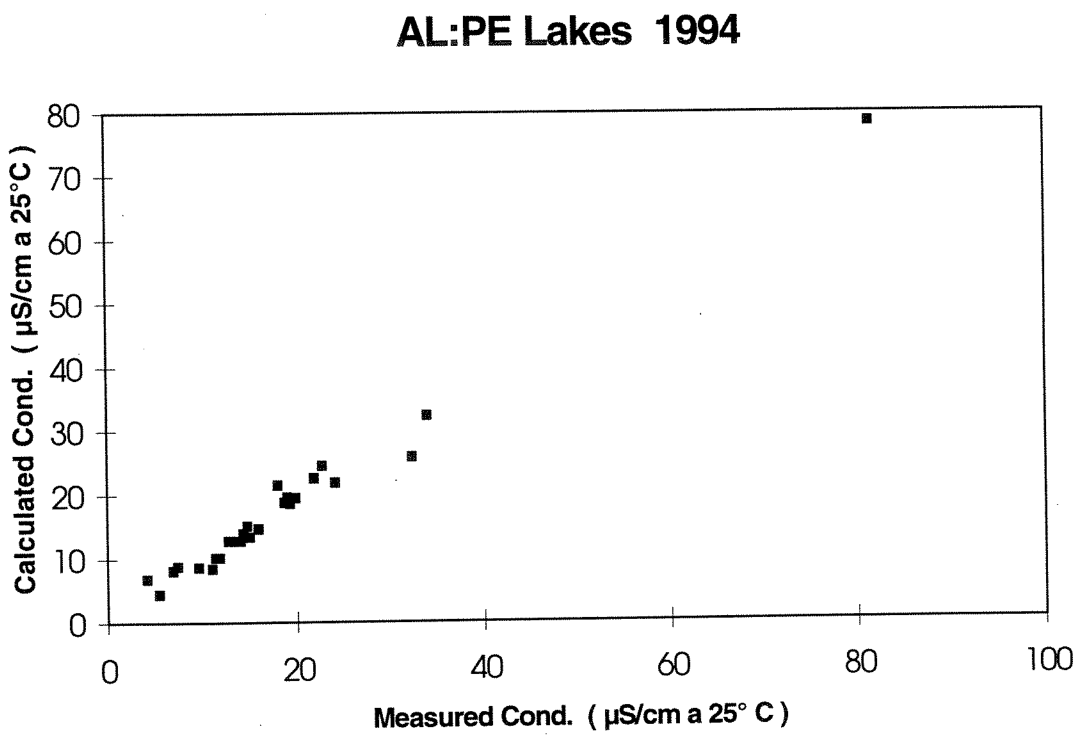


Figure 2.2b. Comparison between measured and calculated conductivity for the 1994 mean values.

2.4.2 Water chemistry

To give an impression of the pollution status of the different lakes and a comparison between the sites with regard to the water chemistry results, the yearly mean lakewater values for pH, SO_4^{2-}, Ca^{2+}, base cations and NO_3-N for 1993 and 1994 are shown in Figures 2.3 - 2.12. Also the heavy metal concentrations are shown in Figures 2.13 - 2.16. All the detailed water chemistry data are shown in Appendix 2.

The yearly mean pH values (Fig. 2.3) range from 4.65 and 4.69 (1993 and 1994) in the most acid Lille Hovvatn to 8.05 and 7,33 (1993 and 1994) in Caldera in the Spanish Sierra Nevada and 7.76 (1994) in Zgornje Krisko Jezero in Slovenia. The results also show the acid gradient in Norway from the unpolluted Øvre Neådalsvatn with pH values 6.37 and 6.32 (1993 and 1994) via the moderately exposed Stavsvatn (pH 5.94 and 6.00) to Lille Hovvatn (pH 4.65 and 4.69), the site in the area most heavily exposed to acid rain. The high pH values in La Caldera and Z. Krisko Jezero result from high base cation concentrations in the lakewater, especially high Ca^{2+} concentrations, as shown in Figures 2.4 and 2.5.

In AL:PE 1 the strongest criteria with respect to acid sensitivity would require sites with lakewater Ca^{2+} concentrations of 50 µeq/l (1 mg/l) or less, and these sites were selected as primary AL:PE sites. For AL:PE 2 this criterion was somewhat modified, due to a wish of working sites with a broader biological spectrum combined with the wish to identify unpolluted sites in Europe suited for studies of climate change. The Ca^{2+} concentrations in the AL:PE lakes are still of great interest and are shown in Figures 2.5 and 2.6. Because of the high Ca^{2+}concentrations in Zgornje Krisko Jezero, a Figure (2.6) was made, which excludes this lake.

In Figure 2.7 the SO_4^{2-} concentrations for the AL:PE lakes are shown. Again the acid gradient in Norway from Øvre Neådalsvatn to Lille Hovvatn is clear. It is also seen that high SO_4^{2-} values may be found in high mountain lakes in all the countries represented in the AL:PE project. The SO_4^{2-} concentrations in Zgornje Krisko Jezero, the Polish Tatras (Dlugi Staw and Zielony Staw) and Italian/Austrian Alps show the highest values registered (mean values from 1993 and 1994 in the area 70 - 100 µeq/l or 3.35 - 4.80 mg/l). Likely in the case of the Zgornje Krisko Jezero there is a contribution of sulphate from the weathering of the watershed, mainly composed by calcareous rocks.

Lac Noir in the French Alps also shows high SO_4^{2-} values in 1994 (as in 1992 which is reported in the AL:PE 1 report), while the nearby lake Lac Blanc show lower values (see Fig. 2.7). It is reported from the French group that sampled the lakes, that Noir has tributaries from springs and small brooks, while Blanc mostly receive its inputs from melting ice and snow. This suggests that the high SO_4^{2-} values in Lac Noir are results from parts of the geology in the watershed or geological bands where the springs have their origin, while the concentrations of Lac Blanc are more representative for the atmospheric deposition in the area.

The lowest SO_4^{2-} values are found as expected, in the reference site Øvre Neådalsvatn, but apart from the reference site, the French and Spanish Pyréneé sites (Étang d'Aubé, lakes Aguilo and Redo) show the lowest values, with the Lac Blanc in the French Alps almost at the same low level.

SO_4^{2-} and Cl^- are shown together in Figure 2.8a and b. The Cl^- concentrations indicate the distance from the sea and the seasalt influence at the different sites, and it is clearly seen that Arresjøen and Lough Maam are situated close to the sea. Also Nan Eun seems to have high mean Cl^- concentration for 1993, due to one sample from May which shows high values both for Na^+ and Cl^-.

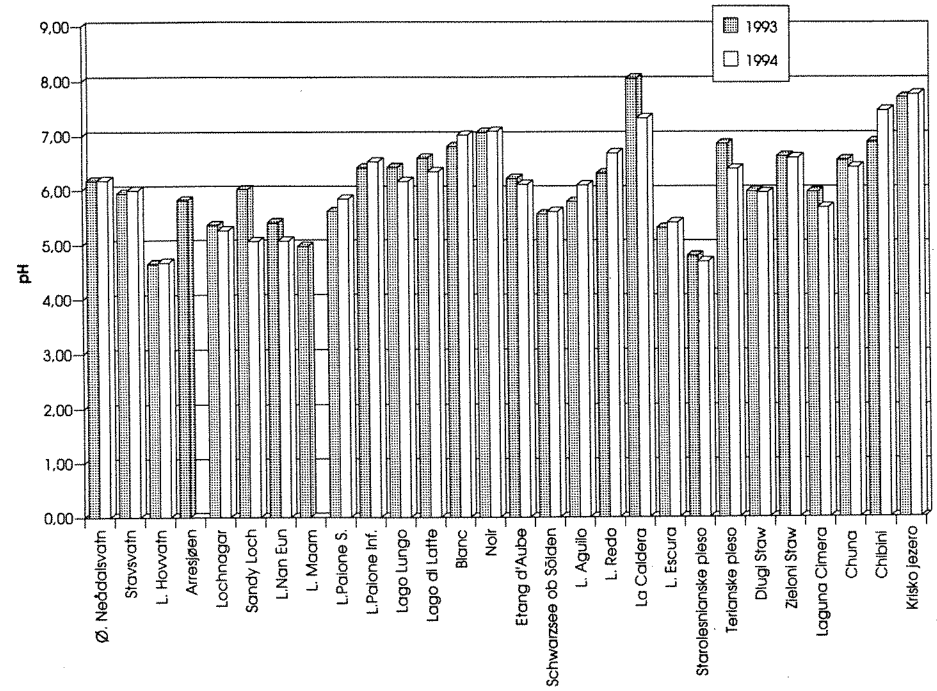


Figure 2.3. Yearly mean pH values for the AL:PE lakes in 1993 and 1994.

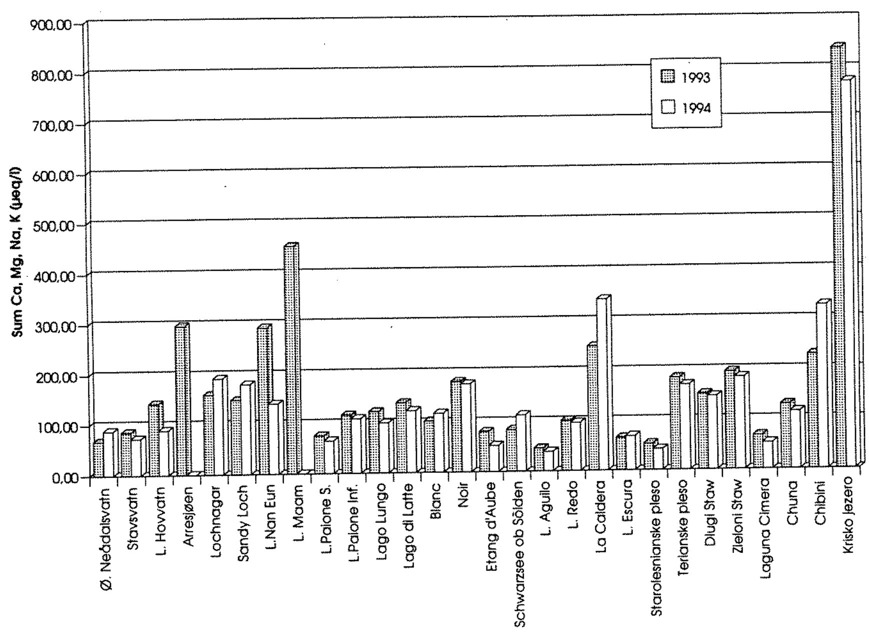


Figure 2.4. Yearly mean values for the sum of the cations Ca^{2+}, Mg^{+}, Na^{+} and K^{+} for the AL:PE lakes in 1993 and 1994.

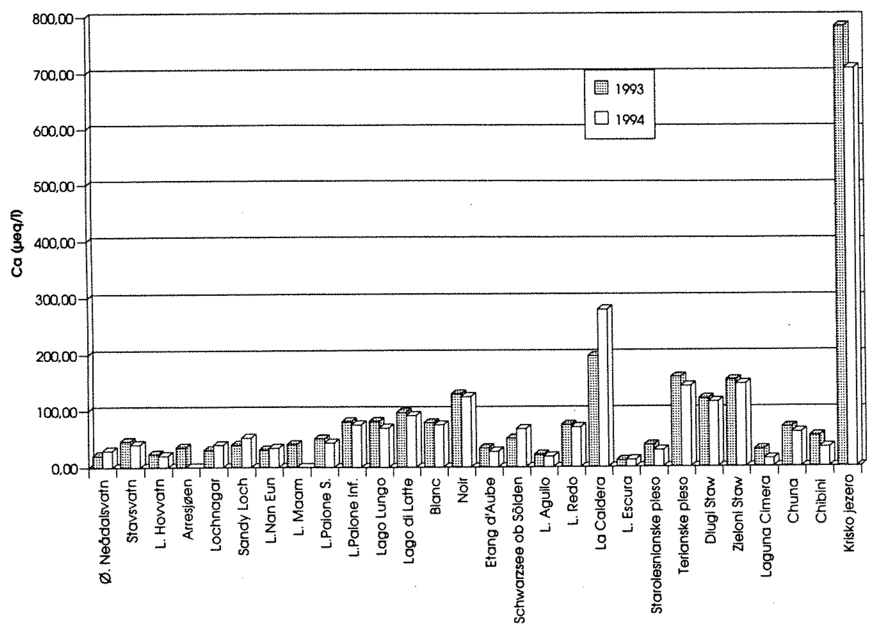


Figure 2.5. Yearly mean Ca^{2+} values for the AL:PE lakes in 1993 and 1994.

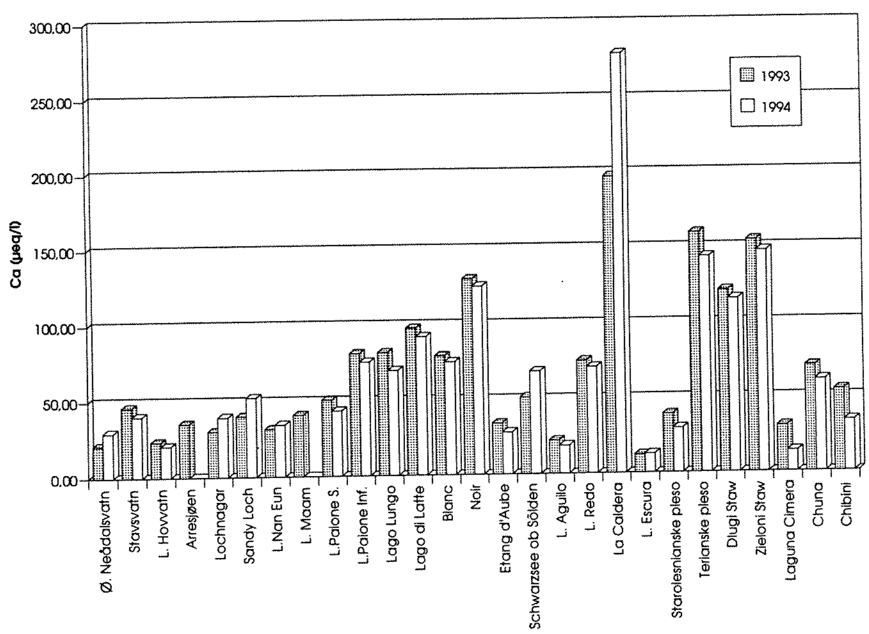


Figure 2.6. Yearly mean Ca^{2+} values for the AL:PE lakes in 1993 and 1994, (without Zgornje Krisko Jezero).

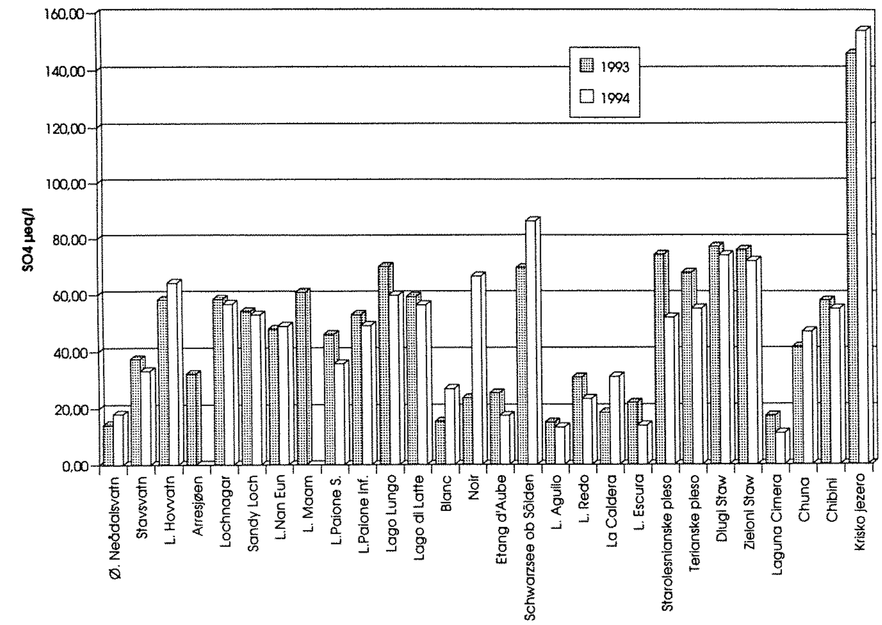


Figure 2.7. Yearly mean SO_4^{2-} values for the AL:PE lakes in 1993 and 1994.

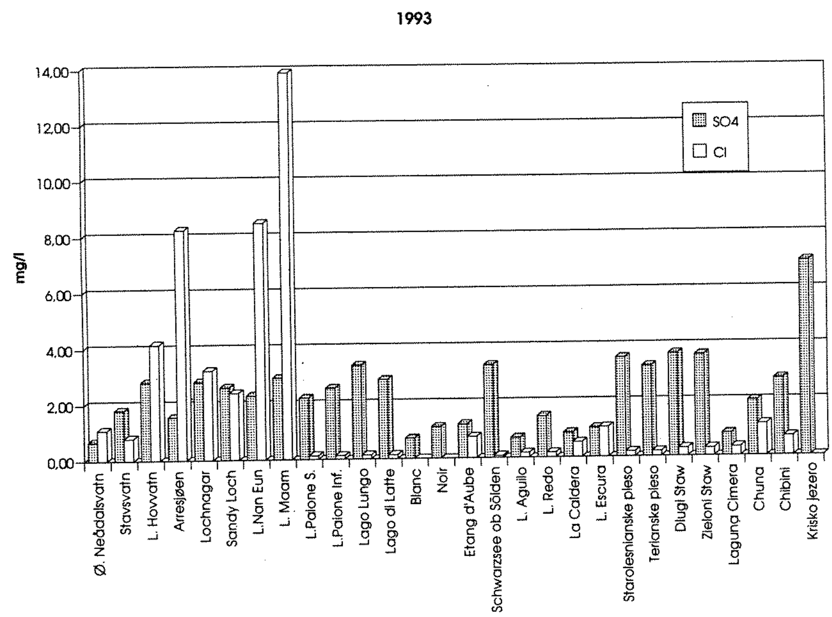


Figure 2.8 a. Yearly mean Cl^- and SO_4^{2-} values for the AL:PE lakes in 1993.

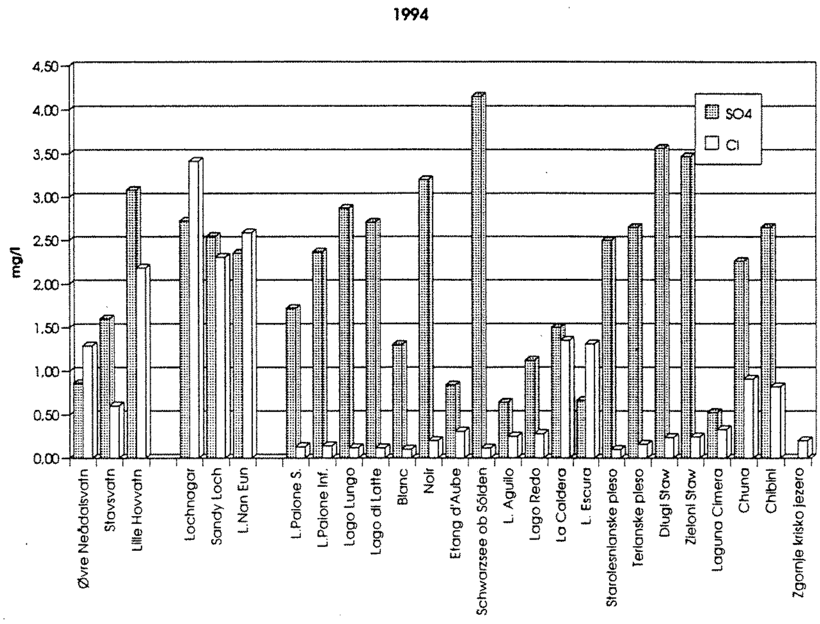


Figure 2.8 b. Yearly mean Cl^- and SO_4^{2-} values for the AL:PE lakes in 1994.

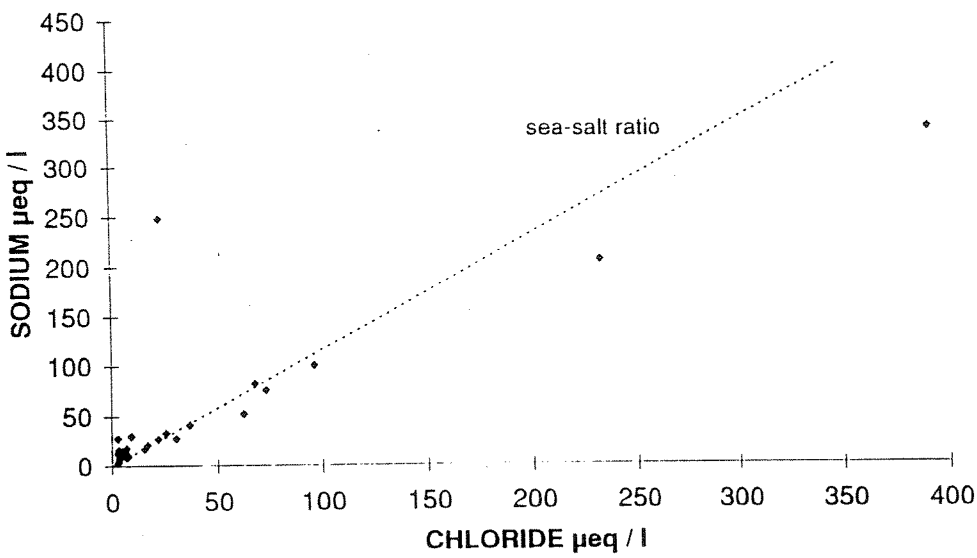


Figure 2.9. Yearly mean Na^+ values plotted against Cl^- for the AL:PE lakes for 1993 and 1994.

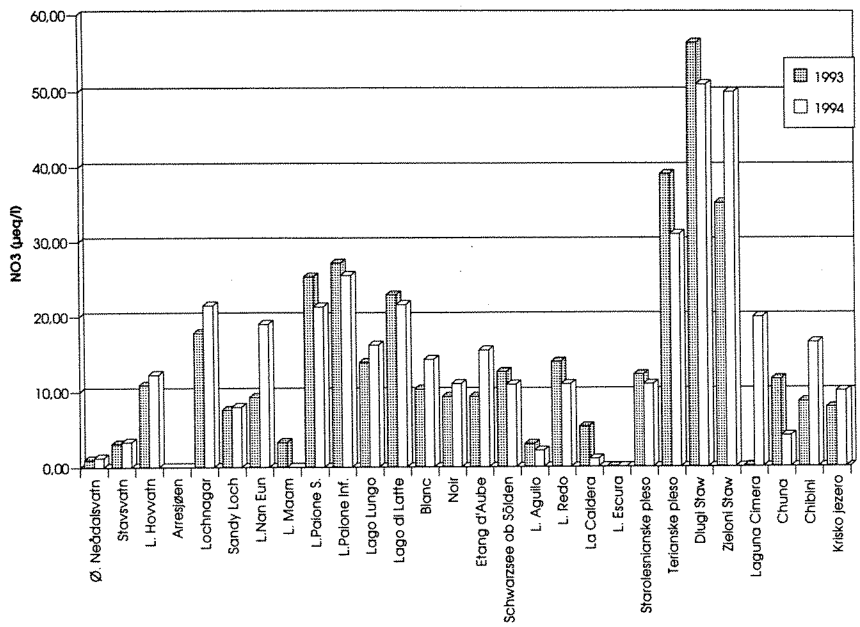


Figure 2.10. Yearly mean NO_3-N values for the AL:PE lakes in 1993 and 1994.

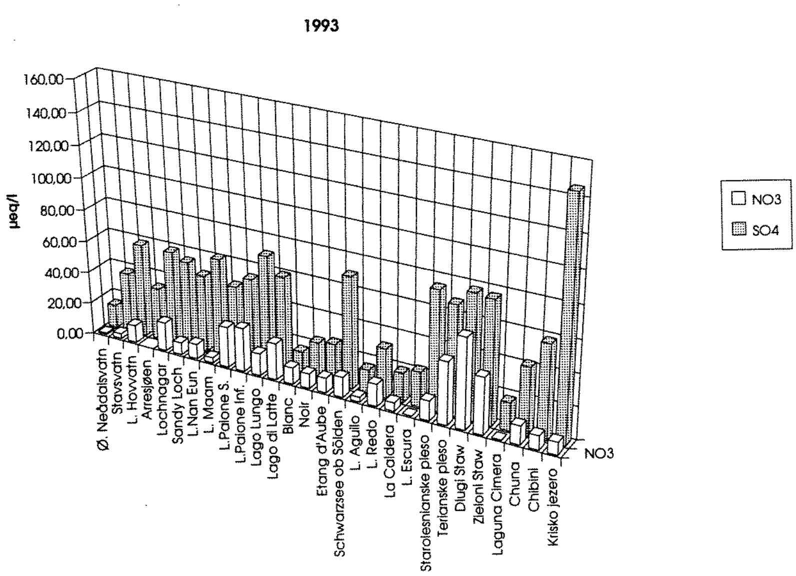


Figure 2.11.Yearly mean SO_4^{2-} and NO_3-N values for the AL:PE lakes in 1993.

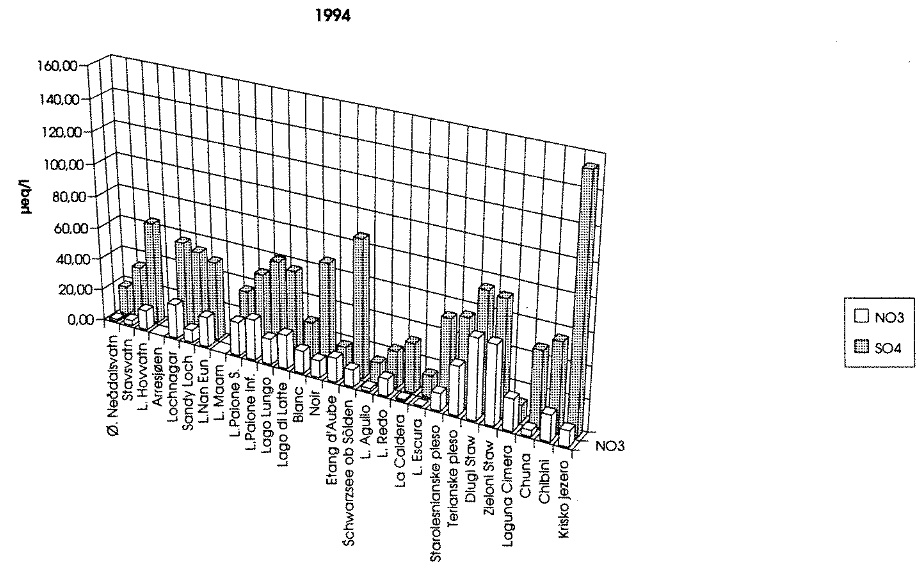


Figure 2.12. Yearly mean SO_4^{2-} and NO_3-N values for the AL:PE lakes in 1994.

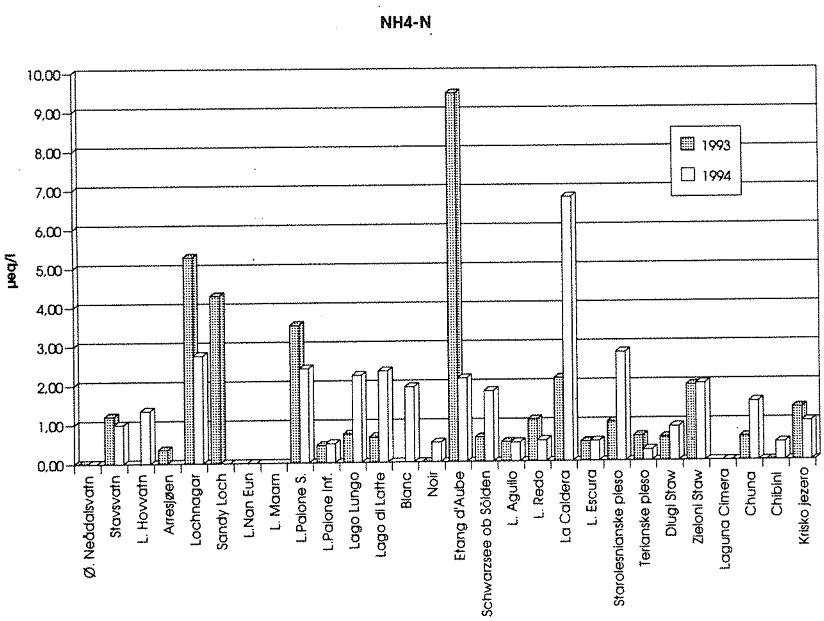


Figure 2.13. Yearly mean NH_4-N values for the AL:PE lakes in 1993 and 1994

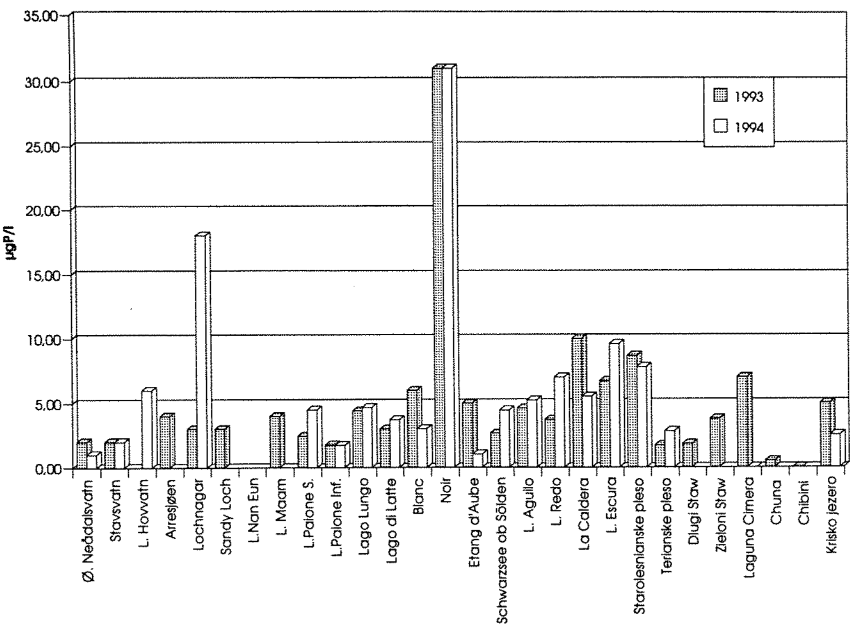


Figure 2.14. Yearly mean TotP values for the AL:PE lakes in 1993 and 1994

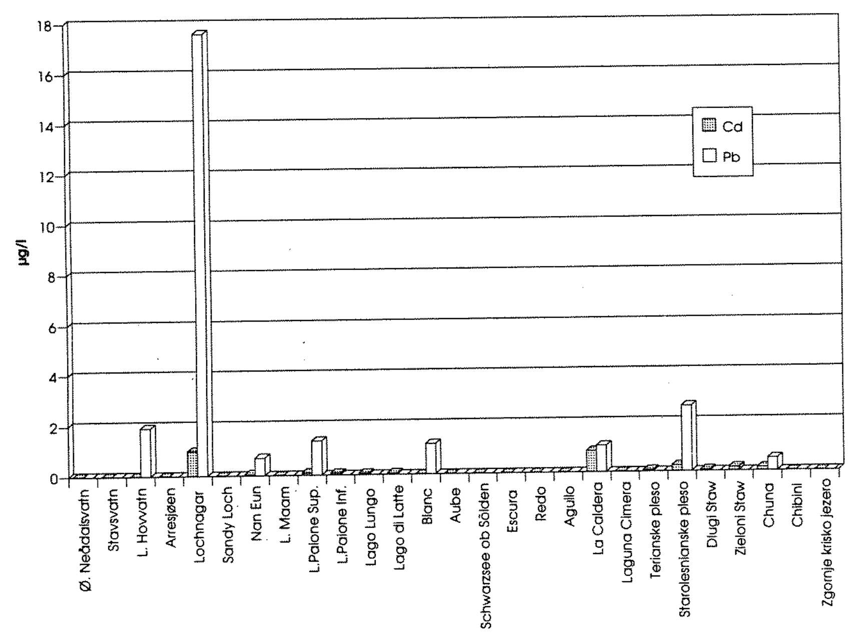


Figure 2.15. Cd and Pb values for the AL:PE lakes in 1993/1994.

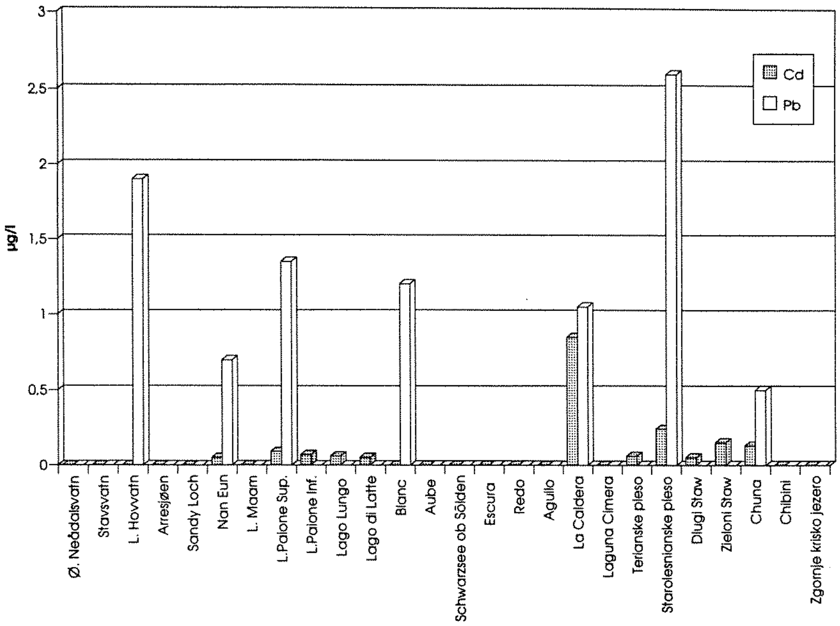


Figure 2.16. Cd and Pb values for the AL:PE lakes in 1993/1994 (without Lochnagar).

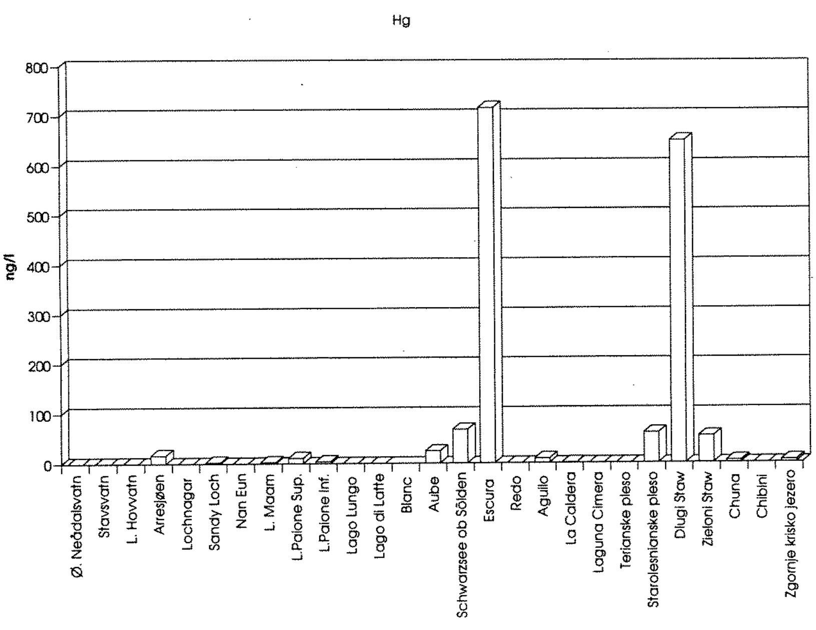


Figure 2.17. Hg values for the AL:PE lakes in 1993/1994.

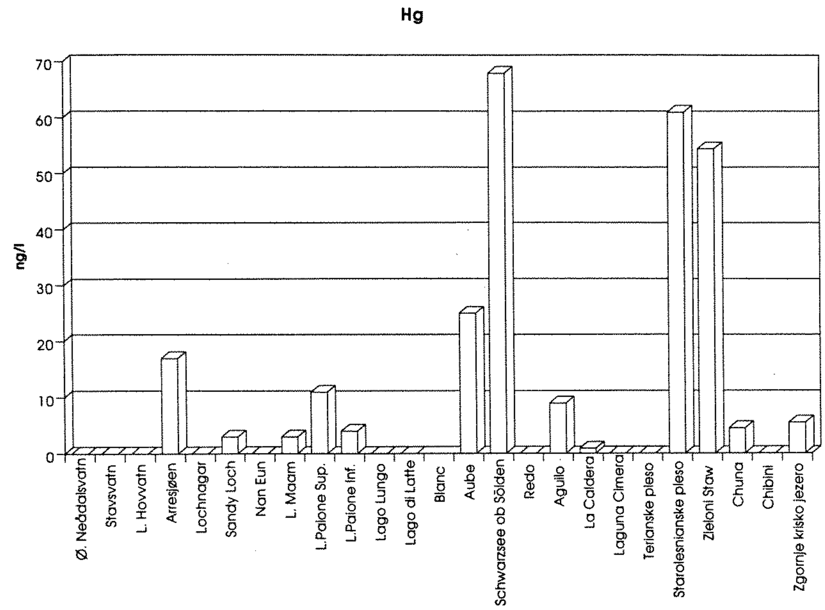


Figure 2.18.Hg values for the AL:PE lakes in 1993/1994 (without Escura and Dlugi Staw).

Cl^- are in most of the cases related to Na^+ concentration, indicating that they are mainly deriving from atmospheric deposition (Fig. 2.9). Only in the case of Lake Chibini, located in a minerary area in the Kola Peninsula, there is a strong excess of Na^+ in relation to Cl^-, indicating a relevant contribution of weathering processes for Na^+. Of course also in the case of the other lakes part of the Na^+ derive from silicate weathering.

In Figure 2.10 the results for NO_3-N are shown. The distribution pattern of the NO_3-N concentrations between the sites is somewhat different from that of SO_4^{2-}. The NO_3-N concentrations in the Tatras are the highest, and there seems to be also a gradient from the north (Svalbard and Norway) to Central Europe (via U.K. to Italy and the Tatras). In Central Europe a gradient also appears from West to East, from low values in Portugal through Spain and then the Italian Alps to the absolutely highest values in the Tatras. Even the relatively clean site in the French Pyrénées, Étang d'Aubé shows higher values than the highest values in Norway and Spain. Inside Norway the gradient from the reference lake to the most affected lake is clearly seen, but, as noted above, the values are lower than for the other European areas.

In Figure 2.11 and 2.12 the results for SO_4^{2-} and NO_3-N in 1993 and 1994 are shown together. The different distribution for the two components is clearly seen with the higher NO_3-N concentrations in the Italian Alpine region compared to the Northern and Western zones.

These results follow and strengthen the conclusions drawn in the first part of the AL:PE project and described in the AL:PE 1 report (Wathne *et al.* 1995). They are also in agreement with earlier results from a comparison of the chemical characteristics of mountain lakes in Norway and Italy (Wathne *et al.* 1990), where it was concluded that NO_3-N plays a more important role in acidification processes in the Alpine lakes than in Norwegian mountain lakes, and that the mobility in the Ossola Valley in the Alps was twice the value found in Skreådalen in Norway, an area not far from Stavsvatn. To follow these results in more detail, atmospheric deposition data for the sites need to be more thoroughly considered.

Ammonium concentrations (Fig. 2.13) are in most cases lower than 5 µeq/l, and lower than the nitrate concentrations (Fig. 2.10). Altogether inorganic nitrogen (ammonium + nitrate) is lower than 30µeq/l (400 µgN/l) in most of the AL:PE lakes, with the exception of the Tatras.

Also the total phosphorus TotP (Fig. 2.14) are very low, mainly below 5 µg P/l, with the exception of Lac Noir, which shows the highest values of 30 µg P/l. These values, considered together with those of inorganic nitrogen, indicate oligotrophic or ultra-oligotrophic conditions for the AL:PE lakes.

For most of the lakes only one sample is taken the heavy metal analysis. All samples are analysed the the laboratory of NIVA. One sample can only give an indication of a possible pollution problem, but in the fish bearing lakes the heavy metal analysis of the fish fillet and organs might strengthen the indications given from the water chemsitry results. The results from the heavy metal analysis of Cd, Pb and Hg are presented in Figures 2.15- 2.18. The results show that Loch Nagar has high Pb concentrations compared to the other lakes. Also Starolesnianske Pleso, Paione Superiore, Lille Hovvatn, Lac Blanc and La Caldera show elevated values for Pb. The results from La Caldera indicates higher values also for Cd. For Hg, Escura and Dlugi Staw show the highest values. Also Schwarssee, Starolesnianske and Zielony Staw show elevated values, and the otherwise relatively unpolluted arctic lake Arresjøen show a noticable value. All measured values for all three heavy metals are below the drinking water standards for the European Community (Council Directive of 15 July, 80/778/EEC).

2.5 Statistical analysis

2.5.1 Numerical analysis of water chemistry data

A large amount of primary data has been collected during the AL:PE 1 and 2 projects, including i.a. data on lake-water chemistry. Multivariate numerical methods of data analysis have been applied to these data in an attempt to detect the major patterns of variation within the data-sets. Such patterns highlight the principal gradients of variation, help to generate hypotheses about the underlying causal processes, and define new research questions.

Data

Determinations for 9 determinands (pH, conductivity, Ca, Mg, Na, NO_3N, K, Cl, SO_4) that meet the quality control criteria within the AL:PE project are available from 30 lakes in 13 countries or areas (Norway (3 lakes), United Kingdom (3), Italy (4), France (5), Spitsbergen (1), Ireland (1), Austria (1), Spain (4), Portugal (1), Slovenia (1), Slovakia (2), Poland (2), and Kola Peninsula (2)). For some lakes, data are available for four years (1991, 1992, 1993, 1994), whereas for other lakes data are only available for one or two years.

All the data have been analysed as annual means for each lake, giving a total of 77 individual samples from 30 lakes.

Numerical analyses

The data have been analysed by principal components analysis (PCA) (ter Braak, 1987), using a correlation matrix between variables. The results are presented as correlation biplots (ter Braak, 1983), in which the correlations between variables can be inferred from the angles between arrows representing the individual variables. Variables with arrows with a sharp angle are positively correlated, and the longer the arrows, the greater the correlation. In contrast, obtuse angles reflect negative correlations, and arrows at right angles to each reflect an absence of correlation.

Results

The first principal component represents 29.7% of the total variance in the data, whereas the second component captures 25.2% of the total variance. Together the two axes represent 55% of the total variance in the chemical data. This is a relatively large amount for such a large data (n=77).

Axis 1 clearly reflects the contrast within the data (Figure 2.19) between lakes with relatively high, above-average Ca, Mg, and SO_4 concentrations and high pH and conductivity values and lakes dilute in Ca, Mg, and SO_4 and with below average pH and conductivity values. Axis 2 contrasts lakes with above-average Na and Cl concentrations from lakes with above-average NO_3N concentrations.

The scatter of the individual 77 samples on PCA axes 1 and 2 is considerable (Figure 2.20), but with a dense concentration of samples with below-average pH, NO_3N, conductivity, Na, and Cl values.

In an attempt to display the differences between lakes and the annual variation in water chemistry within a lake, the annual means for each lake are plotted on PCA axes 1 and 2 of the correlation biplot of Figure 2.19. In general there is little between-year, within-lake variation, in contrast to the considerable between-lake variation in chemical composition. On the basis of the PCA results (Figures 3-32 shown in Appendix 2), the 30 AL:PE lakes can be grouped into the following four general types.

The first group contains lakes with high, above-average Na and Cl concentrations and low pH, Ca, and NO_3N values. All lakes in this group are positioned in the top-left quadrant of the PCA space of axes 1 and 2. The group includes Lough Maam (Ireland - Appendix 2 Figure 3), Arresjøen (Spitsbergen - Appendix 2 Figure 4), Lochnagar (Scotland - Appendix 2 Figure 5), Sandy Loch (Scotland - Annex 2 Figure 6), Loch Nan Eun (Scotland - Appendix 2 Figure 7), Lille Hovvatn (Norway - Appendix 2 Figure 8), and Lake Chibini (Kola - Appendix 2 Figure 9).

The second group is characterised by low, below-average Mg, SO_4, Ca, Na, Cl, and K concentrations and low conductivity values, and are all positioned in the lower-left quadrant of the PCA plot (Figure 2.20). The lakes in this group are Lago Escura (Portugal - Appendix 2 Figure 10), Laguna Cimera (Spain - Appendix 2 Figure 11), Estany Redo (Spain - Figure Appendix 2 12), Estany Aguiló (Spain - Appendix 2 Figure 13), Étang d'Aubé (France - Appendix 2 Figure 14), Øvre Neådalsvatn (Norway - Appendix 2 Figure 15), Stavsvatn (Norway - Appendix 2 Figure 16), Lago Paione Superiore (Italy - Figure Appendix 2 17), Lake Chuna (Kola - Appendix 2 Figure 18), and Starolesnianske Pleso (Slovakia - Appendix 2 Figure 19).

The third group occurs in the lower-right quadrant of the PCA plot (Figure 2.20) and is characterised by above-average NO_3N, Ca, and SO_4 concentrations and above-average pH and conductivity values. The group contains Terianske Pleso (Slovakia - Appendix 2 Figure 20), Zieloni Staw (Poland - Appendix 2 Figure 21), Dlugi Staw (Poland - Appendix 2 Figure 22), Le Caldera (Spain - Appendix 2 Figure 23), Combeynod (France - Appendix 2 Figure 24), Lac Noir (France - Appendix 2 Figure 25), Lago di Latte (France - Annex 2 Figure 26), Lago Paione Inferiore (Italy - Appendix 2 Figure 27), and Lago Lungo (Italy - Appendix 2 Figure 28).

The fourth small group contains two lakes only that are characterised by high Ca, SO_4, pH, and conductivity values. The lakes are positioned in the top-right quadrant of the PCA plot (Figure 2.20) and are Lac Rond (France - Appendix 2 Figure 29) and Zgornje krisko jezero (Slovenia - Appendix 2 Figure 30).

There are two lakes whose individual annual means fall within two of the PCA quadrants. These are Lac Blanc (France - Appendix 2 Figure 31) and Schwarzsee ob Sölden (Austria - Appendix 2 Figure 32). They are both characterised by slightly above-average pH and NO_3N values but appear to show a slightly larger between-year variation in chemical composition than the other AL:PE lakes.

Conclusions
The PCA results summarise the major patterns of variation in lake-water chemistry in the 30 AL:PE lakes. They highlight the contrast in composition between lakes in oceanic areas of northern and western Europe where sea-salts are important (e.g. Appendix 2 Figures 3-9) and between lakes in southern, central, and eastern Europe where Na and Cl values are below average but where NO_3N, Ca, and SO_4 concentrations are above average (e.g. Appendix 2 Figures 20-28). There are 10 lakes (Portugal, Spain (including the Pyrenees), the French Pyrenees, central Norway, northern Italy, Kola, and Slovakia (Appendix 2 Figures 10-19) with below-average values for all chemical determinands.

Figure 2.19. Principal components correlation biplot showing the biplot arrows for the nine determinands including in the analysis on principal components analysis (PCA) axis 1 and 2. The variable scores are variance adjusted.

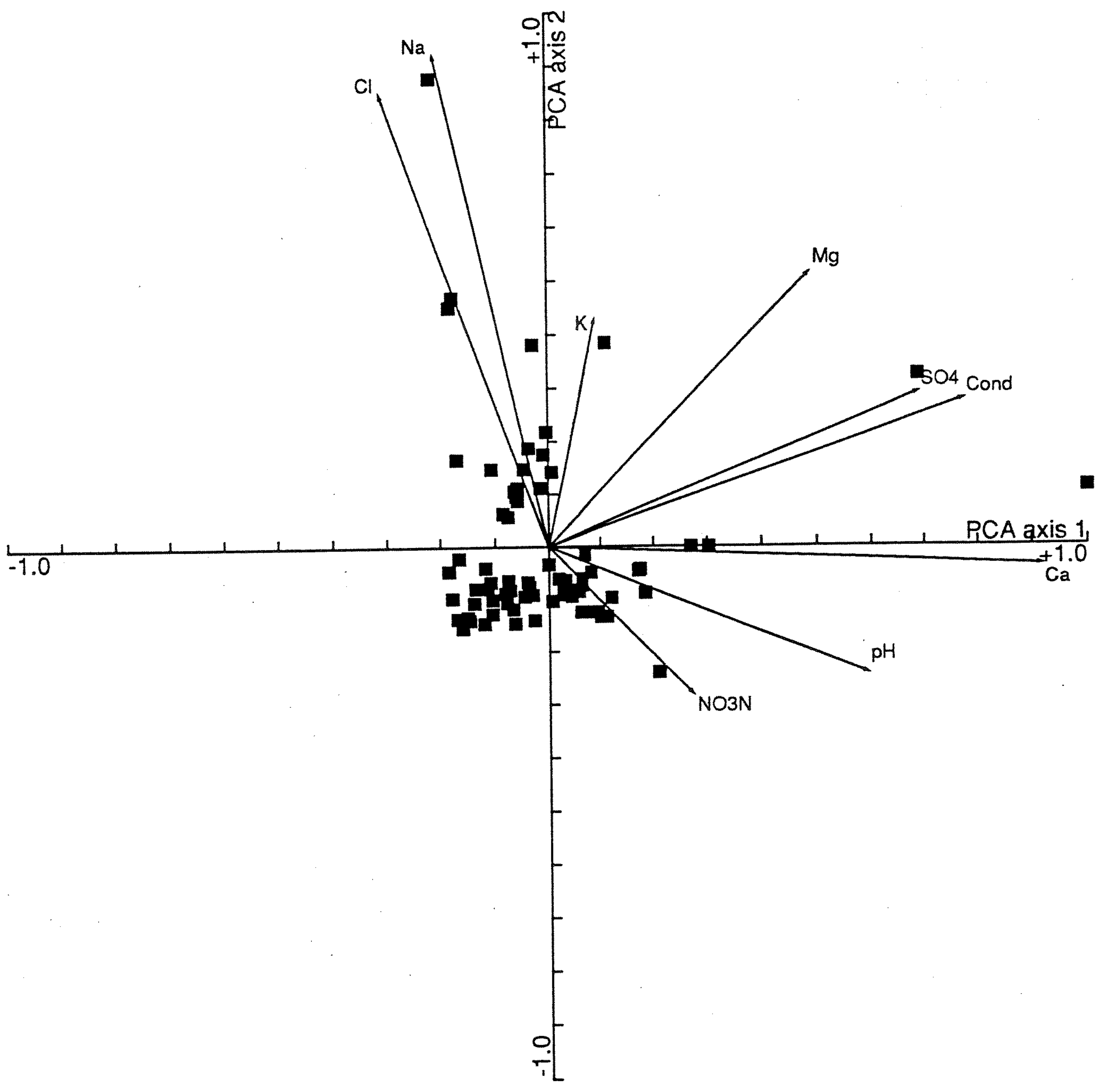
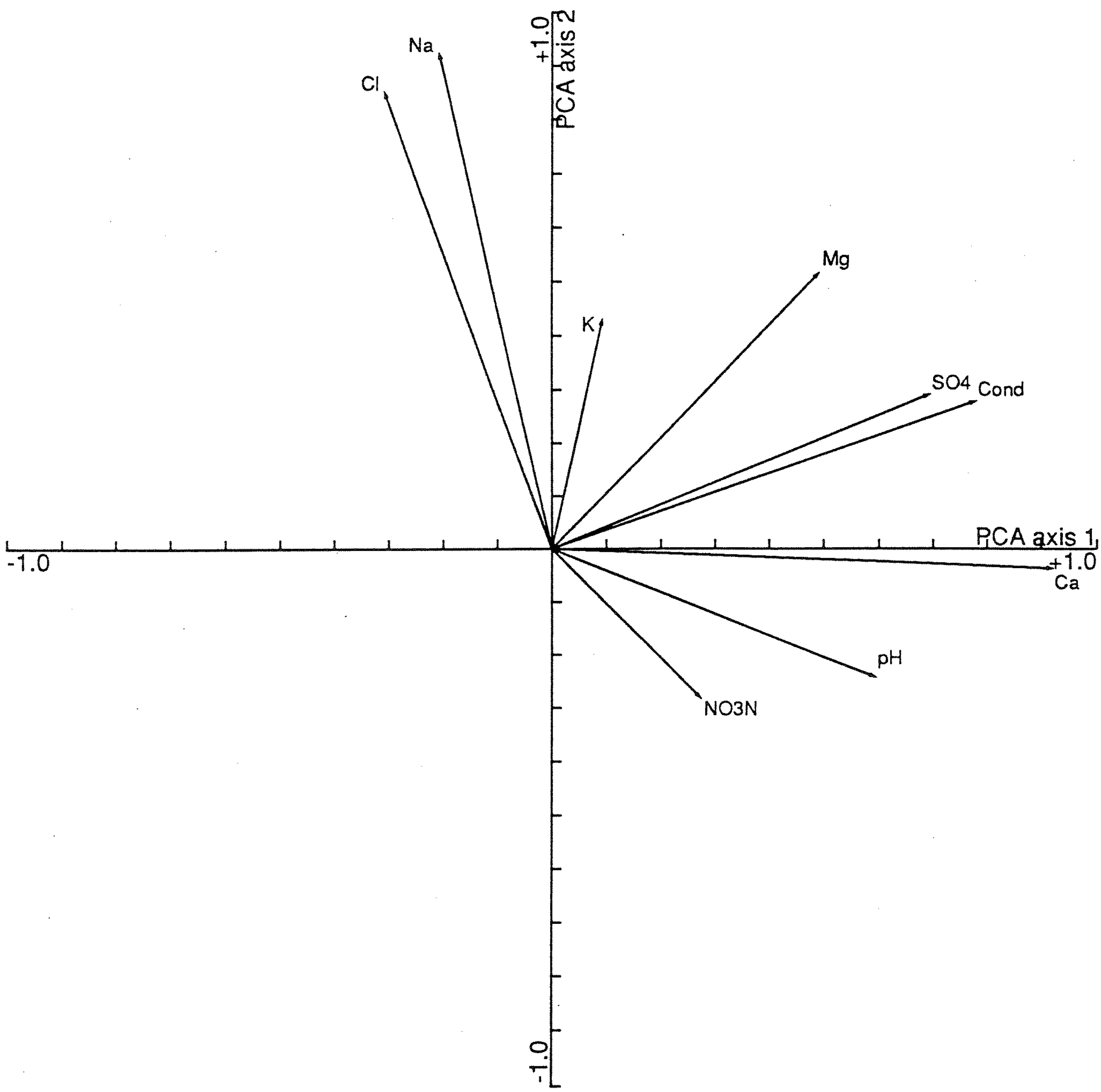


Figure 2.20 Position of the 77 annual means from 30 AL:PE lakes on PCA axes 1 and 2, along with the nine determinands. The plot is the correlation biplot of Figure 2.19.



2.5.2 Clustering of the AL:PE lakes

A further comparison of the lakes on the basis of main ion concentrations may be made using cluster analysis (Fig. 2.21 and Tab. 2.3). The data used are a mean of the 1993-94 values. If a linkage distance of 200 is arbitrarily assumed as significant, seven different categories of lakes are identified. Two of them (groups 1 and 3 of Tab. 2.3) are composed of single lakes showing peculiar chemical characteristics due to the lithology of the watersheds. Zgornje Krisko Jezero (Slovenia), draining a calcareous watershed, shows the highest alkalinity, sulphate and calcium concentrations, while Lake Chibini (Kola Peninsula) shows high sodium and alkalinity, due to the presence in the watershed of alkaline rocks (apatite, nepheline syenites) (Moiseenko 1994). A further type of chemical composition (group 2 of Tab. 2.3) emerges in lakes Arresjøen and Maam, characterised by a high sea-salt contribution. The mean Na/Cl ratio of these lakes is 0.88, very close to the value for sea water (0.86).

Group four (lakes Caldera, Zieloni, Terianski, Noir) is formed by lakes with relatively high alkalinity (mean 107, range 68-195 μeq/l), although lower than the values of lakes Zgornje and Chibini (212 and 557 μeq/l, respectively). Group five (Lochnagar, Nan Eun, Sandy Loch and Hovvatn) shows relatively high sodium and chloride concentrations, although lower than group two. However, the Na/Cl mean ratio is 1.04, higher than the value of cluster 2 and of the sea water ratio, indicating a contribution of sodium due to silicate weathering. Groups six and seven contain the highest number of lakes (7 and 9 respectively), which are characterised by low solute concentrations, with the prevalence of calcium, alkalinity and sulphate. The main differences are in the concentrations of sulphate and nitrate, which are higher in group 6 than in group 7 (Tab. 2.3).

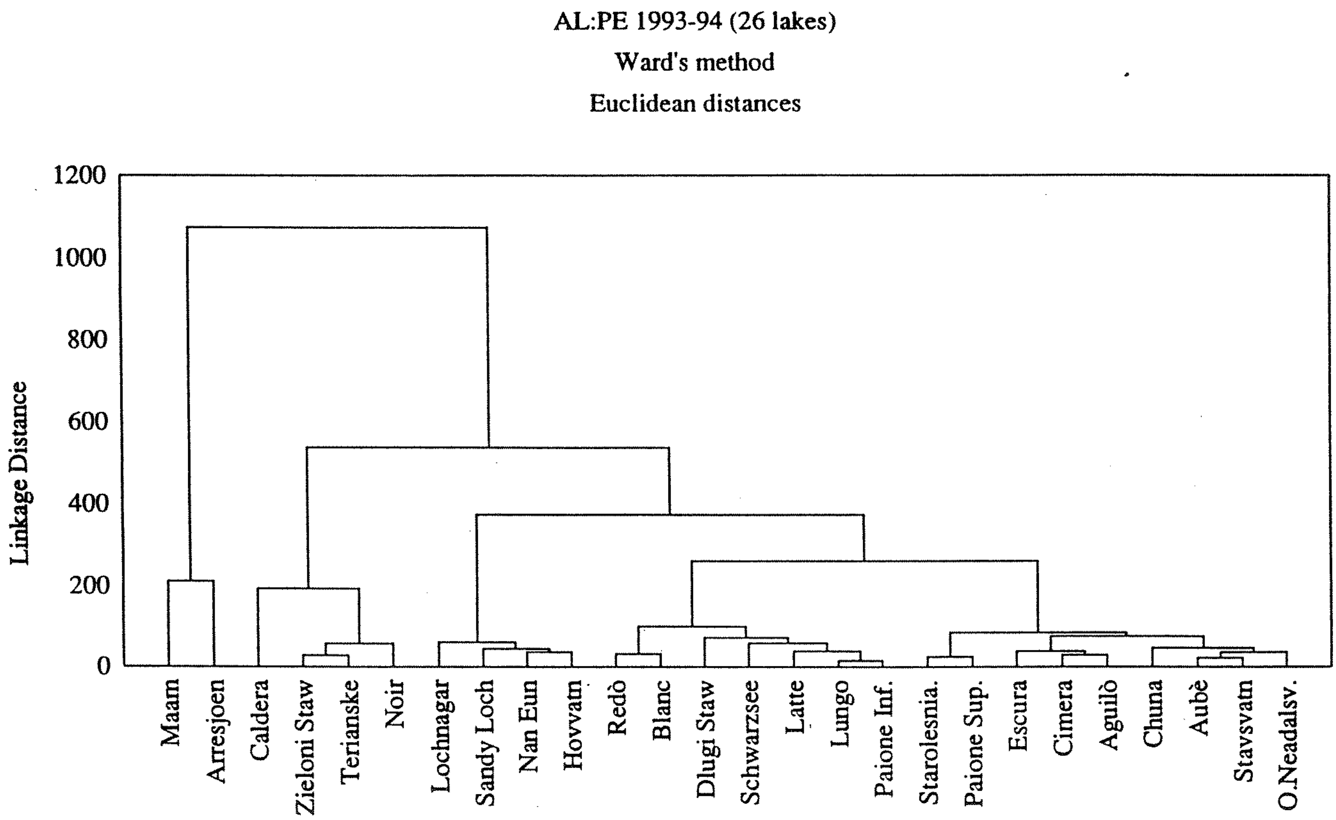
Another analysis of the chemistry of the AL:PE lakes may be made considering the clusters among the main ion concentrations (Fig. 2.21). The analysis was made excluding lakes Zgornje and Chibini, because of the peculiarity of their chemical composition. The results underline the close relationship between sodium and chloride, and their importance in determining conductivity. Furthermore, sodium and chloride are related both with magnesium, a significant quantity of which derive from sea salt, and, to a lower extent, with potassium. Closely related are also the two acid anions sulphate and nitrate and, in a different cluster, pH, alkalinity and calcium.

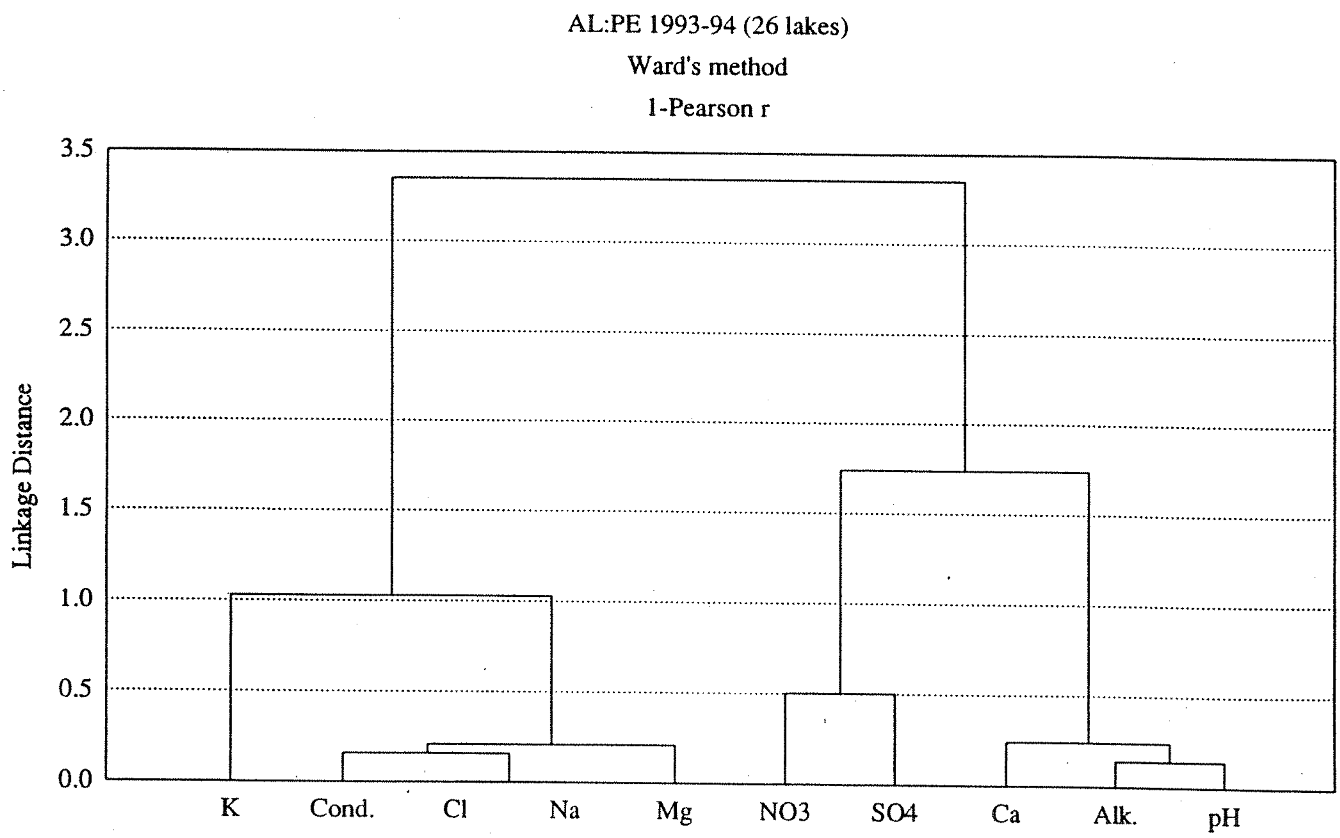
Table 2.3. Clustering of AL:PE lakes

CLUSTERING OF AL:PE LAKES (1993-94). CONCENTRATIONS IN μeq l^{-1}, CONDUCTIVITY IN mS m-1 AT 25° C

CLUSTER	pH	H+	NH4	Ca	Mg	Na	K	Alk	SO4	SO4NM	NO3	Cl	COND	S.AN	S.CAT	Na/Cl
1°																
Zgornje krisko jezero	7.76	0	1	709	33	28	3	557	154	154	10	3	8.15	724	774	10.099
2°																
Arresjøen	5.81	2	0	35	49	207	6	24	32	9	0	233	3.76	288	299	0.889
L. Maam	4.96	20	0	40	63	341	9	7	61	22	3	392	5.95	463	473	0.870
Mean	**5.38**	**11**	**0**	**38**	**56**	**274**	**8**	**15**	**47**	**15**	**1.62**	**312**	**4.85**	**376**	**386**	**0.879**
3°																
L. Chibini	7.47	0	0	34	6	248	39	212	55	53	17	23	3.40	307	327	10.746
4°																
L. Noir	7.09	0	0	125	33	13	5	92	67	66	11	6	1.99	175	176	2.313
La Caldera	8.05	0	2	197	31	17	3	195	19	17	5	15	2.60	234	251	1.137
Terianske pleso	6.40	0	0	143	7	16	4	68	55	55	31	5	1.87	159	170	3.469
Zieloni Staw	6.60	0	2	147	14	19	4	75	72	71	50	7	2.19	204	186	2.709
Mean	**7.04**	**0**	**1**	**153**	**21**	**16**	**4**	**107**	**53**	**52**	**24**	**8**	**2.16**	**193**	**196**	**2.407**
5°																
Lille Hovvatn	4.67	22	1	21	13	53	2	0	64	58	12	62	2.41	139	112	0.845
Lochnagar	5.25	6	3	39	43	101	8	7	57	47	22	96	2.28	181	199	1.049
Sandy Loch	6.01	1	4	40	21	82	4	26	54	47	8	68	1.91	156	153	1.217
L.Nan Eun	5.06	9	0	34	25	76	4	-7	49	42	19	73	1.90	134	148	1.041
Mean	**5.25**	**10**	**2**	**33**	**25**	**78**	**5**	**6**	**56**	**49**	**15**	**75**	**2.13**	**152**	**153**	**1.038**
6°																
L.Paione Inf.	6.53	0	0	75	12	14	8	26	49	49	26	4	1.35	104	109	3.426
Lago Lungo	6.17	1	2	69	13	12	5	27	60	59	16	3	1.40	106	102	3.630
Lago di Latte	6.35	1	2	92	11	13	7	51	56	56	22	3	1.62	132	126	4.099
L. Blanc	7.02	0	2	75	19	13	10	72	27	27	14	3	1.40	116	119	4.626
Schwarzsee	5.60	2	2	68	24	16	4	7	86	86	11	3	1.59	108	116	5.007
Lago Redo	6.69	0	1	71	13	10	2	44	23	23	11	8	1.18	86	96	1.237
Dlugi Staw	5.96	2	1	115	10	17	4	17	74	74	51	7	1.93	149	148	2.551
Mean	**6.33**	**1**	**1**	**81**	**14**	**14**	**6**	**35**	**54**	**53**	**22**	**4**	**1.50**	**115**	**117**	**3.511**
7°																
Ø. Neådalsvatn	6.19	1	0	29	12	42	5	32	18	14	1	37	1.14	88	89	1.126
Stavsvatn	6.00	1	1	40	9	21	2	16	33	32	3	17	0.73	70	74	1.259
L.Paione S.	5.84	2	2	43	7	8	6	1	36	35	21	4	0.95	62	69	2.211
Etang d'Aube	6.22	1	9	34	6	27	13	29	26	23	9	22	1.08	85	90	1.253
L. Aguilo	6.10	1	0	18	10	9	2	11	13	13	2	7	0.54	33	40	1.273
L. Escura	5.31	5	0	12	23	28	2	6	22	19	0	31	1.33	59	70	0.915
Starolesnianske pleso	4.69	20	3	29	6	3	3	0	52	52	11	3	1.43	66	65	1.233
Laguna Cimera	5.69	2	0	14	9	30	2	17	11	10	20	9	0.42	57	57	3.271
L. Chuna	6.43	0	2	61	16	33	4	37	47	44	4	26	1.50	114	116	1.304
Mean	**5.83**	**4**	**2**	**31**	**11**	**23**	**4**	**17**	**29**	**27**	**8**	**17**	**1.01**	**70**	**74**	**1.538**

Figur 2.19. Clustring of the AL:PE lakes after Ward's method.





2.6 Critical load of acidity to surface waters.

Critical loads and exceedance of critical loads were calculated for all the AL:PE sites where sufficient informations were available. The calculation of both critical load and exceedance were performed on the annual mean value of water analysis for each locality for 1993 or 1994. The figures representing each lake were selected according to an acceptable ion balance, and representativity of the analyses compared to the other data sets from each lake.

Critical loads of acidity for 23 of the AL:PE lakes are shown in Figure 2.22. Øvre Neådalsvatn has a critical load of 0. It means that the lake can not tolerate any load of acidity without causing harm to biological indicators. It also means the original concentration of non-marine base cations was less than 20 µeq/l (compare the ANC_{limit} = 20 µeq/l in the formula). The lakes Lille Hovvatn, Arresjøen, Estany Aguilo, and Laguna Cimera are in the same category.

Many of the AL:PE lakes have a critical load less than 50 keq/km^2/yr: Stavsvatn, Lochnagar, Sandy Loch, Loch Nan Eun, Lago Paione Superiore, Lago Lungo, Schwarzsee ob Sölden, Estany Redo, Starolesnianske Pleso, and Lake Chuna, while the critical loads of Zgornje Krisko Jezero is the only extremely high; 989 keq/km^2/yr.

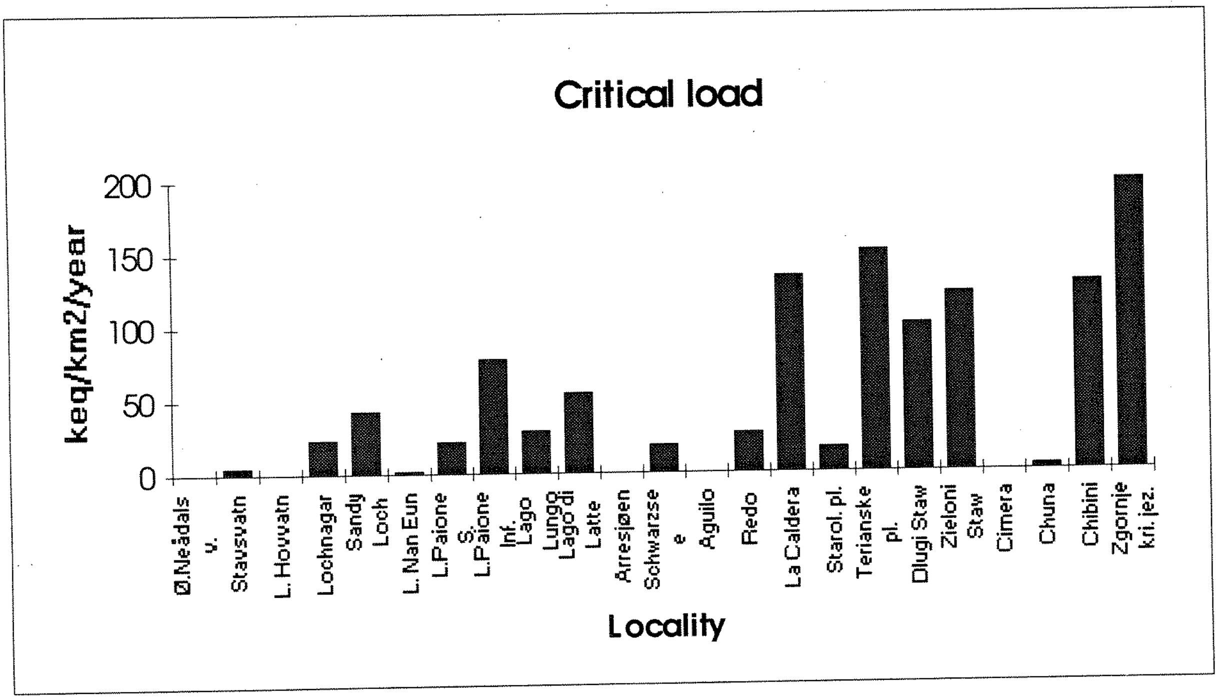


Figure 2.22. Critical load of acidity to AL:PE lakes 1993/94.

Fig. 2 23. shows the exceedance of critical loads of acidity for 23 AL:PE lakes. The exceedance of critical loads are estimated according to deposition of sulphur (CLexS, white bars), and according to deposition of sulphur plus leaching of nitrate from the catchment (CLex S+N, black bars). Negative exceedance means that critical load is not exceeded, and the higher negative values of exceedance, the more acid can be received before the critical level is reached.

The six lakes Lille Hovvatn, Estany Aguilo, Estany Redo, Starolesnianske Pleso, Dlugi Staw, and Zielony Staw show exceedance of critical loads for sulphur. The critical loads of other five lakes: Stavsvatn, Loch Nan Eun, Lago Paione Superiore, Schwarzsee ob Sölden, and Nizne Terianske Pleso are also exceeded, when both sulphur and nitrogen were taken into account. These lakes showed no exceedance of critical load when only the sulphur was estimated. No exceedance of critical load was observed for half of the examined AL:PE lakes.

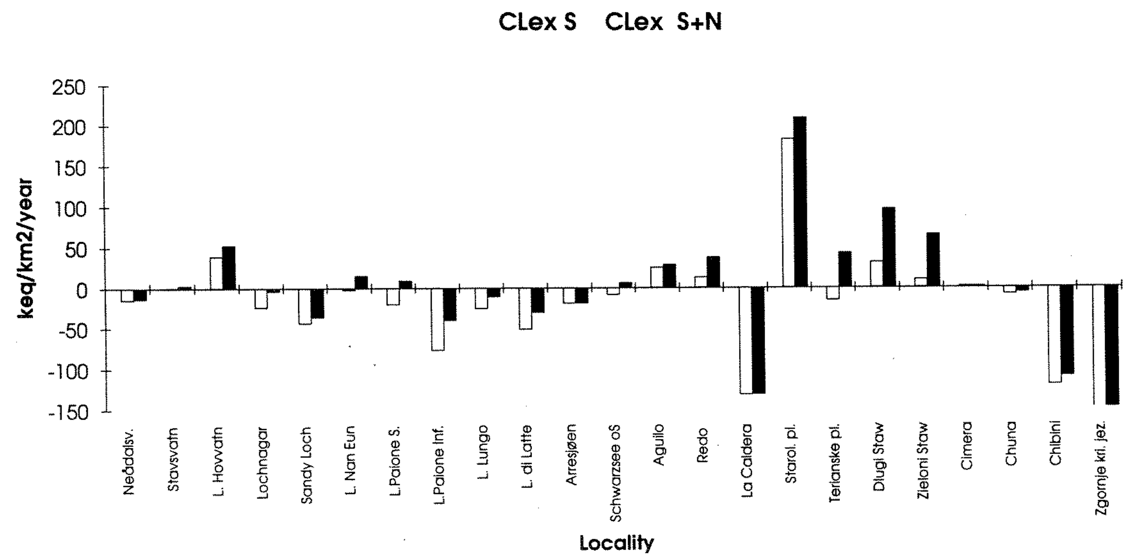


Figure 2.23. Exceedance of critical load of acidity for AL:PE lakes 1993/94.

The importance of nitrogen to the exceedance of the lakes can also be seen in Fig. 2.23. The contribution of nitrogen are highest in the central south-east Europe (Tatra Mts.), decreasing towards west (The Alps), and further reduction to south-west (The Pyrenees) and to southern Spain. A pronounced and gradually reduction is also observed towards north-west from central south-east Europe. None of the lakes was exceeded due to nitrogen only.

2.7 Overall summary and conclusions

Water sampling followed the protocol agreed under the AL:PE 1 project, and the samples were taken from the outlet of the lake. The minimum number of samples required was one yearly sample in the late autumn (at the turnover time for the lake), taken as a representative annual mean sample for the physical-chemical parameters in the lake. Most of the lakes were sampled more frequently than the minimum.

The analytical quality and the comparability of the chemical results were tested by yearly intercomparison exercises, and data validation was given special interest. Confidence in comparability between sites and countries was a basis for our work, and all participants needed to feel secure about the data presented, and relay completely on the reported results from others. The AQC shows satisfactory results for the AL:PE laboratories.

To give an impression of the pollution status of the different lakes and a comparison between the sites, the water chemistry results are compared. The yearly mean pH values range from as low as 4.65 in the most acid Lille Hovvatn to 8.05 in Caldera in the Spanish Sierra Nevada and 7.76 in Zgornje Krisko Jezero in Slovenia. The results also show the acid gradient in Norway from the unpolluted reference lake Øvre Neådalsvatn with annual mean pH values 6.37 and 6.32 via the moderately exposed Stavsvatn (pH close to 6) to Lille Hovvatn, the site in the area most heavily exposed to acid rain. The same gradient is seen for SO_4^{2-}. The high pH values in La Caldera and Z. Krisko Jezero result from high base cation concentrations in the lakewater, especially high Ca^{2+} concentrations. It is also seen that high SO_4^{2-} values may be found in high mountain lakes in all the countries represented in the AL:PE project. The SO_4^{2-} concentrations in Zgornje Krisko Jezero, the Polish Tatras (Dlugi Staw and Zielony Staw) and Italian/Austrian Alps show the highest values registered (yearly mean values of 70 - 100 µeq/l or 3.35 - 4.80 mg/l). Likely in the case of the Zgornje Krisko Jezero there is a contribution of sulphate from the weathering of the watershed, mainly composed by calcareous rocks. Also in the French Alps there are indications that high SO_4^{2-} values in one of the lakes (Lac Noir), are due to impact from geological bands in the watershed, while the concentrations of another nearby lake (Lac Blanc) show lower values, and are more representative for the atmospheric deposition in the area. The lowest SO_4^{2-} values are found as expected, in the reference site Øvre Neådalsvatn, but apart from the reference site, the French and Spanish Pyréneé sites (Étang d'Aubé, lakes Aguilo and Redo) show the lowest values, with the Lac Blanc in the French Alps almost at the same low level.

The Cl^- concentrations indicate the distance from the sea and the seasalt influence at the different sites, and it is clearly seen that Arresjøen and Lough Maam are situated close to the sea. Cl^- are in most of the cases related to Na^+ concentration, indicating that they are mainly deriving from atmospheric deposition. Only in the case of Chibini, located in a minerary area in the Kola Peninsula, there is a strong excess of Na^+ in relation to Cl^-, indicating a relevant contribution of weathering processes for Na^+. Of course also in the case of the other lakes part of the Na^+ derive from silicate weathering.

When comparing the distribution pattern of the NO_3-N concentrations between the sites we find that it is somewhat different from that of SO_4^{2-}. The NO_3-N concentrations in the Tatras are the highest, and there seems to be also a gradient from the north (Svalbard and Norway) to Central Europe (via UK to Italy and the Tatras). In Central Europe a gradient also appears from West to East, from low values in Portugal through Spain and then the Italian Alps to the absolutely highest values in the Tatras. Even the relatively clean site in the French Pyrénées, Étang d'Aubé shows higher values than the highest values in Norway and Spain. Inside Norway the gradient from the reference lake to the most affected lake is clearly seen, but, as noted above, the values are lower than for the other European areas.

For most of the lakes only one sample is taken for the heavy metal analysis. The data then may only indicate possible pollution problems. The results show that Loch Nagar has high Pb concentrations compared to the other lakes. Also Starolesnianske Pleso, Paione Superiore, Lille Hovvatn, Lac Blanc and La Caldera show elevated values for Pb. The results from La Caldera indicates higher values also for Cd. For Hg, Escura and Dlugi Staw show the highest values. Also Schwarssee, Starolesnianske and Zielony Staw show elevated values. All measured values are below the drinking water standards for the European Community

Statistical analysis results summarise the major patterns of variation in lake-water chemistry in the 30 AL:PE lakes. They highlight the contrast in composition between lakes in oceanic areas of northern and western Europe where sea-salts are important and between lakes in southern, central, and eastern Europe where Na and Cl values are below average but where NO_3-N, Ca^{2+}, and SO_4^{2-} concentrationsare above average. There are 10 lakes (Portugal, Spain (including the Pyrenees), the French Pyrenees, central Norway, northern Italy, Kola, and Slovakia with below-average values for all chemical determinands.

Critical loads and exceedance of critical loads were calculated for all the AL:PE sites where sufficient informations were available. The calculation of both critical load and exceedance were performed on the annual mean value of water analysis for each locality for 1993 or 1994. The figures representing each lake were selected according to an acceptable ion balance, and representativity of the analyses compared to the other data sets from each lake. The six lakes Lille Hovvatn, Estany Aguilo, Estany Redo, Starolesnianske Pleso, Dlugi Staw, and Zielony Staw show exceedance of critical loads for sulphur. The critical loads of other five lakes: Stavsvatn, Loch Nan Eun, Lago Paione Superiore, Schwarzsee ob Sölden, and Nizne Terianske Pleso are also exceeded, when both sulphur and nitrogen were taken into account. These lakes showed no exceedance of critical load when only the sulphur was estimated. No exceedance of critical load was observed for half of the examined AL:PE lakes. The importance of nitrogen to the exceedance of critical the loads are highest in the central south-east Europe (Tatra Mts.), decreasing towards west (The Alps), and further reduction to south-west (The Pyrenees) and to southern Spain. A pronounced and gradually reduction is also observed towards north-west from central south-east Europe. None of the lakes was exceeded due to nitrogen only

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Appendix 2. Water chemistry data

Part A.

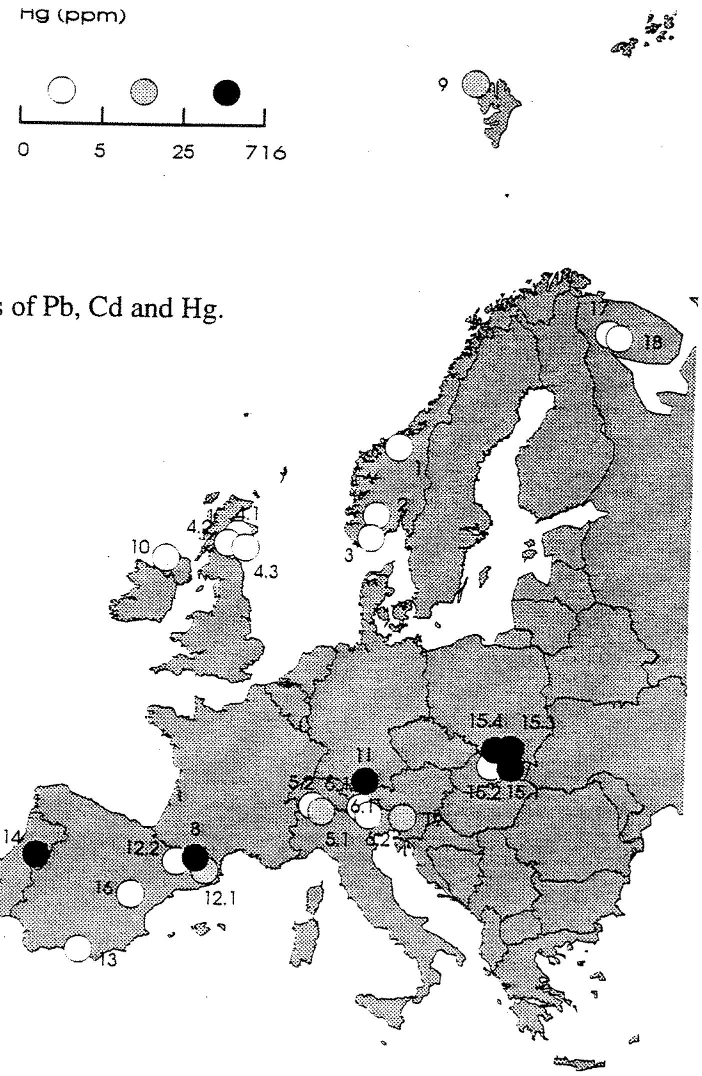
Analytical results for each water sample taken in 1993 and 1994 within the AL:PE programme. Only values for surface water to 0,5 m are given. Results marked with an (N) mean that the analysis is performed at NIVA.

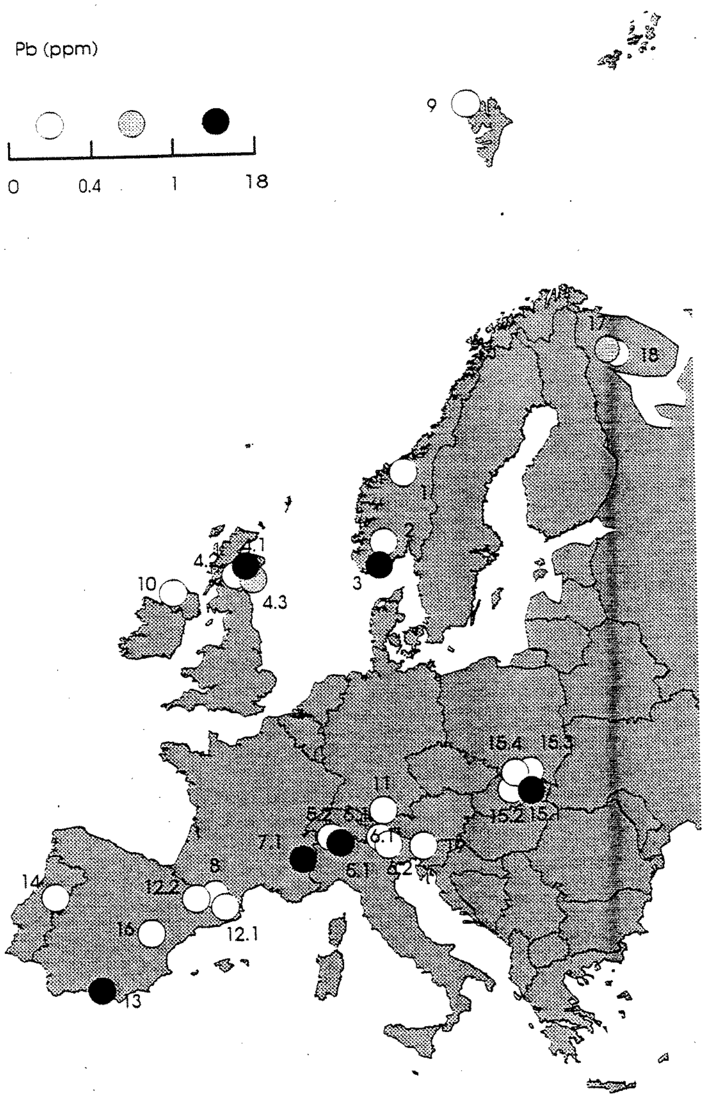
Part B.

Overview of the heavy metal concentrations of Pb, Cd and Hg in the AL:PE lakes.

Part C.

Principal component analysis diagrams of the mean values from each of the AL:PE 1 and AL:PE 2 lakes





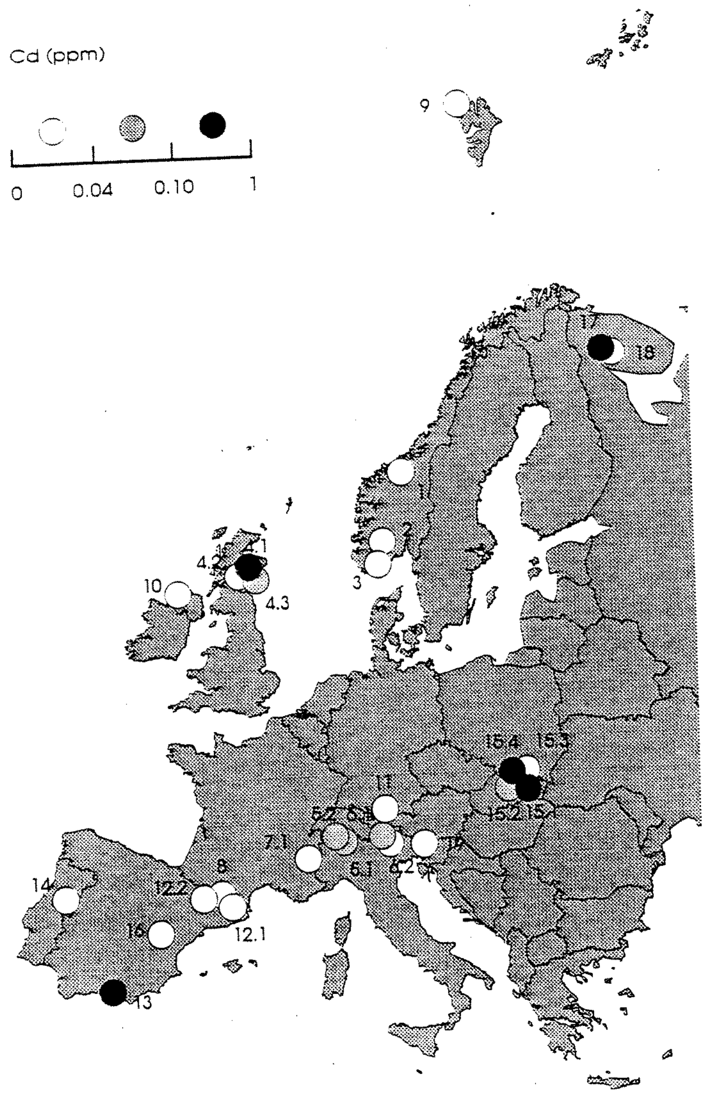


Figure 1. Overview of the heavy metal concentrations of Pb, Cd and Hg.

AL:PE 2 Water chemistry for 1993-1994																										
Lake n°		Date	pH	Cond.	Cond.	NH4	Ca	Mg	Na	K	Alk	SO4	SO4*	NO3	Cl	F	TN	TP	TOC	TAL	RAL	ILAL	LAL	Cd	Pb	Hg
				µS/cm 25°C	mS/m 25°C	µgN/l	mg/l	mg/l	mg/l	mg/l	µeq /l	mg/l	mg/l	µgN/l	mg/l	µg/l	µgN/l	µg/l	mg C/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l
1	Ø. Neådalsvatn	06/06/93	5,96	13,20	1,32		0,47	0,17	1,16	0,14	8	0,80	0,48	28	2,30		57		0,50		10	<10	0			
1	Ø. Neådalsvatn	24/06/93	6,07	10,00	1,00		0,41	0,12	0,96	0,13	21	0,60	0,39	22	1,50		51		0,83		10	<10	0			
1	Ø. Neådalsvatn	08/07/93	6,29	8,20	0,82		0,30	0,10	0,87	0,10	15	0,70	0,55	17	1,10		56		0,62		<10	<10	0			
1	Ø. Neådalsvatn	21/07/93	6,12	10,60	1,06		0,30	0,07	0,68	0,10	15	0,60	0,47	11	0,90		55		0,49		<10	<10	0			
1	Ø. Neådalsvatn	05/08/93	6,00	7,40	0,74		0,34	0,07	0,65	0,10	12	0,60	0,47	4	0,90		36		0,62		<10	<10	0			
1	Ø. Neådalsvatn	27/08/93	6,16	7,10	0,71		0,34	0,07	0,60	0,11	15	0,60	0,52	<1	0,60		75		0,81		10	10	0			
1	Ø. Neådalsvatn	07/09/93	6,28	7,10	0,71		0,35	0,07	0,62	0,10	25	0,60	0,52	<1	0,60		51		0,90		<10	<10				
1	Ø. Neådalsvatn	21/09/93	6,41	7,10	0,71		0,41	0,09	0,60	0,11	25	0,60	0,52	2	0,60		57		0,77		<10	<10				
1	Ø. Neådalsvatn	30/09/93	6,40	7,70	0,77		0,44	0,08	0,73	0,15	28	0,70	0,60	2	0,70		77		0,91		<10	<10	0			
1	Ø. Neådalsvatn	29/10/93	5,94	8,40	0,84	<5	0,39	0,09	0,75	0,15	13	0,70	0,53	15	1,20	<0.1	53	2	0,89		15	11		<0.10	<0.5	<2.0
1	Ø. Neådalsvatn	13/11/93	6,28	1,03	0,10		0,62	0,16	0,97	0,20		0,80	0,62	18	1,30		170		1,10		17	13	4			
1	Ø. Neådalsvatn	24/11/93	6,23	1,21	0,12		0,66	0,17	1,02	0,19		0,90	0,70	17	1,40		78		0,86		15	11	4			
Mean 93	**Ø. Neådalsvatn**	**M 93**	**6,18**	**7,42**	**0,74**		**0,42**	**0,11**	**0,80**	**0,13**	**18**	**0,68**	**0,53**	**14**	**1,09**		**68**	**2**	**0,78**		**13**	**11**	**1**			
1	Øvre Neådalsvatn	06/01/94	6,11	10,00	1,00		0,80	0,15	0,96	0,20	41	1,10	0,95	14	1,10		50		0,60	M 10.00	M 10.00	0				
1	Øvre Neådalsvatn	29/01/94	6,31	10,10	1,01		0,92	0,20	0,99	0,21	49	1,30	1,15	15	1,10		57		0,49							
1	Øvre Neådalsvatn	12/02/94	6,09	12,30	1,23		0,85	0,19	0,94	0,20	48	1,20	1,05	16	1,10		40		0,59	M 10.00	M 10.00	0				
1	Øvre Neådalsvatn	28/02/94	6,17	32,00	3,20		0,97	0,19	1,00	0,73	54	1,90	1,75	19	1,10		74		0,54	M 10.00	M 10.00	0				
1	Øvre Neådalsvatn	12/03/94	5,95	11,60	1,16		0,84	0,18	0,98	0,20	47	1,10	0,96	17	1,00		53		0,56	M 10.00	M 10.00	0				
1	Øvre Neådalsvatn	15/04/94	6,16	13,60	1,36		0,90	0,19	0,92	0,20	50	1,10	0,95	19	1,10		60		0,53	19	M 10.00	9				
1	Øvre Neådalsvatn	24/04/94	5,99	14,00	1,40		1,01	0,19	0,97	0,22	50	1,20	1,03	17	1,20		92		0,59	M 10.00	M 10.00	0				
1	Øvre Neådalsvatn	01/05/94	5,90	22,60	2,26		1,15	0,34	1,98	0,43	31	1,40	0,94	68	3,30		135		1,40	12	9	3				
1	Øvre Neådalsvatn	07/05/94	5,77	21,10	2,11		0,85	0,32	1,85	0,37	21	1,20	0,74	44	3,30		113		1,50	19	M 10.00	9				
1	Øvre Neådalsvatn	17/05/94	6,00	14,20	1,42		0,61	0,22	1,33	0,23	18	0,60	0,25	42	2,50		75		0,69	M 10.00	M 10.00	0				
1	Øvre Neådalsvatn	22/05/94	5,80	14,80	1,48		0,60	0,21	1,35	0,25	19	0,80	0,45	38	2,50		93		0,88	M 10.00	M 10.00	0				
1	Øvre Neådalsvatn	01/06/94	5,90	13,90	1,39		0,65	0,19	1,23	0,23	21	0,90	0,61	36	2,10		89		0,92	12	<10.00	2				
1	Øvre Neådalsvatn	11/06/94	6,15	9,70	0,97		0,42	0,13	0,90	0,18	22	0,70	0,52	31	1,30		71		0,95	<10.00	<10.00	0				
1	Øvre Neådalsvatn	19/06/94	5,90	9,10	0,91		0,36	0,12	0,79	0,17	31	0,60	0,45	23	1,10		72		0,96	18	20	-2				
1	Øvre Neådalsvatn	25/06/94	6,25	7,30	0,73		0,29	0,10	0,64	0,12	15	0,50	0,36	18	1,00		53		0,89	<10.00	<10.00	0				
1	Øvre Neådalsvatn	30/06/94	6,12	8,90	0,89		0,43	0,12	0,81	0,15	21	0,60	0,45	18	1,10		87		0,73	12	11	1				
1	Øvre Neådalsvatn	09/07/94	6,75	7,90	0,79		0,32	0,08	0,62	0,11	20	0,50	0,37	10	0,90		50		0,39	<10.00	<10.00	0				
1	Øvre Neådalsvatn	17/07/94	6,24	6,60	0,66		0,25	0,02	0,63	0,10	21	0,50	0,40	10	0,70		47		0,52	<10.00	<10.00	0				
1	Øvre Neådalsvatn	24/07/94	6,35	7,10	0,71		0,16	0,04	0,66	0,10	24	0,50	0,42	<1.00	0,60		44		0,71	<10.00	<10.00	0				
1	Øvre Neådalsvatn	01/08/94	6,35	7,50	0,75		0,20	0,05	0,68	0,11	21	0,50	0,42	3	0,60		38		0,49	<10.00	<10.00	0				
1	Øvre Neådalsvatn	21/08/94	6,37	7,40	0,74		0,21	0,09	0,70	0,10	42	0,60	0,53	<1.00	0,50		60		0,85	<10.00	11	-1				
1	Øvre Neådalsvatn	28/08/94	6,32	8,30	0,83		0,45	0,10	0,74	0,12	29	0,50	0,43	<1.00	0,50		71		0,78	<10.00	<10.00	0				
1	Øvre Neådalsvatn	05/09/94	6,45	8,10	0,81		0,43	0,10	0,74	0,11	31	0,80	0,70	2	0,70		60		1,01	<10.00	<10.00	0				
1	Øvre Neådalsvatn	12/09/94	6,15	7,60	0,76		0,41	0,08	0,70	0,13	35	0,80	0,69	<1.00	0,80		54		1,02	10	<10.00	0				
1	Øvre Neådalsvatn	18/09/94	6,37	7,60	0,76		0,45	0,06	0,69	0,15	32	0,80	0,70	2	0,70		54		0,94	<10.00	<10.00	0				
1	Øvre Neådalsvatn	26/09/94	6,39	7,80	0,78		0,44	0,08	0,67	0,14	35	0,80	0,69	<1.00	0,80		68		0,86	12	<10.00	2				
1	Øvre Neådalsvatn	02/10/94	6,35	8,00	0,80		0,41	0,08	0,70	0,15	31	0,80	0,69	<1.00	0,80		63		0,93	10	<10.00	0				
1	Øvre Neådalsvatn	08/10/94	6,21	8,50	0,85	<5	0,32	0,05	0,68	0,10		0,70	0,60	4	0,70	<0.1	60	1	0,64	10				<0.10	<0.5	<2.0
1	Øvre Neådalsvatn	13/10/94	6,42	8,90	0,89		0,53	0,13	0,87	0,15		0,70	0,52	5	1,30		65		0,80		10	<10.00	0			
1	Øvre Neådalsvatn	31/10/94	6,30	10,10	1,01		0,54	0,14	1,00	0,21		0,80	0,59	11	1,50		123		0,88		13	<10.00	3			
1	Øvre Neådalsvatn	13/11/94	6,31	9,70	0,97		0,61	0,14	0,93	0,14		0,80	0,63	23	1,20		65		0,95		22	18	4			
1	Øvre Neådalsvatn	04/12/94	6,18	14,90	1,49		0,82	0,21	1,38	0,18		1,10	0,79	28	2,20		50		0,68		16	11	5			
1	Øvre Neådalsvatn	21/12/94	6,14	13,70	1,37		0,88	0,21	1,24	0,18		1,00	0,69	18	2,20		56		0,72		20	14	6			
Mean94	**Øvre Neådalsvatn**	**M94**	**6,19**	**11,36**	**1,14**		**0,58**	**0,14**	**0,95**	**0,19**	**31,81**	**0,86**	**0,68**	**20**	**1,29**		**68**	**1**	**0,79**	**13**	**15**	**2**	**4**			

Lake n°		Date	pH	Cond.	Cond.	NH4	Ca	Mg	Na	K	Alk	SO4	SO4*	NO3	Cl	F	TN	TP	TOC	TAL	RAL	ILAL	LAL	Cd	Pb	Hg
				µS/cm 25°C	mS/m 25°C	µgN/l	mg/l	mg/l	mg/l	mg/l	µeq /l	mg/l	mg/l	µgN/l	mg/l	µg/l	µgN/l	µg/l	mg C/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l
2	Stavsvatn	29/03/93	5,76	12,10	1,21	25	1,02	0,14	0,63	0,11	13	2,00	1,89	64	0,80	0		2	1,00		74	15				
2	Stavsvatn	23/09/93	6,12	10,90	1,09	9	0,82	0,12	0,57	0,08	0	1,60	1,49	22	0,80	2	155	2	1,01		76	22		<0.5	<0.5	<2
Mean 93	**Stavsvatn**	**M 93**	**5,94**	**11,50**	**1,15**	**17**	**0,92**	**0,13**	**0,60**	**0,10**	**7**	**1,80**	**1,69**	**43**	**0,80**	**1**	**155**	**2**	**1,01**		**75**	**19**		**<0.5**	**<0.5**	**<2**
2	Stavsvatn	28/09/94	6,00	7,33		14	0,80	0,11	0,49	0,08	46	1,60	1,52	46	0,60	0,15	135	2	1,30		76	23		<0.10	<5	<2
Mean 94	**Stavsvatn**	**M 94**	**6,00**	**7,33**		**14**	**0,80**	**0,11**	**0,49**	**0,08**	**46**	**1,60**	**1,52**	**46**	**0,60**	**0,15**	**135**	**2**	**1,30**		**76**	**23**		**<0.11**	**<5**	**<2**
3	L. Hovvatn	23/02/93	4,34	47,90	4,79		0,44	0,31	3,10	0,11		2,80	1,92	170	6,30				2,90		245	75				
3	L. Hovvatn	11/05/93	4,58	24,40	2,44		0,42												2,60		228	43				
3	L. Hovvatn	30/06/93	4,63	28,70	2,87		0,40	0,21	1,99	0,12		2,80	2,30	160	3,60				1,30		218	<10				
3	L. Hovvatn	27/07/93	4,86	25,40	2,54		0,53	0,22	1,88	0,11		2,70	2,24	140	3,30				0,86		197	<10				
3	L. Hovvatn	21/09/93	4,85	27,20	2,72		0,53	0,22	1,80	0,12		2,90	2,42	142	3,40				1,40		195	28				
Mean 93	**L. Hovvatn**	**M 93**	**4,65**	**30,72**	**3,07**		**0,46**	**0,24**	**2,19**	**0,12**		**2,80**	**2,22**	**153**	**4,15**				**1,81**		**217**	**49**				
3	Lille Hovvatn	06/01/94	4,54	28,30	2,83		0,49	0,20	1,62	0,09	<4,50	3,40	3,08	215	2,30				3,70		225	109	116			
3	Lille Hovvatn	16/03/94	4,50	33,00	3,30		0,46	0,22	1,78	0,09		3,40	3,04	260	2,60		510		3,40		243	68	175			
3	Lille Hovvatn	31/05/94	4,90	22,60	2,26		0,37	0,16	1,46	0,09	8	3,00	2,68	155	2,30		350		2,40		185	42	143			
3	Lille Hovvatn	03/08/94	4,79	22,40	2,24		0,34				11								1,70		132	20	112			
3	Lille Hovvatn	07/09/94	4,80	20,40	2,04		0,47	0,17	1,12	0,15	<5	2,60	2,35	127	1,80		475		3,60		152	61	91			
3	Lille Hovvatn	07/09/94	4,57	21,40	2,14	19	0,35	0,15	1,22	0,10		3,00	2,73	126	1,90	<0,1	335	6	2,50		134	48	86	<0,10	1,9	<2,0
3	Lille Hovvatn	02/11/94	4,60	20,70	2,07		0,39	0,17	1,29	0,14	7	3,10	2,79	149	2,20		425		3,90		185	67	118			
Mean 94	**Lille Hovvatn**	**M 94**	**4,67**	**24,11**	**2,41**	**19,00**	**0,41**	**0,18**	**1,42**	**0,11**	**8,67**	**3,08**	**2,78**	**172**	**2,18**		**419**	**6**	**3,03**		**179**	**59**	**120**		**1,90**	
9	Arresjøen	13/08/93	5,59	37,60	3,76	5	0,71	0,59	4,77	0,24	20	1,60	0,45	<1	8,20	<0.1	116	4	0,47		<10	<10	0	<0.1	<0.5	23,5
9	Arresjøen	17/08/93	6,03	37,50	3,75	<5	0,70	0,59	4,74	0,24	27	1,50	0,34	<1	8,30	<0.1	71	4	0,39		<10	<10	0	<0.1	<0.5	10,5
Mean 93	**Arresjøen**	**M 93**	**5,81**	**37,55**	**3,76**	**5**	**0,71**	**0,59**	**4,76**	**0,24**	**24**	**1,55**	**0,40**	**<1**	**8,25**	**<0.1**	**94**	**4**	**0,43**		**<10**	**<10**	**0**	**<0.1**	**<0.5**	**17,0**
4.1 (N)	Lochnagar	R 15.10.93	5,53	22,30	2,23	74	0,52	0,36	2,10	0,43	14	2,90	2,48	235	3,00	<0.1	510	3	0,69		55	51		0,99	17,6	
4.1 (N)	Lochnagar	R 22.11.93																								<2.0
4,1	Lochnagar	09/03/93	5,01	28,00	2,80		0,62	0,31	2,65	0,27		2,74	2,15	294	4,20				1,00		147	10	137			
4,1	Lochnagar	05/06/93	5,61	23,00	2,30		0,66	0,36	2,09	0,20	15	2,74	2,32	252	2,98				0,30		9	5	4			
4,1	Lochnagar	07/07/93	5,26	22,00	2,20		0,56	0,30	1,96	0,16	9	2,54	2,15	238	2,84				0,50		28	10	18			
4,1	Lochnagar	30/08/93	5,38	21,00	2,10		0,56	0,32	2,00	0,20	12	2,83	2,41	238	3,05				0,70		23	10	13			
4,1	Lochnagar	01/09/93	5,70	22,00	2,20		0,80	0,29	2,05	0,39	17	2,69	2,27	224	3,01				0,60		6	4	2			
4,1	Lochnagar	04/12/93	4,95	27,00	2,70		0,50	0,46	2,12	0,31	0	3,22	2,74	266	3,40				1,60		105	34	71			
Mean 93	**Lochnagar**	**M 93**	**5,35**	**23,61**	**2,36**	**74,00**	**0,60**	**0,34**	**2,14**	**0,28**	**11,17**	**2,81**	**2,36**	**250**	**3,21**		**510**	**3**	**0,77**		**53**	**18**	**41**	**0,99**	**####**	
4,1	Lochnagar	28/03/94	5,05	29,00	2,90	84	0,74	0,57	2,92	0,31	-5	2,93	2,27	392	4,68			18	0,70	125		16	109			
4,1	Lochnagar	01/07/94	5,26	22,00	2,20	0	0,66	0,47	2,23	0,23	-3	2,59	2,15	280	3,19				0,90	40		17	23			
4,1	Lochnagar	24/08/94	5,30	20,00	2,00	0	0,78	0,46	2,07	0,39	-3	2,59	2,18	266	2,94				0,60	19		12	7			
4,1	Lochnagar	04/09/94	5,40	20,00	2,00	70	0,96	0,57	2,07	0,27	-3	2,79	2,39	266	2,84				0,50	25		10	15			
Mean 94	**Lochnagar**	**M 94**	**5,25**	**22,75**	**2,28**	**39**	**0,79**	**0,52**	**2,32**	**0,30**	**-4**	**2,73**	**2,25**	**301**	**3,41**			**18**	**0,68**	**52**		**14**	**39**			
4.2 (N)	Sandy Loch	R 15.10.93	5,70	19,70	1,97	60	0,68	0,36	1,94	0,22	24	2,80	2,44	143	2,60	<0.1	390	3	1,80		60	68		<0.05	<0.5	
4.2 (N)	Sandy Loch	R 22.11.93		0,00																						3,0
4,2	Sandy Loch	06/06/93	5,86	19,00	1,90		0,88	0,24	1,79	0,20	15	2,50	2,18	126	2,24				0,70		12	10	2			
4,2	Sandy Loch	11/06/93	5,89	18,00	1,80		0,60	0,20	1,70	0,16	19	2,54	2,23	126	2,28				1,10		15	12	3			
4,2	Sandy Loch	30/08/93	6,39	19,00	1,90		0,78	0,24	2,02	0,12	37	2,59	2,25	70	2,45				1,50		7	7	0			
4,2	Sandy Loch	05/09/93	6,23	20,00	2,00		1,04	0,24	2,02	0,12	37	2,59	2,25	70	2,45				1,00		7	6	1			
Mean 93	**Sandy Loch**	**M 93**	**6,01**	**15,95**	**1,91**	**60,00**	**0,80**	**0,26**	**1,90**	**0,16**	**26,40**	**2,60**	**2,27**	**107**	**2,40**		**390**	**3**	**1,22**		**20**	**21**	**2**			**3,00**
4,2	Sandy Loch	24/08/94	5,05	18,00	1,80	0	1,04	0,41	2,02	0,20	9	2,55	2,22	112	2,30				2,70	59		54	5			
Mean 94	**Sandy Loch**	**M 94**	**5,05**	**18,00**	**1,80**	**0**	**1,04**	**0,41**	**2,02**	**0,20**	**9**	**2,55**	**2,22**	**112**	**2,30**				**2,70**	**59**		**54**	**5**			
4.3 (N)	L.Nan Eun	R 14.10.93																						0,05	0,7	
4.3 (N)	L.Nan Eun	R 22.11.93																								<2.0
4,3	L.Nan Eun	19/02/93	5,35	81,00	8,10		0,84	1,14	10,65	0,47	11	3,07	0,19	0	20,62				1,90		5	5	0			

Lake n°		Date	pH	Cond.	Cond.	NH4	Ca	Mg	Na	K	Alk	SO4	SO4*	NO3	Cl	F	TN	TP	TOC	TAL	RAL	ILAL	LAL	Cd	Pb	Hg
				µS/cm 25°C	mS/m 25°C	µgN/l	mg/l	mg/l	mg/l	mg/l	µeq /l	mg/l	mg/l	µgN/l	mg/l	µg/l	µgN/l	µg/l	mg C/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l
4,3	L.Nan Eun	26/05/93	6,10	64,00	6,40		0,84	0,97	8,99	0,43	27	2,40	0,20	0	15,72				3,80		4	4	0			
4,3	L.Nan Eun	11/06/93	5,04	21,00	2,10		0,52	0,23	1,73	0,16	2	2,54	2,17	280	2,66				1,00		73	4	69			
4,3	L.Nan Eun	11/07/93	5,62	29,00	2,90		0,42	0,41	4,39	0,12	18	0,96	0,00	0	6,83				4,30		12	9	3			
4,3	L.Nan Eun	13/07/93	5,11	20,00	2,00		0,58	0,23	1,66	0,12	4	2,40	2,04	266	2,59				0,50		44	7	37			
4,3	L.Nan Eun	30/08/93	5,15	20,00	2,00		0,56	0,23	1,70	0,12	6	2,45	2,10	238	2,52				0,50		53	8	45			
Mean 93	**L.Nan Eun**	**M 93**	**5,40**	**39,17**	**3,92**		**0,63**	**0,53**	**4,85**	**0,23**	**11**	**2,30**	**1,12**	**131**	**8,49**				**2,00**		**32**	**6**	**26**			
4,3	Loch Nan Eun	24/08/94	5,06	19,00	1,90	0	0,68	0,30	1,75	0,16	-7	2,35	1,99	266	2,59				0,60	55		7	48			
Mean 94	**L.Nan Eun**	**M 94**	**5,06**	**19,00**	**1,90**	**0**	**0,68**	**0,30**	**1,75**	**0,16**	**-7**	**2,35**	**1,99**	**266**	**2,59**				**0,60**	**55**		**7**	**48**			
10 (N)	L. Maam	10/09/93	5,45	27,80	2,78	18	0,45	0,40	4,13	0,16		1,80	0,89	55	6,50	<0.1	285	4			79	70		<0.1	<0.5	3,0
10	L. Maam	23/03/93	4,97	100,00	10,00		1,20	1,42	12,97	0,51	0	4,66	1,38	56	23,42				2,70		60	35	25			
10	L. Maam	26/04/93	4,24	54,00	5,40		0,86	0,65	6,90	0,35	9	2,45	0,69	28	12,53				3,00		38	28	10			
10	L. Maam	23/05/93	5,26	54,00	5,40		0,72	0,68	7,41	0,47	9	2,88	1,01	42	13,34				2,60		48	38	10			
10	L. Maam	10/09/93	5,36	30,00	3,00		0,46	0,30	4,07	0,16	10	1,73	0,85	56	6,27				4,60		68	58	10			
Mean 93	**L. Maam**	**M 93**	**4,96**	**59,50**	**5,95**		**0,81**	**0,76**	**7,84**	**0,37**	**7**	**2,93**	**0,98**	**46**	**13,89**			**4**	**3,23**		**54**	**40**	**14**			
5.1 (N)	L.Paione Sup.	21/09/93	5,53	11,00	1,10	34	0,91	0,07	0,13	0,26	31	2,20	2,17	340	0,20	<<0.1	415	3	0,33		25	<10	<0.1	0,09	1,4	11,0
5,1	L.Paione S.	12/01/93	5,78	11,11	1,11	10	1,02	0,10	0,24	0,27	1	2,31	2,29	288	0,11		298	2		34						
5,1	L.Paione S.	09/03/93	5,81	11,29	1,13	6	1,10	0,12	0,25	0,26	1	2,29	2,27	275	0,13		281	3		28						
5,1	L.Paione S.	25/05/93	5,36	17,29	1,73	152	1,34	0,14	0,28	0,41	-2	3,00	2,98	604	0,15		756	3		135						
5,1	L.Paione S.	29/06/93	5,55	10,52	1,05	79	0,98	0,11	0,26	0,26	-3	1,83	1,81	351	0,16		430	1		90						
5,1	L.Paione S.	07/07/93	5,52	10,07	1,01	66	0,89	0,09	0,20	0,23	1	1,88	1,86	348	0,14		414	2		68						
5,1	L.Paione S.	27/07/93	5,66	10,60	1,06	42	0,95	0,10	0,20	0,23	-6	1,96	1,95	366	0,09		408	5		43						
5,1	L.Paione S.	21/09/93	5,58	11,32	1,13	30	0,98	0,11	0,22	0,26	-2	2,27	2,25	339	0,11		369	1		48						
5,1	L.Paione S.	09/11/93	5,66	10,72	1,07	25	0,87	0,10	0,22	0,25	0	2,15	2,13	285	0,13		310	2		45						
Mean 93	**L.Paione S.**	**M 93**	**5,61**	**11,55**	**1,15**	**49,33**	**1,00**	**0,10**	**0,22**	**0,27**	**2,33**	**2,21**	**2,19**	**355**	**0,14**		**409**	**2**	**0,33**	**61**	**25**			**0,09**	**1,35**	**11,00**
5,1	L.Paione S.	05/07/94	5,70	9,20	0,92	42	0,77	0,08	0,19	0,16	2	1,50	1,48	293	0,12		335	5								
5,1	L.Paione S.	26/07/94	5,84	8,09	0,81	38	0,73	0,07	0,15	0,18	0	1,48	1,47	242	0,10		280	4								
5,1	L.Paione S.	13/09/94	5,76	10,30	1,03	41	0,90	0,10	0,19	0,27	0	1,92	1,90	329	0,14		370	6								
5,1	L.Paione S.	27/10/94	6,05	10,59	1,06	14	1,05	0,11	0,23	0,31	3	1,98	1,96	331	0,17		345	3								
Mean 94	**L.Paione S.**	**M 94**	**5,84**	**9,54**	**0,95**	**34**	**0,86**	**0,09**	**0,19**	**0,23**	**1**	**1,72**	**1,70**	**299**	**0,13**		**333**	**5**								
5.2 (N)	L.Paione Inf.	21/09/93	6,39	13,30	1,33	14	1,50	0,11	0,25	0,33	8	2,70	2,67	365	0,20	<0.1	415	3	0,66		<10	<10	<0.1	0,07	<0.5	4,0
5,2	L.Paione Inf.	12/01/93	6,56	14,96	1,50	3	1,66	0,15	0,35	0,38	34	2,74	2,72	326	0,12		329	1		10						
5,2	L.Paione Inf.	09/03/93	6,49	15,78	1,58	4	1,92	0,17	0,35	0,36	40	2,75	2,73	326	0,13		330	1		10						
5,2	L.Paione Inf.	25/05/93	6,21	14,96	1,50	14	1,67	0,15	0,32	0,30	26	2,40	2,38	442	0,15		456	3								
5,2	L.Paione Inf.	29/06/93	6,38	12,86	1,29	11	1,52	0,15	0,29	0,31	15	2,33	2,31	439	0,13		450	1								
5,2	L.Paione Inf.	07/07/93	6,42	13,44	1,34	7	1,60	0,16	0,31	0,33	20	2,40	2,38	455	0,12		462	1								
5,2	L.Paione Inf.	27/07/93	6,61	14,38	1,44	3	1,68	0,16	0,33	0,37	22	2,62	2,60	414	0,12		417	5								
5,2	L.Paione Inf.	21/09/93	6,39	14,03	1,40	3	1,50	0,14	0,31	0,31	22	2,66	2,64	346	0,13		349	1								
5,2	L.Paione Inf.	09/11/93	6,37	13,21	1,32	5	1,41	0,14	0,26	0,29	24	2,48	2,46	297	0,14		302	1								
Mean 93	**L.Paione Inf.**	**M 93**	**6,43**	**14,20**	**1,42**	**6**	**1,62**	**0,15**	**0,31**	**0,33**	**25**	**2,55**	**2,53**	**381**	**0,13**		**387**	**2**		**10**						
5,2	L.Paione Inf.	25/01/94	6,49	15,55	1,55	4	1,76	0,16	0,35	0,30	41	2,73	2,71	332	0,15		336	1								
5,2	L.Paione Inf.	31/05/94	6,39	13,68	1,37	11	1,45	0,15	0,37	0,29	17	2,28	2,25	454	0,18		465	1								
5,2	L.Paione Inf.	23/06/94	6,48	12,16	1,22	3	1,32	0,13	0,26	0,22	17	2,10	2,09	364	0,10		367	1								
5,2	L.Paione Inf.	05/07/94	6,50	12,63	1,26	6	1,34	0,13	0,30	0,17	19	2,18	2,16	374	0,16		380	2								
5,2	L.Paione Inf.	26/07/94	6,60	12,86	1,29	14	1,43	0,13	0,29	0,34	23	2,30	2,28	334	0,12		348	3								
5,2	L.Paione Inf.	13/09/94	6,58	13,79	1,38	8	1,58	0,14	0,30	0,35	28	2,47	2,45	327	0,12		335	3								
5,2	L.Paione Inf.	27/10/94	6,70	14,14	1,41	2	1,66	0,15	0,33	0,39	34	2,48	2,46	320	0,16		322	1								
Mean 94	**L.Paione Inf.**	**M 94**	**6,53**	**13,54**	**1,35**	**7**	**1,51**	**0,14**	**0,31**	**0,29**	**26**	**2,36**	**2,34**	**358**	**0,14**		**365**	**2**								

Lake n°		Date	pH	Cond. µS/cm 25°C	Cond. mS/m 25°C	NH4 µgN/l	Ca mg/l	Mg mg/l	Na mg/l	K mg/l	Alk µeq /l	SO4 mg/l	SO4* mg/l	NO3 µgN/l	Cl mg/l	F µg/l	TN µgN/l	TP µg/l	TOC mg C/l	TAL µg/l	RAL µg/l	ILAL µg/l	LAL µg/l	Cd µg/l	Pb µg/l	Hg ng/l
6.1 (N)	Lago Lungo	20/09/93	6,53	13,40	1,34	9	1,56	0,15	0,27	0,22	60	2,60	2,60	150	<0.2	<0.1	360	7	0,90		<10	<10	0	0,06	<0.5	<2
6,1	Lago Lungo	01/02/93	6,34	14,10	1,41	15	1,71	0,19	0,42	0,33	31	3,60	3,58	184	0,15		241	3								
6,1	Lago Lungo	31/03/93	6,01	17,70	1,77	29	2,22	0,25	0,50	0,38	33	4,60	4,57	258	0,18		319	6								
6,1	Lago Lungo	12/07/93	6,51	11,50	1,15	6	1,43	0,16	0,33	0,24	30	2,70	2,68	196	0,11			4								
6,1	Lago Lungo	02/08/93	6,47	11,70	1,17	3	1,42	0,15	0,31	0,22	28	2,90	2,88	176	0,11		239	4								
6,1	Lago Lungo	20/09/93	6,83	12,10	1,21	5	1,43	0,16	0,35	0,24	27	3,00	2,98	146	0,14		211	6								
6,1	Lago Lungo	06/12/93	6,43	13,70	1,37	4	1,57	0,25	0,46	0,33	30	3,40	3,37	209	0,19		210	4								
Mean 93	**Lago Lungo**	**M 93**	**6,43**	**13,47**	**1,35**	**10**	**1,63**	**0,19**	**0,40**	**0,29**	**30**	**3,37**	**3,35**	**195**	**0,15**		**244**	**4**								
6,1	Lago Lungo	05/09/94	6,76	11,82	1,30	1	1,31	0,15	0,27	0,18	28	2,81	2,80	137	0,07			6								
6,1	Lago Lungo	18/07/94	6,20	10,89	1,20	10	1,31	0,13	0,23	0,17	24	2,54	2,52	220	0,13			4								
6,1	Lago Lungo	10/05/94	5,58	15,13	1,66	101	1,46	0,17	0,32	0,19	16	3,30	3,28	409	0,16		654									
6,1	Lago Lungo	24/01/94	6,14	13,10	1,44	13	1,49	0,16	0,31	0,18	40	2,84	2,82	142	0,12		240	4								
Mean94	**Lago Lungo**	**M94**	**6,17**	**12,74**	**1,40**	**31**	**1,39**	**0,15**	**0,28**	**0,18**	**27**	**2,87**	**2,86**	**227**	**0,12**		**447**	**5**								
6.2 (N)	Lago di Latte	21/09/93	6,71	17,00	1,70	9	2,16	0,15	0,34	0,33	86	2,70	2,70	320	<0.2	<0.1	440	2	0,90		<10	<10		0,05	<0.5	<2
6,2	Lago di Latte	20/01/93	6,44	15,30	1,53	11	1,98	0,15	0,41	0,42	43	2,80	2,79	324	0,10			2								
6,2	Lago di Latte	05/05/93	6,37	16,10	1,61	22	2,11	0,17	0,44	0,41	45	3,10	3,07	369	0,18		411	3								
6,2	Lago di Latte	13/07/93	6,64	14,70	1,47	4	1,91	0,15	0,41	0,37	64	2,70	2,68	303	0,11		268	3								
6,2	Lago di Latte	03/08/93	6,81	14,40	1,44	4	1,83	0,15	0,36	0,33	53	2,70	2,69	301	0,10		340	2								
6,2	Lago di Latte	21/09/93	6,67	15,80	1,58	9	2,03	0,15	0,41	0,40	61	2,90	2,88	306	0,13		382	5								
6,2	Lago di Latte	13/12/93	6,67	15,40	1,54	5	1,84	0,21	0,50	0,39	54	2,90	2,86	324	0,27		386	4								
Mean 93	**Lago di Latte**	**M 93**	**6,60**	**15,28**	**1,53**	**9**	**1,95**	**0,16**	**0,42**	**0,39**	**53**	**2,85**	**2,83**	**321**	**0,15**		**357**	**3**								
6,2	Lago di Latte	06/09/94	6,79	15,99	1,76	0	1,92	0,15	0,35	0,30	58	3,00	3,00	244	0,03		390	5								
6,2	Lago di Latte	21/07/94	6,27	11,86	1,30	19	1,53	0,10	0,25	0,28	38	2,26	2,24	292	0,14		460									
6,2	Lago di Latte	09/05/94	6,08	15,60	1,72	97	1,84	0,13	0,29	0,28	41	2,95	2,93	388	0,17		575									
6,2	Lago di Latte	24/01/94	6,26	15,60	1,72	15	2,05	0,14	0,33	0,28	66	2,63	2,61	288	0,12		468	2								
Mean94	**Lago di Latte**	**M94**	**6,35**	**14,76**	**1,62**	**33**	**1,84**	**0,13**	**0,31**	**0,29**	**51**	**2,71**	**2,69**	**303**	**0,12**		**473**	**4**								
7.3 (N)	Blanc	06/11/93	7,10	20,50	2,05	12	2,45	0,40	0,80	0,48		1,80	1,77	265	0,20	0	345	5	1,11		<10	<10		<0.1	1,2	
7,3	Blanc	24/07/93	6,70	9,00	0,90		1,10	0,16	0,10			0,40	0,40	136		140		6		51						
7,3	Blanc	24/07/93	6,76	11,00	1,10		1,40	0,18	0,20			0,50	0,50	113		130		6		42						
7,3	Blanc	24/07/93	6,76	10,00	1,00		1,10	0,17	0,10			0,50	0,50	113		130				55						
7,3	Blanc	24/07/93	6,80	10,00	1,00		1,30	0,17	0,10			0,40	0,40	113		140				43						
7,3	Blanc	04/11/93	7,04	20,00	2,00		3,00	0,04	0,80			1,90	1,90	249												
Mean 93	**Blanc**	**M 93**	**6,81**	**12,00**	**1,20**		**1,58**	**0,14**	**0,26**			**0,74**	**0,74**	**145**		**135**		**6**		**48**						
7,3	Blanc	12/10/94	7,02	14,03	1,40	27	1,50	0,23	0,30	0,40	72	1,30	1,29	200	0,10		227	3								
Mean 94	**Blanc**	**M 94**	**7,02**	**14,03**	**1,40**	**27**	**1,50**	**0,23**	**0,30**	**0,40**	**72**	**1,30**	**1,29**	**200**	**0,10**		**227**	**3**								
7,4	Noir	24/07/93	7,30	24,00	2,40	0	3,50	0,33	0,20			0,90	0,90	113		50		33		6						
7,4	Noir	24/07/93	6,80	16,00	1,60	0	1,90	0,32	0,20			0,90	0,90	113		60		29		9						
7,4	Noir	24/07/93	7,01	17,00	1,70	0	2,00	0,33	0,20			0,80	0,80	113		60		33		9						
7,4	Noir	24/07/93	7,00	17,00	1,70	0	2,10	0,33	0,20			1,00	1,00	113		6				7						
7,4	Noir	04/11/93	7,23	25,00	2,50	0	3,50	0,45	0,80	0,30		2,10	2,10	203				29								
Mean 93	**Noir**	**M 93**	**7,07**	**19,80**	**1,98**	**0**	**2,60**	**0,35**	**0,32**			**1,14**	**1,14**	**131**		**44**		**31**		**8**						
7,4	Noir	12/10/94	7,09	19,87	1,99	7	2,50	0,40	0,30	0,18	92	3,20	3,17	155	0,20		162	31								
Mean 94	**Noir**	**M 94**	**7,09**	**19,87**	**1,99**	**7**	**2,50**	**0,40**	**0,30**	**0,18**	**92**	**3,20**	**3,17**	**155**	**0,20**		**162**	**31**								
8	Etang d'Aube	15/07/93	6,00	8,00	0,80	<14	0,64	0,10	0,35	0,12	12	1,25	1,22	140	0,25											
8(N)	Etang d'Aube		6,32	13,60	1,36	139	0,71	0,07	0,85	0,82	37	1,20	1,03	136	1,20	<0.1	690	5	0,90		<10	<10		<0.1	<0.5	14,0
8	Etang d'Aube	13/10/93	6,12	7,91	0,79	126	0,64	0,07	0,41	0,20	20	1,25	1,20	126	0,35											
Mean 93	**Etang d'Aube**	**M 93**	**6,22**	**10,76**	**1,08**	**133**	**0,68**	**0,07**	**0,54**	**0,51**	**29**	**1,23**	**1,12**	**131**	**0,60**		**690**	**5**	**0,90**							**14,0**
8	Etang d'Aube	31/08/94	6,17	7,00	0,70	46	0,55	0,07	0,42	0,11	48	1,10	1,06	127	0,30			1								35,0

Lake n°		Date	pH	Cond.	Cond.	NH4	Ca	Mg	Na	K	Alk	SO4	SO4*	NO3	Cl	F	TN	TP	TOC	TAL	RAL	ILAL	LAL	Cd	Pb	Hg
				µS/cm 25°C	mS/m 25°C	µgN/l	mg/l	mg/l	mg/l	mg/l	µeq /l	mg/l	mg/l	µgN/l	mg/l	µg/l	µgN/l	µg/l	mg C/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l
8	Etang d'Aube	09/09/94	6,05	6,71	0,67	14	0,56	0,07	0,32	0,08	12	0,58	0,53	308	0,32					13						
Mean94	**Etang d'Aube**	**M94**	**6,11**	**6,86**	**0,69**	**30**	**0,56**	**0,07**	**0,37**	**0,09**	**30**	**0,84**	**0,79**	**218**	**0,31**			**1**		**13**						**35,0**
11 (N)	Schwarzsee ob Sölden	18/08/93	5,16	15,60	1,56	8	1,14	0,21	0,22	0,10		3,70	3,66	200	0,30	<0.1	290	2	0,41		43	<10		<0.1	<0.5	
11	Schwarzsee ob Sölden	02/07/93	5,49	9,40	0,94	14	0,84	0,16	0,23	0,08	0	2,43	2,42	115	0,06	4		3			38					
11	Schwarzsee ob Sölden	18/08/93	5,85	12,80	1,28	3	1,07	0,24	0,29	0,11	0	3,90	3,89	97	0,07	4		2			18					
11	Schwarzsee ob Sölden	20/09/93	5,33	16,80	1,68	9	1,14	0,25	0,32	0,13	0	3,70	3,69	320	0,10	5		2			28					
Mean 93	**Schwarzsee ob Sölder**	**M 93**	**5,56**	**13,00**	**1,30**	**9**	**1,02**	**0,22**	**0,28**	**0,11**	**0**	**3,34**	**3,33**	**177**	**0,08**	**4**		**3**			**28**					
11	Schwarzsee ob Sólden	14/01/94	5,80	16,85	1,69	22	1,51	0,31	0,43	0,17	9	4,50	4,49	170	0,11	6,00		3	0,45		1					
11	Schwarzsee ob Sólden	23/02/94	5,77	16,40	1,64	27	1,50	0,31	0,40	0,15	6	4,90	4,89	145	0,11	5,00		5	0,40		1					
11	Schwarzsee ob Sólden	28/03/94	5,68	16,20	1,62	30	1,47	0,30	0,40	0,17	6	4,00	3,98	140	0,14	6,00		5	0,30		1					
11	Schwarzsee ob Sólden	20/04/94	5,54	16,72	1,67	26	1,43	0,30	0,39	0,16	17	5,00	4,99	140	0,12	7,00		5	0,25		1					
11	Schwarzsee ob Sólden	11/05/94	5,66	18,08	1,81	32	1,45	0,31	0,37	0,16	3	4,40	4,39	180	0,10	5,00		4	0,35		1					
11	Schwarzsee ob Sólden	31/05/94	5,35	15,77	1,58	47	1,38	0,26	0,32	0,15	8	3,70	3,68	210	0,16	4,00		3	0,45		1					
11	Schwarzsee ob Sólden	12/07/94	5,38	11,20	1,12	16	0,95	0,20	0,35	0,11	2	2,80	2,79	140	0,10	4,00		2	0,25		1					
11	Schwarzsee ob Sólden	01/09/94	5,65	16,22	1,62	3	1,20	0,30	0,36	0,14	7	3,90	3,89	105	0,09	5,00		9			1					
11	Schwarzsee ob Sólden	09/09/94																								68,0
Mean94	**Schwarzsee ob Sóldei**	**M94**	**5,60**	**15,93**	**1,59**	**25**	**1,36**	**0,29**	**0,38**	**0,15**	**7**	**4,15**	**4,14**	**154**	**0,12**	**5,25**		**4**	**0,35**		**1**					
12.1 (N)	Aguilo	19/10/93	5,61	6,10	0,61	15	0,49	0,08	0,19	0,06	-7	0,90	0,86	48	0,30	<0.1	147	2	0,73		<10	12		<0.5	<0.5	9,0
12,1	L. Aguilo	19/10/93	5,79	6,40	0,64	7	0,44	0,16	0,21	0,08	18	0,72	0,70	42	0,18			5	1,28							
Mean 93	**L. Aguilo**	**M 93**	**5,79**	**6,40**	**0,64**	**7**	**0,44**	**0,16**	**0,21**	**0,08**	**18**	**0,72**	**0,70**	**42**	**0,18**			**5**	**1,28**							
12,1	Lago Aguilo	10/10/94	6,10	5,40	0,54	7	0,37	0,12	0,20	0,07	11	0,64	0,61	30	0,25			5	0,59							
Mean 94	**L. Aguilo**	**M 94**	**6,10**	**5,40**	**0,54**	**7**	**0,37**	**0,12**	**0,20**	**0,07**	**11**	**0,64**	**0,61**	**30**	**0,25**			**5**	**0,59**							
12,2	L. Redo	16/10/93	6,32	12,30	1,23	15	1,50	0,17	0,21	0,08	42	1,49	1,46	196	0,18			4	0,95							
Mean 93	**L. Redo**	**M 93**	**6,32**	**12,30**	**1,23**	**15**	**1,50**	**0,17**	**0,21**	**0,08**	**42**	**1,49**	**1,46**	**196**	**0,18**			**4**	**0,95**							
12,2	Lago Redo	11/10/94	6,69	11,80	1,18	8	1,41	0,15	0,23	0,08	44	1,12	1,08	155	0,28			7	0,63							
Mean 94	**L. Redo**	**M 94**	**6,69**	**11,80**	**1,18**	**8**	**1,41**	**0,15**	**0,23**	**0,08**	**44**	**1,12**	**1,08**	**155**	**0,28**			**7**	**0,63**							
13	La Caldera	14/07/93	8,46	22,00	2,20	9	3,58	0,33	0,31	0,12	180	0,80	0,75	124	0,37		266	12	3,22	29				1,30	0,6	0,8
13	La Caldera	07/09/93	7,64	30,00	3,00	51	4,31	0,43	0,49	0,11	209	0,98	0,88	25	0,72		223	8	2,94	35				0,40	1,5	1,0
Mean 93	**La Caldera**	**M 93**	**8,05**	**26,00**	**2,60**	**30**	**3,95**	**0,38**	**0,40**	**0,12**	**195**	**0,89**	**0,82**	**75**	**0,54**		**244**	**10**	**3,08**	**32**				**0,85**	**1,1**	**0,9**
13	La Caldera	20/07/94	8,40	22,00	2,20	1	4,56	0,46	0,93	0,22	270	0,85		72	0,49		84	9	1,39					0,20	1,6	<1
13	La Caldera	02/08/94	8,10	30,00	3,00	28	4,37	0,56	2,85	0,83	268	1,14		103	1,26		528	12	4,48					0,30	10,0	<1
13	La Caldera	01/09/94	7,85	36,00	3,60	67	6,44	0,58	1,14	0,25	284	1,45		25	0,81		107	12	1,88					0,10	5,0	<1
13	La Caldera	13/09/94	7,31	32,00	3,20	87	5,61	0,57	0,30	0,17	330	1,20	1,13	13	0,50	<0.5	285	6	0,99		19	<10		<0.10	0,7	10,5
13	La Caldera	13/09/94	7,34	32,70	3,27	103	5,57	0,54	0,28	0,16	346	1,80	1,49	16	2,20	<0.1	280	5	0,78		17	<10		<0.10	1,9	13,0
Mean94	**La Caldera**	**M94**	**7,80**	**30,54**	**3,05**	**57**	**5,31**	**0,54**	**1,10**	**0,33**	**300**	**1,29**	**1,31**	**46**	**1,05**		**257**	**9**	**1,90**		**18**			**0,20**	**3,84**	**11,75**
14 (N)	Escura	06/10/93	5,34	12,10	1,21	15	0,36	0,16	0,98	0,11	-10	1,10	0,86	5	1,70	<0.1	123	6	1,20		32	20		<0.5	<0.5	716,0
14	L. Escura	06/10/93	5,31	13,30	1,33	7	0,24	0,28	0,64	0,08	6	1,06	0,90	0	1,09			7	1,81							
Mean 93	**L. Escura**	**M 93**	**5,31**	**13,30**	**1,33**	**7**	**0,24**	**0,28**	**0,64**	**0,08**	**6**	**1,06**	**0,90**	**0**	**1,09**			**7**	**1,81**							
14	Lago Escura	17/09/94	5,41	11,00	1,10	7	0,25	0,22	0,73	0,21	-5	0,66	0,48	0	1,31			10	2,15							
Mean 94	**L. Escura**	**M 94**	**5,41**	**11,00**	**1,10**	**7**	**0,25**	**0,22**	**0,73**	**0,21**	**-5**	**0,66**	**0,48**	**0**	**1,31**			**10**	**2,15**							
15.1 (N)	Starolesnianske pleso	28/09/93	4,89	15,30	1,53	11	0,82	0,08	0,02	0,07		3,10	3,07	175	0,20	<0.1	405	8	1,80		179	11		0,24	2,6	61,0
15,1	Starolesnianske pleso	VS-15	4,70	15,10	1,51	17	0,73	0,10	0,19	0,08		4,04	4,02	169	0,17			9	2,75		193	17	176			
Mean 93	**Starolesnianske plesq**	**M 93**	**4,80**	**15,20**	**1,52**	**14,00**	**0,78**	**0,09**	**0,11**	**0,08**		**3,57**	**3,54**	**172**	**0,19**		**405**	**9**	**2,28**		**186**	**14**	**176**	**0,24**	**2,60**	**61,00**
15,1	Starolesnianske Pleso	27/10/94	4,69	14,30		39	0,59	0,07	0,08	0,11	-18	2,50	2,49	147	0,10	0,01	339	8	1,55							
Mean 94	**Starolesnianske pleso**	**M 94**	**4,69**	**14,30**		**39**	**0,59**	**0,07**	**0,08**	**0,11**	**-18**	**2,50**	**2,49**	**147**	**0,10**	**0,01**	**339**	**8**	**1,55**							
15.2 (N)	Terianske pleso	29/09/93	6,92	22,10	2,21	<5	3,20	0,08	0,13	0,11	61	3,10	3,07	585	0,20	<0.1	630	1	0,27		13	<10		0,06	<0.5	<2
15,2	Terianske pleso	NE-3	6,80	20,40	2,04	9	3,18	0,14	0,45	0,13		3,42	3,39	510	0,18			2	0,75		9					
Mean 93	**Terianske pleso**	**M 93**	**6,86**	**21,25**	**2,13**	**9,00**	**3,19**	**0,11**	**0,29**	**0,12**	**61,00**	**3,26**	**3,23**	**548**	**0,19**		**630**	**2**	**0,51**		**11**			**0,06**		

Lake n°		Date	pH	Cond.	Cond.	NH4	Ca	Mg	Na	K	Alk	SO4	SO4*	NO3	Cl	F	TN	TP	TOC	TAL	RAL	ILAL	LAL	Cd	Pb	Hg
				µS/cm 25°C	mS/m 25°C	µgN/l	mg/l	mg/l	mg/l	mg/l	µeq /l	mg/l	mg/l	µgN/l	mg/l	µg/l	µgN/l	µg/l	mg C/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l
15,2	Terianske Pleso	27/10/94	6,40	18,70		4	2,87	0,08	0,36	0,16	68	2,65	2,63	428	0,16	0,03	481	3	0,41							
Mean 94	**Terianske pleso**	**M 94**	**6,40**	**18,70**		**4**	**2,87**	**0,08**	**0,36**	**0,16**	**68**	**2,65**	**2,63**	**428**	**0,16**	**0,03**	**481**	**3**	**0,41**							
15.3 (N)	Dlugi Staw	23/09/93	5,97	19,40	1,94	6	2,20	0,10	0,15	0,13	-2	3,60	3,57	755	0,20	<0.1	770	<1	0,23		33	<10		0,05	<0.5	650,0
15,3	Dlugi Staw	GA-4		18,00	1,80	12	2,15	0,13	0,39	0,18		3,94	3,91		0,18			2			48					
15,3	Dlugi Staw	03/01/93	6,26	22,60	2,26		2,89	0,15	0,44	0,11	21	4,20		885	0,40		910		M 0.20		M 10.00	M 10.0	0			
15,3	Dlugi Staw	19/01/93	6,38	21,70	2,17	1	2,95	0,20	0,46	0,18	61	3,90		580	0,30		640		M 0.20		M 10.00	M 10.0	0			
15,3	Dlugi Staw	31/01/93	6,41	22,40	2,24	<5	2,57	0,16	0,47	0,14	22	3,80	3,76	885	0,30		900		M 0.20		M 10.00	M 10.0	0			
15,3	Dlugi Staw	01/03/93	6,47	23,40	2,34	3	2,75	0,14	0,46	0,17	27	4,10	4,04	885	0,40		925		M 0.20		M 10.00	M 10.0	0			
15,3	Dlugi Staw	06/04/93	6,21	23,10	2,31		2,91	0,16	0,46	0,13	25	4,20	4,16	905	0,30		970		0,55		M 10.00	M 10.0	0			
15,3	Dlugi Staw	15/04/93	6,25	22,50	2,25	5	2,96	0,16	0,47	0,15	23	3,60	3,56	895	0,30		930		M 0.20		M 10.00	M 10.0	0			
15,3	Dlugi Staw	20/04/93	6,37	24,60	2,46	8	3,11	0,15	0,49	0,14	21	4,40	4,33	940	0,50		965		M 0.20		M 10.00	M 10.0	0			
15,3	Dlugi Staw	03/05/93	6,06	23,50	2,35	13	2,82	0,14	0,33	0,14	6	4,00	3,96	980	0,30		1020		0,14		M 10.00	M 10.0	0			
15,3	Dlugi Staw	17/05/93	5,14	21,20	2,12		1,83	0,10	0,30	0,16	0	3,30	3,24	870	0,40		980		0,33		135	M 10.0	125			
15,3	Dlugi Staw	01/06/93	5,22	16,00	1,60	29	1,52	0,08	0,17	0,12	3	2,90	2,86	675	0,30		725		M 0.20		130	M 10.0	120			
15,3	Dlugi Staw	14/06/93	5,33	15,90	1,59	11	1,56	0,08	0,24	0,13	4	3,10	3,06	615	0,30		650		0,37		68	M 10.0	58			
15,3	Dlugi Staw	01/07/93	5,43	17,40	1,74	8	1,65	0,08	0,25	0,11	0	2,90	2,86	625	0,30		660		0,25		57	M 10.0	47			
15,3	Dlugi Staw	12/07/93	5,94	18,50	1,85	<5	2,10	0,10	0,29	0,13	6	3,10	3,07	705	0,20		745		M 0.20		10	M 10.0	0			
15,3	Dlugi Staw	22/08/93	5,89	19,50	1,95	26	2,24	0,12	0,40	0,22	5	3,20	3,16	730	0,30		840		0,28		M 10.00	M 10.0	0			
15,3	Dlugi Staw	02/09/93	5,72	17,20	1,72	<5	1,97	0,12	0,31	0,14	0	3,60	3,57	625	0,20		655		M 0.20		46	M 10.0	36			
15,3	Dlugi Staw	13/09/93	5,84	18,40	1,84	11	2,09	0,10	0,33	0,15		3,50	3,47	750	0,20		800		0,85		31	M 10.0	21			
15,3	Dlugi Staw	23/09/93	5,97	19,40	1,94	6	2,20	0,10	0,15	0,13	0	3,60	3,57	755	0,20	M 0.10	770	M 1.0	0,23		33	M 10.0	23	0,05	M 0.5	650,0
15,3	Dlugi Staw	27/09/93	5,92	19,10	1,91	<5	2,25	0,11	0,37	0,15	18	3,70	3,66	755	0,30		795		0,26		22	M 10.0	12			
15,3	Dlugi Staw	01/10/93																2								
15,3	Dlugi Staw	15/11/93	6,05	21,60	2,16	<5	2,73	0,15	0,38	0,13	21	4,10	4,07	790	0,20		830		0,25		<10.00	<10.00	0			
15,3	Dlugi Staw	30/11/93	6,06	22,50	2,25	<5	2,79	0,16	0,38	0,15	24	4,20	4,14	825	0,40		915		<0.20		<10.00	<10.00	0			
15,3	Dlugi Staw	14/12/93	6,41	23,20	2,32	<5	3,00	0,15	0,46	0,14	20	4,20	4,16	865	0,30		965		<0.20		<10.00	<10.00	0			
Mean 93	**Dlugi Staw**	**M 93**	**5,97**	**20,48**	**2,05**	**10,72**	**2,40**	**0,13**	**0,35**	**0,14**	**14**	**3,70**	**3,63**	**786**	**0,29**		**835**	**2**	**0,34**		**56**		**21**	**0,05**		
15,3	Dlugi Staw	01/01/94	6,26	23,10	2,31	<5	2,92	0,15	0,48	0,13	20	4,20	4,17	850	0,20		880		<0.20		<10.00	<10.00	0			
15,3	Dlugi Staw	17/01/94	6,65	24,90	2,49	11	3,45	0,24	0,48	0,18	91	3,80	3,77	500	0,20		570		0,41		<10.00	<10.00	0			
15,3	Dlugi Staw	04/02/94	6,63	23,20	2,32	<5	2,87	0,16	0,50	0,14	24	4,10	4,07	855	0,20		850		<0.20		<10.00	<10.00	0			
15,3	Dlugi Staw	15/02/94	6,40	22,70	2,27	<5	2,92	0,16	0,45	0,14	25	4,20	4,17	860	0,20		875		<0.20		<10.00	<10.00	0			
15,3	Dlugi Staw	28/02/94	6,17	22,30	2,23	<5	2,88	0,15	0,44	0,12	26	4,60	4,56	845	0,30		880		0,20		<10.00	<10.00	0			
15,3	Dlugi Staw	14/03/94	6,16	22,70	2,27	<5	2,84	0,14	0,47	0,14	23	4,10	4,07	865	0,20		885		<0.20		<10.00	<10.00	0			
15,3	Dlugi Staw	29/03/94	6,17	23,10	2,31	<5	2,87	0,16	0,49	0,13	24	4,10	4,07	925	0,20		895		<0.20		<10.00	<10.00	0			
15,3	Dlugi Staw	19/04/94	6,18	24,90	2,49	6	3,17	0,17	0,49	0,14	31	4,00	3,96	910	0,30		1040		0,42		<10.00	<10.00	0			
15,3	Dlugi Staw	04/05/94	5,96	23,40	2,34	<5	2,93	0,16	0,42	0,13	15	3,80	3,76	960	0,30		995		<0.20		<10.00	<10.00	0			
15,3	Dlugi Staw	17/05/94	5,67	18,40	1,84	36	2,04	0,12	0,34	0,12	4	3,00	2,96	670	0,30		730		0,44		16	<10.00	6			
15,3	Dlugi Staw	22/05/94	5,36	16,10	1,61	45	1,47	0,10	0,26	0,14	0	2,90	2,86	625	0,30		695		0,35		87	<10.00	77			
15,3	Dlugi Staw	31/05/94	5,32	15,60	1,56	21	1,46	0,10	0,26	0,13	2	2,90	2,87	590	0,20		650		0,20		92	<10.00	82			
15,3	Dlugi Staw	20/06/94	5,27	16,30	1,63	15	1,54	0,06	0,26	0,11	2	2,90	2,87	545	<0.20		600		0,20		74	<10.00	64			
15,3	Dlugi Staw	04/07/94	5,63	15,10	1,51	9	1,50	0,05	0,30	0,12	6	2,80	2,77	490	<0.20		555		<0.20		41	<10.00	31			
15,3	Dlugi Staw	18/07/94	5,54	14,10	1,41	10	1,42	0,04	0,25	0,10	3	2,70	2,67	470	<0.20		510		<0.20		25	<10.00	15			
15,3	Dlugi Staw	25/07/94	5,91	17,00	1,70	<5	1,97	0,11	0,35	0,12	11	3,90	3,87	535	<0.20		595		<0.20		<10.00	<10.00	0			
15,3	Dlugi Staw	16/08/94	5,95	17,70	1,77	15	1,93	0,11	0,41	0,23	12	3,30	3,26	560	0,30		655		<0.20		<10.00	<10.00	0			
15,3	Dlugi Staw	29/08/94	5,86	15,90	1,59	16	1,83	0,09	0,26	0,16	12	3,20	3,17	595	0,20		655		<0.20		23	<10.00	13			
15,3	Dlugi Staw	19/09/94	5,91	16,20	1,62	22	1,92	0,11	0,40	0,15	10	3,20	3,16	715	0,30		725		<0,2		20	<10.00	10			
15,3	Dlugi Staw	02/10/94	5,99	17,80	1,78	21	2,08	0,12	0,47	0,22	12	3,40	3,37	705	0,20		830		0,26		19	<10.00	9			
15,3	Dlugi Staw	18/10/94	5,94	17,80	1,78	14	2,16	0,12	0,33	0,13	11	3,40	3,39	715	0,10		735		0,29		13	<10.00	3			

Lake n°		Date	pH	Cond.	Cond.	NH4	Ca	Mg	Na	K	Alk	SO4	SO4*	NO3	Cl	F	TN	TP	TOC	TAL	RAL	ILAL	LAL	Cd	Pb	Hg
				µS/cm 25°C	mS/m 25°C	µgN/l	mg/l	mg/l	mg/l	mg/l	µeq /l	mg/l	mg/l	µgN/l	mg/l	µg/l	µgN/l	µg/l	mg C/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l
15,3	Dlugi Staw	01/11/94	5,73	17,90	1,79	8	2,25	0,13	0,39	0,16	13	3,50	3,47	725	0,20		745		0,25		13	<10.00	3			
15,3	Dlugi Staw	15/11/94	6,05	18,20	1,82	<5	2,31	0,13	0,32	0,13	15	3,50	3,47	780	0,20		770		0,20		<10	<10.00	0			
15,3	Dlugi Staw	30/11/94	6,09	18,40	1,84	<5	2,44	0,14	0,36	0,12	18	3,60	3,56	775	0,30		755		0,26		<10	<10.00	0			
15,3	Dlugi Staw	23/12/94	6,25	19,50	1,95	<5	2,52	0,13	0,45	0,11		3,90	3,86	775	0,30		775		<0.20		<10.00	<10.00	0			
Mean94	**Dlugi Staw**	**M94**	**5,96**	**19,29**	**1,93**	**17,79**	**2,31**	**0,13**	**0,39**	**0,14**	**17,07**	**3,56**	**3,53**	**714**	**0,24**		**754**		**0,29**		**38**		**13**			
15.4 (N)	Zieloni Staw	23/09/93	7,07	23,20	2,32	<5	3,11	0,19	0,27	0,19	79	3,50	3,46	390	0,30	<0.1	470	3	0,52		13	<10		0,15	<0.5	54,5
15,4	Zieloni Staw	GA-7	6,70	22,20	2,22	13	3,08	0,24	0,63	0,25		3,75	3,72	350	0,25			5								
15,4	Zieloni Staw	03/01/93	6,45	23,00	2,30		3,04	0,21	0,47	0,16	64	3,70	3,66	525	0,30		595		0,25		M 10.00	M 10.00	0			
15,4	Zieloni Staw	19/01/93	6,32	21,30	2,13	3	2,85	0,15	0,45	0,14	16	3,90	3,86	905	0,30		905		M 0.20		M 10.00	M 10.00	0			
15,4	Zieloni Staw	31/01/93	6,53	22,70	2,27	13	2,65	0,20	0,47	0,19	59	3,60	3,56	590	0,30		650		0,26		M 10.00	M 10.00	0			
15,4	Zieloni Staw	16/02/93	6,51	21,40	2,14	36	2,98	0,21	0,44	0,20	65	3,50	3,46	560	0,30		635		0,30		M 10.00	M 10.00	0			
15,4	Zieloni Staw	01/03/93	6,66	24,00	2,40	16	3,03	0,21	0,47	0,21	84	3,80	3,76	510	0,30		590		0,28		M 10.00	M 10.00	0			
15,4	Zieloni Staw	06/04/93	6,57	25,00	2,50		3,23	0,22	0,50	0,24	86	3,80	3,76	575	0,30		780		0,40		M 10.00	M 10.00	0			
15,4	Zieloni Staw	15/04/93	6,52	23,80	2,38	13	3,26	0,22	0,47	0,19	79	3,30	3,26	545	0,30		610		M 0.20		M 10.00	M 10.00	0			
15,4	Zieloni Staw	20/04/93	6,45	26,60	2,66	142	3,31	0,22	0,55	0,21	74	3,90	3,84	630	0,40		855		0,37		M 10.00	M 10.00	0			
15,4	Zieloni Staw	03/05/93	5,98	24,90	2,49	137	2,85	0,19	0,40	0,18	23	4,40	4,34	770	0,40		950		0,68		10	M 10.00	0			
15,4	Zieloni Staw	17/03/93	6,24	19,70	1,97		2,53	0,16	0,34	0,15	51	3,00	2,96	480	0,30		570		0,43		M 10.00	M 10.00	0			
15,4	Zieloni Staw	01/06/93	6,65	22,60	2,26	5	3,24	0,21	0,37	0,17	89	3,50	3,46	485	0,30		535		0,36		M 10.00	M 10.00	0			
15,4	Zieloni Staw	14/06/93	6,81	22,20	2,22	8	2,91	0,19	0,43	0,17	82	3,50	3,46	460	0,30		515		0,38		10	M 10.00	0			
15,4	Zieloni Staw	01/07/93	6,82	22,20	2,22	10	2,94	0,19	0,41	0,16	84	3,40	3,36	420	0,30		500		0,25		10	M 10.00	0			
15,4	Zieloni Staw	12/07/93	6,72	22,70	2,27	23	3,00	0,20	0,38	0,16	84	3,20	3,16	415	0,30		495		0,30		M 10.00	M 10.00	0			
15,4	Zieloni Staw	22/08/93	6,63	21,80	2,18	21	2,96	0,19	0,43	0,18	71	3,30	3,27	410	0,20		480		0,51		M 10.00	M 10.00	0			
15,4	Zieloni Staw	02/09/93	6,71	21,80	2,18	26	3,01	0,21	0,39	0,18	79	3,50	3,47	395	0,20		470		0,59		M 10.00	M 10.00	0			
15,4	Zieloni Staw	13/09/93	6,70	22,10	2,21	17	2,96	0,19	0,43	0,19	79	3,40	3,36	410	0,30		500		0,71		M 10.00	M 10.00	0			
15,4	Zieloni Staw	23/09/93	7,07	23,20	2,32	<5	3,11	0,19	0,27	0,19	83	3,50	3,46	390	0,30	M 0.10	470	3	0,52		13	M 10.00	3	0,15	M 0.50	54,5
15,4	Zieloni Staw	27/09/93	6,78	22,20	2,22	23	3,09	0,20	0,46	0,18	73	3,60	3,56	400	0,30		490		0,50		M 10.00	M 10.00	0			
15,4	Zieloni Staw	10/01/93	6,70	22,20	2,22	13	3,08	0,24	0,63	0,25		3,75	3,72	350	0,25		130	5								
15,4	Zieloni Staw	15/11/93	6,66	23,30	2,33		3,31	0,23	0,43	0,17	94	3,70	3,67	405	0,20		540		0,59		314	M 10.00	304			
15,4	Zieloni Staw	30/11/93	6,74	27,40	2,74	6	3,71	0,26	0,47	0,20	105	4,60	4,54	460	0,40		550		0,42		<10.00	<10.00	0			
15,4	Zieloni Staw	14/12/93	6,83	26,20	2,62	14	3,93	0,27	0,56	0,21	109	4,30	4,26	495	0,30		590		0,47		<10.00	<10.00	0			
Mean 93	**Zieloni Staw**	**M 93**	**6,63**	**23,11**	**2,31**	**28,37**	**3,09**	**0,21**	**0,44**	**0,19**	**74,31**	**3,66**	**3,61**	**493**	**0,30**		**578**	**4**	**0,43**		**62**		**14**	**0,15**		**54,50**
15,4	Zieloni Staw	01/01/94	6,73	25,20	2,52	20	3,54	0,24	0,51	0,18	96	3,80	3,77	465	0,20		560		0,42		<10.00	<10.00	0			
15,4	Zieloni Staw	17/01/94	6,39	23,50	2,35	<5	2,91	0,16	0,45	0,13	21	4,10	4,07	835	0,20		865		<0.10		<10.00	<10.00	0			
15,4	Zieloni Staw	01/02/94	6,65	26,30	2,63	57	3,39	0,24	0,60	0,23	94	3,60	3,56	515	0,30		745		0,37		<10.00	<10.00	0			
15,4	Zieloni Staw	15/02/94	6,69	25,30	2,53	27	3,31	0,23	0,51	0,25	93	3,60	3,56	485	0,30		600		0,23		<10.00	<10.00	0			
15,4	Zieloni Staw	28/02/94	6,56	24,50	2,45	52	3,27	0,21	0,44	0,19	94	3,60	3,56	485	0,30		655		0,34		<10.00	<10.00	0			
15,4	Zieloni Staw	14/03/94	6,61	24,20	2,42	9	3,29	0,22	0,47	0,17	92	3,50	3,46	490	0,30		560		0,39		<10.00	<10.00	0			
15,4	Zieloni Staw	29/03/94	6,45	24,50	2,45	13	3,27	0,23	0,50	0,16	87	3,50	3,46	550	0,30		610		0,51		<10.00	<10.00	0			
15,4	Zieloni Staw	19/04/94	6,41	25,40	2,54	42	3,32	0,23	0,47	0,18	80	3,50	3,46	570	0,30		715		0,30		<10.00	<10.00	0			
15,4	Zieloni Staw	04/05/94	6,17	22,60	2,26	100	2,75	0,18	0,39	0,14	55	3,50	3,46	570	0,30		720		0,44		12	<10.00	2			
15,4	Zieloni Staw	17/05/94	6,15	21,70	2,17	57	2,66	0,18	0,40	0,15	46	3,10	3,06	555	0,30		645		0,55		<10.00	<10.00	0			
15,4	Zieloni Staw	22/05/94	6,41	19,80	1,98	14	2,57	0,17	0,40	0,16	66	3,10	3,07	460	0,20		515		0,27		12	<10.00	2			
15,4	Zieloni Staw	31/05/94	6,47	19,70	1,97	6	2,60	0,17	0,39	0,15	73	3,00	2,97	430	0,20		460		0,23		<10.00	<10.00	0			
15,4	Zieloni Staw	20/06/94	6,87	21,60	2,16	6	3,04	0,15	0,40	0,15	88	3,20	3,17	380	<0.20		420		0,25		<10.00	<10.00	0			
15,4	Zieloni Staw	04/07/94	6,83	20,50	2,05	14	2,58	0,11	0,39	0,15	72	3,40	3,37	355	<0.20		405		0,33		<10.00	<10.00	0			
15,4	Zieloni Staw	18/07/94	6,71	19,70	1,97	16	2,51	0,14	0,40	0,14	67	3,30	3,27	340	<0.20		405		0,39		<10.00	<10.00	0			
15,4	Zieloni Staw	25/07/94	6,50	19,60	1,96	21	2,55	0,17	0,44	0,16	65	3,70	3,66	330	0,30		435		0,52		<10.00	<10.00	0			
15,4	Zieloni Staw	16/08/94	6,79	20,30	2,03	34	2,65	0,18	0,42	0,16	73	3,80	3,77	335	0,20		450		0,47		<10.00	<10.00	0			

Lake n°		Date	pH	Cond.	Cond.	NH4	Ca	Mg	Na	K	Alk	SO4	SO4*	NO3	Cl	F	TN	TP	TOC	TAL	RAL	ILAL	LAL	Cd	Pb	Hg
				µS/cm 25°C	mS/m 25°C	µgN/l	mg/l	mg/l	mg/l	mg/l	µeq /l	mg/l	mg/l	µgN/l	mg/l	µg/l	µgN/l	µg/l	mg C/l	µg/l	µg/l	µg/l	µg/l	µg/l	µg/l	ng/l
15,4	Zieloni Staw	29/08/94	6,78	18,70	1,87	39	2,61	0,17	0,32	0,18	80	3,30	3,27	315	0,20		415		0,47		10	<10.00	0			
15,4	Zieloni Staw	19/09/94	6,74	20,20	2,02	37	2,87	0,20	0,54	0,22	95	3,30	3,27	300	0,20		440		0,66		<10.00	<10.00	0			
15,4	Zieloni Staw	02/10/94	6,84	20,30	2,03	42	2,88	0,20	0,43	0,17	94	3,80	3,77	295	<0,2		435		0,49		<10.00	<10.00	0			
15,4	Zieloni Staw	18/10/94	6,76	20,90	2,09	30	3,01	0,22	0,44	0,18	95	3,40	3,37	325	<0,2		410		0,48		<10.00	<10.00	0			
15,4	Zieloni Staw	01/11/94	6,57	20,10	2,01	19	2,94	0,19	0,44	0,16	90	3,30	3,27	325	0,20		395		0,56		<10.00	<10.00	0			
15,4	Zieloni Staw	15/11/94	6,59	20,70	2,07	<5	2,88	0,21	0,39	0,18	90	3,40	3,37	340	0,20		400		0,49		<10.00	<10.00	0			
Mean94	**Zieloni Staw**	**M94**	**6,59**	**21,97**	**2,20**	**31**	**2,93**	**0,19**	**0,44**	**0,17**	**78,51**	**3,47**	**3,44**	**437**	**0,25**		**533**		**0,42**		**11**		**0**			
16 (N)	Laguna Cimera	mar-93		9,30	0,93																					
16	Laguna Cimera	jun-93	5,83	7,10	0,71						25															
16	Laguna Cimera	jul-93	6,15	7,60	0,76						25															
16	Laguna Cimera	aug-93	5,95	6,30	0,63						26															
16	Laguna Cimera	sep-93	6,06	7,20	0,72						29															
16	Laguna Cimera	nov-93	5,44	8,40	0,84						13															
16	Laguna Cimera	18/09/93	6,30	7,30	0,73	<5	0,60	0,17	0,27	0,07	37	0,90	0,86	1	0,30	<0.1	116	7	0,80		<10	<10		<0.05	<0.5	<2
16	Laguna Cimera	18/09/93	6,06	7,20	0,72	<100	0,62	<0.01	0,70	<0.2		0,75	0,70		0,36			<100								
Mean 93	**Laguna Cimera**	**M 93**	**5,97**	**7,55**	**0,76**		**0,61**	**0,17**	**0,49**	**0,07**	**26**	**0,83**	**0,78**	**1**	**0,33**		**116**	**7**	**0,80**							
16	Laguna Cimera	22/01/94	5,78	2,60	0,26		0,15	0,14	<0.15	<0.2	9	0,40		320	<0.10			<10								
16	Laguna Cimera	16/10/94	5,59	5,70	0,57		0,40	0,07	0,70	<0.2	25	0,65		240	0,33			<10								
Mean 94	**Laguna Cimera**	**M 94**	**5,69**	**4,15**	**0,42**		**0,28**	**0,11**	**0,70**		**17,15**	**0,53**		**280**	**0,33**			**<10**								
17	Chuna	R25.10.93	6,57	17,00	1,70		1,21	0,25	0,53	0,14	62	2,00	1,83	162	1,21			0		5						
17 (N)	Chuna		6,56	17,20	1,72	17	1,61	0,26	1,06	0,09	60	2,00	1,85	165	1,10	<0.1	245	1	0,28		<10	<10		0,13	0,5	4,5
Mean 93	**Chuna**	**M 93**	**6,57**	**17,10**	**1,71**	**17**	**1,41**	**0,26**	**0,80**	**0,12**	**61,00**	**2,00**	**1,84**	**164**	**1,16**		**245**	**1**	**0,28**	**5**				**0,13**	**0,5**	**4,5**
17	Chuna	27/03/94	6,72	25,00	2,50	40	2,00	0,34	1,10	0,27	80	3,20	3,03	156	1,20					8						
17	Chuna	21/04/94	6,24	20,00	2,00	45	1,40	0,22	1,20	0,30	33	2,70	2,49	48	1,50					10						
17	Chuna	17/08/94	6,40	10,00	1,00	6	0,90	0,13	0,50	0,05	23	1,80	1,71	26	0,62					36						
17	Chuna	17/08/94	6,37	10,00	1,00	13	0,95	0,16	0,48	0,03	24	1,70	1,61	36	0,62					47						
17	Chuna	07/09/94	6,43	10,00	1,00	2	0,85	0,14	0,56	0,05	26	1,90	1,82	17	0,60					11						
Mean94	**Chuna**	**M94**	**6,43**	**15,00**	**1,50**	**21**	**1,22**	**0,20**	**0,77**	**0,14**	**37**	**2,26**	**2,13**	**57**	**0,91**					**22**						
18	Chibini	R25.10.93	7,15	35,00	3,50		0,39	0,06	6,00	1,47	251	3,18	3,05	79	0,91			0		77						
18 (N)	Chibini		6,64	15,40	1,54	<5	1,78	0,21	0,64	0,06	56	2,40	2,33	165	0,50	<0.1	190	<1	0,30		<10	<10		<0.1	<0.5	<2
Mean 93	**Chibini**	**M 93**	**6,90**	**25,20**	**2,52**		**1,09**	**0,14**	**3,32**	**0,77**	**154**	**2,79**	**2,69**	**122**	**0,71**		**190**	**0**	**0,30**	**77**						
18	Chibini	10/07/94	7,39	36,00	3,60	7	0,70	0,07	5,80	1,55	234	2,80	2,68	273	0,83					60						
18	Chibini	10/07/94	7,54	32,00	3,20	6	0,65	0,07	5,63	1,50	190	2,50	2,39	190	0,81					54						
Mean94	**Chibini**	**M94**	**7,47**	**34,00**	**3,40**	**7**	**0,68**	**0,07**	**5,72**	**1,53**	**212**	**2,65**	**2,54**	**232**	**0,82**					**57**						
19	Krisko jezero	31/08/93	7,70	104,60	10,46	19	15,70		1,00	0,48	737	7,01	7,01	110			528	5								
Mean 93	**Krisko jezero**	**M 93**	**7,70**	**104,60**	**10,46**	**19**	**15,70**		**1,00**	**0,48**	**737**	**7,01**	**7,01**	**110**			**528**	**5**								
19	Zgornje krisko jezero	27/07/94	7,86	75,60	7,56	28	14,90	0,80	0,11	0,04	467			190	0,20	0,10	275	3	0,41					<0.10	<0.5	5,5
19	Zgornje krisko jezero	31/08/94	7,66	87,30	8,73	0	13,50		1,20	0,17	647	4,80	4,77	92			600	2								
Mean94	**Zgornje krisko jezero**	**M94**	**7,76**	**81,45**	**8,15**	**14**	**14,20**	**0,80**	**0,66**	**0,11**	**557**	**4,80**	**4,77**	**141**	**0,20**	**0,10**	**438**	**3**	**0,41**							**5,5**

	Date	H+	NH4	Ca	Mg	Na	K	Alk	SO4	NO3	Cl	F	S Cat.	S An.	% Diff.	S Ions	Measured	Measured	Calculated
		µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l		µeq/l		µS/cm 25°C	25°C
Ø. Neådalsvatn	06/06/93	1,1		23	14	50	4	8	17	2	65		93	92	0,56	184	13	13	12
Ø. Neådalsvatn	24/06/93	0,9		20	10	42	3	21	12	2	42		76	77	-0,73	154	10	10	10
Ø. Neådalsvatn	08/07/93	0,5		15	8	38	3	15	15	1	31		64	62	1,81	126	8	8	8
Ø. Neådalsvatn	21/07/93	0,8		15	6	30	3	15	12	1	25		54	54	-0,04	107	11	11	7
Ø. Neådalsvatn	05/08/93	1,0		17	6	28	3	12	12	0	25		55	50	4,19	105	7	7	7
Ø. Neådalsvatn	27/08/93	0,7		17	6	26	3	15	12		17		52	44			7	7	
Ø. Neådalsvatn	07/09/93	0,5		17	6	27	3	25	12		17		53	54			7	7	
Ø. Neådalsvatn	21/09/93	0,4		20	7	26	3	25	12	0	17		57	55	2,32	112	7	7	7
Ø. Neådalsvatn	30/09/93	0,4		22	7	32	4	28	15	0	20		65	62	1,62	127	8	8	8
Ø. Neådalsvatn	29/10/93	1,1		19	7	33	4	13	15	1	34			62			8	8	
Ø. Neådalsvatn	13/11/93	0,5		31	13	42	5	26	17	1	37				11,22				
Ø. Neådalsvatn	24/11/93	0,6		33	14	44	5	35	19	1	39				2,69				
Ø. Neådalsvatn	**M 93**	**0,71**		**21**	**9**	**35**	**3**	**20**	**14**	**1**	**31**		**63**	**61**	**2,63**	**131**	**9**	**9**	**8**
Øvre Neådalsvatn	06/01/94	0,8		40	12	42	5	41	23	1	31		100	96	2,07	196	10	11	
Øvre Neådalsvatn	29/01/94	0,5		46	16	43	5	49	27	1	31		111	109	1,26	220	10	12	
Øvre Neådalsvatn	12/02/94	0,8		42	16	41	5	48	25	1	31		105	105	-0,28	210	12	11	
Øvre Neådalsvatn	28/02/94	0,7		48	16	44	19	54	40	1	31		127	125	0,56	252	32	14	
Øvre Neådalsvatn	12/03/94	1,1		42	15	43	5	47	23	1	28		106	100	2,94	205	12	11	
Øvre Neådalsvatn	15/04/94	0,7		45	16	40	5	50	23	1	31		106	106	0,33	212	14	11	
Øvre Neådalsvatn	24/04/94	1,0		50	16	42	6	50	25	1	34		115	110	1,98	225	14	12	
Øvre Neådalsvatn	01/05/94	1,3		57	28	86	11	31	29	5	93		184	159	7,37	342	23	20	
Øvre Neådalsvatn	07/05/94	1,7		42	26	80	9	21	25	3	93		160	142	6,09	302	21	18	
Øvre Neådalsvatn	17/05/94	1,0		30	18	58	6	18	12	3	71		113	104	4,51	217	14	12	
Øvre Neådalsvatn	22/05/94	1,6		30	17	59	6	19	17	3	71		114	108	2,45	222	15	13	
Øvre Neådalsvatn	01/06/94	1,3		32	16	54	6	21	19	3	59		109	101	3,54	210	14	12	
Øvre Neådalsvatn	11/06/94	0,7		21	11	39	5	22	15	2	37		76	75	0,55	151	10	9	
Øvre Neådalsvatn	19/06/94	1,3		18	10	34	4	31	12	2	31		68	76	-5,80	144	9	8	
Øvre Neådalsvatn	25/06/94	0,6		14	8	28	3	15	10	1	28		54	55	-0,98	109	7	6	
Øvre Neådalsvatn	30/06/94	0,8		21	10	35	4	21	12	1	31		71	66	4,11	137	9	8	
Øvre Neådalsvatn	09/07/94	0,2		16	7	27	3	20	10	1	25		53	56	-3,37	109	8	6	
Øvre Neådalsvatn	17/07/94	0,6		12	2	27	3	21	10	1	20		45	52	-7,20	96	7	5	
Øvre Neådalsvatn	24/07/94	0,5		8	3	29	3	24	10	0	17		43	51	-8,88	94	7	5	
Øvre Neådalsvatn	01/08/94	0,5		10	4	30	3	21	10	0	17		47	48	-1,43	95	8	5	
Øvre Neådalsvatn	21/08/94	0,4		10	7	30	3	42	12	0	14		51	69	-14,44	120	7	6	
Øvre Neådalsvatn	28/08/94	0,5		22	8	32	3	29	10	0	14		66	54	10,43	120	8	6	
Øvre Neådalsvatn	05/09/94	0,4		21	8	32	3	31	17	0	20		65	68	-2,20	133	8	7	
Øvre Neådalsvatn	12/09/94	0,7		20	7	30	3	35	17	0	23		62	74	-9,14	135	8	7	
Øvre Neådalsvatn	18/09/94	0,4		22	5	30	4	32	17	0	20		62	69	-5,63	131	8	7	
Øvre Neådalsvatn	26/09/94	0,4		22	7	29	4	35	17	0	23		62	74	-9,01	136	8	7	
Øvre Neådalsvatn	02/10/94	0,5		20	7	30	4	31	17	0	23		62	71	-6,75	133	8	7	
Øvre Neådalsvatn	08/10/94	0,6																	
Øvre Neådalsvatn	13/10/94	0,4		26	11	38	4	35	15	0	37				-7,00		9	9	
Øvre Neådalsvatn	31/10/94	0,5		27	12	44	5	32	17	1	42				-4,40		10	10	
Øvre Neådalsvatn	13/11/94	0,5		30	12	40	4	30	17	2	34				3,97		10	9	
Øvre Neådalsvatn	04/12/94	0,7		41	17	60	5	32	23	2	62				4,04		15	14	
Øvre Neådalsvatn	21/12/94	0,7		44	17	54	5	32	21	1	62				3,81		14	13	
Øvre Neådalsvatn	**M94**	**0,73**		**29**	**12**	**42**	**5**	**32**	**18**	**1**	**37**		**87**	**86**	**-0,83**	**173**	**11**	**10**	

	Date	H+	NH4	Ca	Mg	Na	K	Alk	SO4	NO3	Cl	F	S Cat.	S An.	% Diff.	S Ions	Measured	Measured	Calculated
		µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l		µeq/l		µS/cm 25°C	25°C
Stavsvatn	29/03/93	1,7	2	51	12	27	3	13	42	5	23	0	96	82	8,08	178	12	12	
Stavsvatn	23/09/93	0,8	1	41	10	25	2	0	33	2	23	0	79	57	15,81	136	11	9	
Stavsvatn	**M 93**	**1,2**	**1**	**46**	**11**	**26**	**2**	**7**	**37**	**3**	**23**	**0**	**88**	**70**	**11,94**	**157**	**12**	**11**	
Stavsvatn	28/09/94	1,0	1	40	9	21	2	16	33	3	17		74	70	3,05	144	0	8	
Stavsvatn	**M 94**	**1,0**	**1**	**40**	**9**	**21**	**2**	**16**	**33**	**3**	**17**		**74**	**70**	**3,05**	**144**	**0**	**8**	
L. Hovvatn	23/02/93	45,7		22	25	135	3		58	12	178		231	248	-3,62	479	48	45	
L. Hovvatn	11/05/93	26,3		21													24	10	
L. Hovvatn	30/06/93	23,4		20	17	87	3		58	11	102		150	171	-6,52	322	29	28	
L. Hovvatn	27/07/93	13,8		26	18	82	3		56	10	93		143	159	-5,42	302	25	24	
L. Hovvatn	21/09/93	14,1		26	18	78	3		60	10	96		140	166	-8,62	306	27	25	
L. Hovvatn	**M 93**	**24,7**		**23**	**20**	**95**	**3**		**58**	**11**	**117**		**166**	**186**	**-6,04**	**352**	**31**	**26**	
Lille Hovvatn	06/01/94	28,8		25	17	70	2	0	71	15	66		143	152	-3,13	295	28	25	2,79
Lille Hovvatn	16/03/94	31,6		23	18	77	2	0	71	19	74		153	164	-3,51	316	33	27	3,01
Lille Hovvatn	31/05/94	12,6		19	13	63	2	0	63	11	66		110	139	-11,67	250	23	18	2,04
Lille Hovvatn	03/08/94	16,2		17	0	0	0	0							99,65	33	22	6	0,67
Lille Hovvatn	07/09/94	15,8		24	14	49	4	0	54	9	51		106	115	-3,93	221	20	17	1,93
Lille Hovvatn	07/09/94	26,9	1	18	13	53	3		63	9	54		114	126	-4,97	240	21	21	2,39
Lille Hovvatn	02/11/94	25,1		20	14	56	4	0	65	11	63		118	138	-7,67	257	21	22	2,45
Lille Hovvatn	**M 94**	**22,45**	**1**	**21**	**13**	**53**	**2**	**0**	**64**	**12**	**62**		**124**	**139**	**9,25**	**230**	**24**	**20**	**2,18**
Arresjøen	13/08/93	2,6	0	35	49	207	6	20	33		231		300	285			38	34	
Arresjøen	17/08/93	0,9		35	49	206	6	27	31		234		297	292	0,74	589	38	34	
Arresjøen	**M 93**	**1,8**	**0**	**35**	**49**	**207**	**6**	**24**	**32**		**233**		**300**	**288**			**38**		
Lochnagar	R 15.10.93	3,0	5	26	30	91	11	14	60	17	85		166	176	-2,83	342	22	23	
Lochnagar	R 22.11.93																0	0	
Lochnagar	09/03/93	9,8		31	26	115	7		57	21	118		188	196	-2,09	385	28	28	
Lochnagar	05/06/93	2,5		33	30	91	5	15	57	18	84		161	174	-3,84	335	23	22	
Lochnagar	07/07/93	5,5		28	25	85	4	9	53	17	80		147	159	-3,86	306	22	21	
Lochnagar	30/08/93	4,2		28	27	87	5	12	59	17	86		151	174	-7,11	325	21	22	
Lochnagar	01/09/93	2,0		40	24	89	10	17	56	16	85		165	174	-2,74	338	22	22	
Lochnagar	04/12/93	11,2		25	38	92	8	0	67	19	96		174	182	-2,26	355	27	27	
Lochnagar	**M 93**	**5,44**	**5**	**30**	**28**	**93**	**7**	**11**	**58**	**18**	**90**		**165**	**176**	**-3,53**	**341**	**21**	**21**	
Lochnagar	28/03/94	8,9	6	37	47	127	8	0	61	28	132		234	221	2,84	455	29	29	3,22
Lochnagar	01/07/94	5,5	0	33	39	97	6	7	54	20	90		180	171	2,70	351	22	22	2,42
Lochnagar	24/08/94	5,0	0	39	38	90	10	8	54	19	83		182	164	5,21	346	20	21	2,37
Lochnagar	04/09/94	4,0	5	48	47	90	7	11	58	19	80		201	168	8,94	369	20	22	2,47
Lochnagar	**M 94**	**5,9**	**3**	**39**	**43**	**101**	**8**	**7**	**57**	**22**	**96**		**199**	**181**	**4,92**	**380**	**23**	**24**	**2,32**
Sandy Loch	R 15.10.93	2,0	4	34	30	84	6	24	58	10	73		160	166	-1,85	326	20	21	
Sandy Loch	R 22.11.93																		
Sandy Loch	06/06/93	1,4		44	20	78	5	15	52	9	63		148	139	3,10	287	19	19	
Sandy Loch	11/06/93	1,3		30	17	74	4	19	53	9	64		126	145	-7,05	271	18	18	
Sandy Loch	30/08/93	0,4		39	20	88	3	37	54	5	69		150	165	-4,76	315	19	20	
Sandy Loch	05/09/93	0,6		52	20	88	3	37	54	5	69		163	165	-0,56	328	20	21	
Sandy Loch	**M 93**	**1,13**	**4**	**40**	**21**	**82**	**4**	**26**	**54**	**8**	**68**		**149**	**156**	**-2,22**	**305**	**19**	**20**	
Sandy Loch	24/08/94	8,9	0	52	34	88	5	9	53	8	65		188	135	16,39	323	18	21	2,30
Sandy Loch	**M 94**	**8,9**	**0**	**52**	**34**	**88**	**5**	**9**	**53**	**8**	**65**		**188**	**135**	**16,39**	**323**	**18**	**21**	**2,30**
L.Nan Eun	R 14.10.93																		
L.Nan Eun	R 22.11.93																		
L.Nan Eun	19/02/93	4,5		42	94	463	12	11	64	0	581		615	656	-3,24	1271	81	83	

	Date	H+	NH4	Ca	Mg	Na	K	Alk	SO4	NO3	Cl	F	S Cat.	S An.	% Diff.	S Ions	Measured	Measured	Calculated
		µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l		µeq/l		µS/cm 25°C	25°C
L.Nan Eun	26/05/93	0,8		42	80	391	11	27	50	0	443		525	520	0,43	1045	64	66	
L.Nan Eun	11/06/93	9,1		26	19	75	4	2	53	20	75		133	150	-6,07	283	21	21	
L.Nan Eun	11/07/93	2,4		21	34	191	3	18	20	0	192		251	230	4,25	481	29	31	
L.Nan Eun	13/07/93	7,8		29	19	72	3	4	50	19	73		130	146	-5,62	276	20	20	
L.Nan Eun	30/08/93	7,1		28	19	74	3	6	51	17	71		131	145	-5,17	276	20	20	
L.Nan Eun	**M 93**	**5,3**		**31**	**44**	**211**	**6**	**11**	**48**	**9**	**239**		**297**	**308**	**-2,57**	**605**	**39**	**40**	
Loch Nan Eun	24/08/94	8,7	0	34	25	76	4	-7	49	19	73		148	134	4,87	282	19	19	2,10
L.Nan Eun	**M 94**	**8,7**	**0**	**34**	**25**	**76**	**4**	**-7**	**49**	**19**	**73**		**148**	**134**	**4,87**	**282**	**19**	**19**	**2,10**
L. Maam	10/09/93	3,5	1	22	33	180	4		37	4	183		244	225	4,09	469	28	31	
L. Maam	23/03/93	10,7		60	116	564	13	0	97	4	660		764	761	0,18	1525	100	101	
L. Maam	26/04/93	57,5		43	53	300	9	9	51	2	353		463	415	5,40	878	54	73	
L. Maam	23/05/93	5,5		36	56	322	12	9	60	3	376		432	448	-1,86	880	54	58	
L. Maam	10/09/93	4,4		23	25	177	4	10	36	4	177		233	227	1,38	460	30	30	
L. Maam	**M 93**	**19,5**		**40**	**63**	**341**	**9**	**7**	**61**	**3**	**392**		**473**	**463**	**1,28**	**936**	**60**	**66**	
L.Paione Sup.	21/09/93	3,0	2	45	6	6	7	31	46	24	6		69	107			11	12	
L.Paione S.	12/01/93	1,7	1	51	8	10	7	1	48	21	3		79	73	3,85	151	11	11	
L.Paione S.	09/03/93	1,5	0	55	10	11	7	1	48	20	4		84	72	7,94	156	11	11	
L.Paione S.	25/05/93	4,4	11	67	12	12	10	-2	62	43	4		117	108	3,91	224	17	17	
L.Paione S.	29/06/93	2,8	6	49	9	11	7	-3	38	25	5		84	65	13,21	149	11	11	
L.Paione S.	07/07/93	3,0	5	44	7	9	6	1	39	25	4		74	69	3,70	143	10	11	
L.Paione S.	27/07/93	2,2	3	47	8	9	6	-6	41	26	3		75	63	8,43	139	11	10	
L.Paione S.	21/09/93	2,6	2	49	9	10	7	-2	47	24	3		79	73	4,10	151	11	11	
L.Paione S.	09/11/93	2,2	2	43	8	10	6	0	45	20	4		71	69	1,76	140	11	10	
L.Paione S.	**M 93**	**2,60**	**4**	**50**	**8**	**10**	**7**	**2**	**46**	**25**	**4**		**81**	**78**	**6**	**157**	**12**	**11**	
L.Paione S.	05/07/94	2,0	3	38	7	8	4	2	31	21	3		62	58	4,02	120	9	9	
L.Paione S.	26/07/94	1,4	3	36	6	7	5	0	31	17	3		57	51	6,05	108	8	8	
L.Paione S.	13/09/94	1,7	3	45	8	8	7	0	40	23	4		73	67	3,96	140	10	10	
L.Paione S.	27/10/94	0,9	1	52	9	10	8	3	41	24	5		81	73	5,60	154	11	11	
L.Paione S.	**M 94**	**1,5**	**2**	**43**	**7**	**8**	**6**	**1**	**36**	**21**	**4**		**69**	**62**	**4,91**	**131**	**10**	**9**	
L.Paione Inf.	21/09/93	0,4	1	75	9	11	8	8	56	26	6		105	96	4,34	201	13	13	
L.Paione Inf.	12/01/93	0,3	0	83	12	15	10	34	57	23	3		120	118	1,16	238	15	15	
L.Paione Inf.	09/03/93	0,3	0	96	14	15	9	40	57	23	4		134	124	3,96	259	16	16	
L.Paione Inf.	25/05/93	0,6	1	83	12	14	8	26	50	32	4		119	112	3,12	231	15	15	
L.Paione Inf.	29/06/93	0,4	1	76	12	13	8	15	49	31	4		110	99	5,47	208	13	14	
L.Paione Inf.	07/07/93	0,4	0	80	13	13	8	20	50	32	3		115	106	4,35	221	13	14	
L.Paione Inf.	27/07/93	0,2	0	84	13	14	9	22	55	30	3		121	109	4,97	230	14	15	
L.Paione Inf.	21/09/93	0,4	0	75	12	13	8	22	55	25	4		109	106	1,39	214	14	14	
L.Paione Inf.	09/11/93	0,4	0	70	12	11	7	24	52	21	4		102	101	0,46	202	13	13	
L.Paione Inf.	**M 93**	**0,4**	**0**	**81**	**13**	**14**	**8**	**25**	**53**	**27**	**4**		**116**	**109**	**3,11**	**226**	**14**	**15**	
L.Paione Inf.	25/01/94	0,3	0	88	13	15	8	41	57	24	4		124	126	-0,51	250	16	16	
L.Paione Inf.	31/05/94	0,4	1	72	12	16	7	17	47	32	5		109	102	3,52	211	14	14	
L.Paione Inf.	23/06/94	0,3	0	66	11	11	6	17	44	26	3		94	90	2,46	184	12	12	
L.Paione Inf.	05/07/94	0,3	0	67	11	13	4	19	45	27	5		96	96	0,05	191	13	12	
L.Paione Inf.	26/07/94	0,3	1	71	11	13	9	23	48	24	3		105	98	3,20	203	13	13	
L.Paione Inf.	13/09/94	0,3	1	79	12	13	9	28	51	23	3		113	106	3,21	219	14	14	
L.Paione Inf.	27/10/94	0,2	0	83	12	14	10	34	52	23	5		120	113	2,94	233	14	15	
L.Paione Inf.	**M 94**	**0,3**	**0**	**75**	**12**	**14**	**8**	**26**	**49**	**26**	**4**		**109**	**104**	**2,12**	**213**	**14**	**14**	

	Date	H+	NH4	Ca	Mg	Na	K	Alk	SO4	NO3	Cl	F	S Cat.	S An.	% Diff.	S Ions	Measured	Measured	Calculated
		µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l		µeq/l		µS/cm 25°C	25°C
Lago Lungo	20/09/93	0,3	1	78	12	12	6	60	54	11			108	125			13	13	
Lago Lungo	01/02/93	0,5	1	85	16	18	8	31	75	13	4		129	123	2,32	253	14	16	
Lago Lungo	31/03/93	1,0	2	111	21	22	10	33	96	18	5		166	152	4,27	318	18	21	
Lago Lungo	12/07/93	0,3	0	71	13	14	6	30	56	14	3		106	103	1,16	209	12	13	
Lago Lungo	02/08/93	0,3	0	71	12	13	6	28	60	13	3		103	104	-0,58	207	12	13	
Lago Lungo	20/09/93	0,1	0	71	13	15	6	27	62	10	4		106	104	1,21	210	12	13	
Lago Lungo	06/12/93	0,4	0	78	21	20	8	30	71	15	5		128	121	2,77	249	14	16	
Lago Lungo	**M 93**	**0,4**	**1**	**81**	**16**	**17**	**7**	**30**	**70**	**14**	**4**		**123**	**118**	**1,86**	**241**	**13**	**16**	
Lago Lungo	05/09/94	0,2	0	65	12	12	5	28	59	10	2	0	94	98	-2,06	193	12	11	1,23
Lago Lungo	18/07/94	0,6	1	65	11	10	4	24	53	16	4	0	92	96	-2,39	188	11	11	1,23
Lago Lungo	10/05/94	2,6	7	73	14	14	5	16	69	29	5	0	115	118	-1,27	234	15	15	1,62
Lago Lungo	24/01/94	0,7	1	74	13	13	5	40	59	10	3	0	107	113	-2,46	220	13	13	1,40
Lago Lungo	**M94**	**1,0**	**2**	**69**	**13**	**12**	**5**	**27**	**60**	**16**	**3**	**0**	**102**	**106**	**-2,04**	**209**	**13**	**12**	**1,37**
Lago di Latte	21/09/93	0,2	1	108	12	15	8	86	56	23			144	165			17	17	
Lago di Latte	20/01/93	0,4	1	99	12	18	11	43	58	23	3		141	127	5,08	268	15	17	
Lago di Latte	05/05/93	0,4	2	105	14	19	10	45	65	26	5		151	141	3,40	292	16	18	
Lago di Latte	13/07/93	0,2	0	95	12	18	9	64	56	22	3		135	145	-3,39	280	15	17	
Lago di Latte	03/08/93	0,2	0	91	12	16	8	53	56	21	3		128	134	-2,04	262	14	16	
Lago di Latte	21/09/93	0,2	1	101	12	18	10	61	60	22	4		143	147	-1,50	289	16	18	
Lago di Latte	13/12/93	0,2	0	92	17	22	10	54	60	23	8		141	145	-1,31	286	15	18	
Lago di Latte	**M 93**	**0,3**	**1**	**97**	**13**	**18**	**10**	**53**	**59**	**23**	**4**		**140**	**140**	**0,04**	**280**	**15**	**17**	
Lago di Latte	06/09/94	0,2	0	96	12	15	8	58	62	17	1		131	139	-2,79	270	16	15	1,66
Lago di Latte	21/07/94	0,5	1	76	8	11	7	38	47	21	4		105	110	-2,43	214	12	12	1,36
Lago di Latte	09/05/94	0,8	7	92	11	13	7	41	61	28	5		130	135	-1,84	265	16	15	1,71
Lago di Latte	24/01/94	0,5	1	102	12	14	7	66	55	21	3		137	145	-2,76	282	16	16	1,73
Lago di Latte	**M94**	**0,5**	**2**	**92**	**11**	**13**	**7**	**51**	**56**	**22**	**3**		**126**	**132**	**-2,45**	**258**	**15**	**15**	**1,61**
Blanc	06/11/93	0,1	1	122	33	35	12		37	19	6	0	203	62	53,21	265	21	15	
Blanc	24/07/93	0,2		55	13	4			8	10		7	73	18	60,20	91	9	5	
Blanc	24/07/93	0,2		70	15	9			10	8		7	94	18	67,01	112	11	6	
Blanc	24/07/93	0,2		55	14	4			10	8		7	73	18	59,78	92	10	5	
Blanc	24/07/93	0,2		65	14	4			8	8		7	83	16	67,13	100	10	6	
Blanc	04/11/93	0,1		150	3	35			40	18			188	57	53,23	245	20	14	
Blanc	**M 93**	**0,2**		**79**	**12**	**11**			**15**	**10**		**7**	**102**	**26**			**12**		
Blanc	12/10/94	0,1	2	75	19	13	10	72	27	14	3		119	116	1,23	235	14	14	
Blanc	**M 94**	**0,1**	**2**	**75**	**19**	**13**	**10**	**72**	**27**	**14**	**3**		**119**	**116**	**1,23**	**235**	**14**	**14**	
Noir	24/07/93	0,1	0	175	27	9			19	8		3	211	27	77,41	237	24	13	
Noir	24/07/93	0,2	0	95	26	9			19	8		3	130	27	65,81	157	16	9	
Noir	24/07/93	0,1	0	100	27	9			17	8		3	136	25	69,18	160	17	9	
Noir	24/07/93	0,1	0	105	27	9			21	8			141	29	65,94	170	17	9	
Noir	04/11/93	0,1	0	175	37	35	8		44	14			254	58	62,73	312	25	17	
Noir	**M 93**	**0,1**	**0**	**130**	**29**	**14**	**8**		**24**	**9**		**3**	**174**	**33**			**20**		
Noir	12/10/94	0,1	0	125	33	13	5	92	67	11	6		176	175	0,16	351	20	21	
Noir	**M 94**	**0,1**	**0**	**125**	**33**	**13**	**5**	**92**	**67**	**11**	**6**		**176**	**175**	**0,16**	**351**	**20**	**21**	
Etang d'Aube	15/07/93	1,0		32	8	15	3	12	26	10	7		59	55	3,82	115	8	7	
Etang d'Aube		0,5	10	35	6	37	21	37	25	10	34		110	106	1,85	215	14	14	
Etang d'Aube	13/10/93	0,8	9	32	6	18	5	20	26	9	10		70	65	4,07	135	8	9	
Etang d'Aube	**M 93**	**0,6**	**9**	**34**	**6**	**23**	**13**	**29**	**26**	**9**	**17**		**90**	**85**	**2,96**	**175**	**11**	**11**	
Etang d'Aube	31/08/94	0,7	3	27	6	18	3	48	23	9	8		58	88	-20,59	147	7	8	0,88

	Date	H+	NH4	Ca	Mg	Na	K	Alk	SO4	NO3	Cl	F	S Cat.	S An.	% Diff.	S Ions	Measured	Measured	Calculated
		µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l		µeq/l		µS/cm 25°C	25°C
Etang d'Aube	09/09/94	1,0	1	28	6	14	2		12	22	9	7		52	51,00	1	7	6	0,65
Etang d'Aube	**M94**	**0,8**	**2**	**28**	**6**	**16**	**2**	**48**	**17**	**16**	**9**	**7**	**58**	**70**	**15,21**	**74**	**7**	**7**	**0,76**
Schwarzsee ob Sölden	18/08/93	6,9	1	57	17	10	3		77	14	8		94	100	-3,10	194	16	15	
Schwarzsee ob Sölden	02/07/93	3,2	1	42	13	10	2	0	51	8	2		71	60	8,24	132	9	10	
Schwarzsee ob Sölden	18/08/93	1,4	0	53	20	13	3	0	81	7	2		90	90	0,05	180	13	13	
Schwarzsee ob Sölden	20/09/93	4,7	1	57	21	14	3	0	77	23	3		100	103	-1,33	203	17	15	
Schwarzsee ob Sölden	**M 93**	**3,1**	**1**	**51**	**18**	**12**	**3**	**0**	**70**	**13**	**2**		**87**	**84**	**2,32**	**172**	**13**	**13**	
Schwarzsee ob Sólden	14/01/94	1,6	2	75	26	19	4	9	94	12	3		127	118	3,7	248	17	15	1,62
Schwarzsee ob Sólden	23/02/94	1,7	2	75	26	17	4	6	102	10	3		125	122	1,5	250	16	15	1,65
Schwarzsee ob Sólden	28/03/94	2,1	2	73	25	17	4	6	83	10	4		124	103	9,1	231	16	13	1,50
Schwarzsee ob Sólden	20/04/94	2,9	2	71	25	17	4	17	104	10	3		122	135	-5,0	260	17	15	1,69
Schwarzsee ob Sólden	11/05/94	2,2	2	72	26	16	4	3	92	13	3		123	110	5,2	236	18	14	1,55
Schwarzsee ob Sólden	31/05/94	4,5	3	69	21	14	4	8	77	15	5		116	105	5,1	226	16	13	1,44
Schwarzsee ob Sólden	12/07/94	4,2	1	47	16	15	3	2	58	10	3		87	73	8,8	165	11	9	1,04
Schwarzsee ob Sólden	01/09/94	2,2	0	60	25	16	4	7	81	8	3		106	98	3,9	208	16	12	1,35
Schwarzsee ob Sólden	09/09/94																		
Schwarzsee ob Sólden	**M94**	**2,5**	**2**	**68**	**24**	**16**	**4**	**7**	**86**	**11**	**3**		**52**	**108**	**4,04**	**228**	**16**	**13**	**1,48**
Aguilo	19/10/93	2,5	1	24	7	8	2	7	19	3	8		44	38	8,21	82	6	5	
L. Aguilo	19/10/93	1,6	0	22	13	9	2	18	15	3	5		48	41	7,86	89	6	6	
L. Aguilo	**M 93**	**1,6**	**0**	**22**	**13**	**9**	**2**	**18**	**15**	**3**	**5**		**48**	**41**	**7,86**	**89**	**6**	**6**	
Lago Aguilo	10/10/94	0,8	0	18	10	9	2	11	13	2	7		40	33	9,11	73	5	4	0,47
L. Aguilo	**M 94**	**0,8**	**0**	**18**	**10**	**9**	**2**	**11**	**13**	**2**	**7**		**40**	**33**	**9,11**	**73**	**5**	**4**	**0,47**
L. Redo	16/10/93	0,5	1	75	14	9	2	42	31	14	5		101	92	4,82	193	12	12	
L. Redo	**M 93**	**0,5**	**1**	**75**	**14**	**9**	**2**	**42**	**31**	**14**	**5**		**101**	**92**	**4,82**	**193**	**12**	**12**	
Lago Redo	11/10/94	0,2	1	71	13	10	2	44	23	11	8		96	86	5,15	182	12	10	1,09
L. Redo	**M 94**	**0,2**	**1**	**71**	**13**	**10**	**2**	**44**	**23**	**11**	**8**		**96**	**86**	**5,15**	**182**	**12**	**10**	**1,09**
La Caldera	14/07/93	0,0	1	179	27	13	3	180	17	9	10		223	216	1,61	439	22	24	
La Caldera	07/09/93	0,0	4	215	35	21	3	209	20	2	20		278	251	5,06	530	30	29	
La Caldera	**M 93**	**0,0**	**2**	**197**	**31**	**17**	**3**	**195**	**19**	**5**	**15**		**251**	**234**	**3,33**	**484**	**26**	**26**	
La Caldera	20/07/94	0,0	0	228	38	40	6	270	18	0	2030		311	2318	-76,31	2630	22	166	
La Caldera	02/08/94	0,01	2	218	46	124	21	268	24	0	0		411	292	17,00	703	30	34	
La Caldera	01/09/94	0,01	5	321	48	50	6	284	30	0	0		430	314	15,52	744	36	36	
La Caldera	13/09/94	0,0	6	280	47	13	4	330	25	1	14		350	370	-2,71	720	32	23	2,52
La Caldera	13/09/94	0,0	7	278	44	12	4	346	37	1	62		346	446	-12,62	792	33	27	2,97
La Caldera	**M94**	**0,02**	**4**	**265**	**45**	**48**	**8**	**300**	**27**	**0**	**421**		**370**	**748**	**-12**	**1118**	**31**	**57**	**2,74**
Escura	06/10/93	4,6	1	18	13	43	3	-10	23	0	48		82	61	14,6		12	11	
L. Escura	06/10/93	4,9	0	12	23	28	2	6	22	0	31		70	59	8,93	129	13	10	
L. Escura	**M 93**	**4,9**	**0**	**12**	**23**	**28**	**2**	**6**	**22**	**0**	**31**		**70**	**59**	**8,93**	**129**	**13**	**10**	
Lago Escura	17/09/94	3,9	1	12	18	32	5	0	14	0	37		72	51	17,57	123	11	8125	0,90
L. Escura	**M 94**	**3,9**	**1**	**12**	**18**	**32**	**5**	**0**	**14**	**0**	**37**		**72**	**51**	**17,57**	**123**	**11**	**8125**	**0,90**
Starolesnianske pleso	28/09/93	12,9	1	41	7	1	2		65	12	6		64	83	-12,87	147	15	14	
Starolesnianske pleso	VS-15	20,0	1	36	8	8	2		84	12	5		76	101	-14,03	177	15	18	
Starolesnianske pleso	**M 93**	**16,42**	**1**	**39**	**7**	**5**	**2**		**74**	**12**	**5**		**70**	**92**	**-13,45**	**161,80**	**15,20**	**16,10**	
Starolesnianske Pleso	27/10/94	20,4	3	29	6	3	3	0	52	11	3		64	55	8,17	130	14	13	
Starolesnianske pleso	**M 94**	**20,4**	**3**	**29**	**6**	**3**	**3**	**0**	**52**	**11**	**3**		**64**	**55**	**8,17**	**130**	**14**	**13**	
Terianske pleso	29/09/93	0,1		160	7	6	3	61	65	42	6		175	173	0,55	348	22	20	
Terianske pleso	NE-3	0,2	1	159	12	20	3		71	36	5		194	113	26,49	307	20	18	
Terianske pleso	**M 93**	**0,14**	**1**	**159**	**9**	**13**	**3**	**61**	**68**	**39**	**5**		**184**	**143**	**13,52**	**327,18**	**21,25**	**18,82**	

	Date	H+	NH4	Ca	Mg	Na	K	Alk	SO4	NO3	Cl	F	S Cat.	S An.	% Diff.	S Ions	Measured	Measured	Calculated
		µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l		µeq/l		µS/cm 25°C	25°C
Dlugi Staw	01/11/94	1,9	1	112	11	17	4	13	73	52	6		146	143	1,04		18	18	
Dlugi Staw	15/11/94	0,9	0	115	11	14	3	15	73	56	6		144	150	-2,04		18	18	
Dlugi Staw	30/11/94	0,8	0	122	12	16	3	18	75	55	7		152	156	-1,30		18	18	
Dlugi Staw	23/12/94	0,6	0	126	11	20	3	18	81	55	8				-3,11		20	19	
Dlugi Staw	**M94**	**1,53**	**1**	**115**	**10**	**17**	**4**	**17**	**74**	**51**	**7**		**148**	**148**	**-0,67**	**299**	**6**	**18**	**2,01**
Zieloni Staw	23/09/93	0,1		155	16	12	5	79	73	28	8		187	188	-0,18	376	23	21	
Zieloni Staw	GA-7	0,2	1	154	20	27	6		78	25	7		208	110	30,85	318	22	19	
Zieloni Staw	03/01/93	0,4		152	17	20	4	64	77	37	8		194	187	1,81	381	23	21	
Zieloni Staw	19/01/93	0,5	0	142	12	20	4	19	81	65	8		178	173	1,57	351	21	21	
Zieloni Staw	31/01/93	0,3	1	132	16	20	5	59	75	42	8		175	184	-2,52	360	23	20	
Zieloni Staw	16/02/93	0,3	3	149	17	19	5	65	73	40	8		193	186	1,79	379	21	21	
Zieloni Staw	01/03/93	0,2	1	151	17	20	5	84	79	36	8		196	208	-2,99	403	24	22	
Zieloni Staw	06/04/93	0,3		161	18	22	6	86	79	41	8		207	214	-1,65	422	25	23	
Zieloni Staw	15/04/93	0,3	1	163	18	20	5	79	69	39	8		207	195	3,16	402	24	22	
Zieloni Staw	20/04/93	0,4	10	165	18	24	5	74	81	45	11		223	212	2,58	435	27	24	
Zieloni Staw	03/05/93	1,1	10	142	16	17	5	23	92	55	11		191	181	2,67	371	25	22	
Zieloni Staw	17/03/93	0,6		126	13	15	4	51	62	34	8		159	157	0,63	315	20	18	
Zieloni Staw	01/06/93	0,2	0	162	17	16	4	89	73	35	8		200	205	-1,21	405	23	22	
Zieloni Staw	14/06/93	0,2	1	145	16	19	4	82	73	33	8		185	196	-2,94	380	22	21	
Zieloni Staw	01/07/93	0,2	1	147	16	18	4	84	71	30	8		185	193	-2,07	378	22	21	
Zieloni Staw	12/07/93	0,2	2	150	16	17	4	84	67	30	8		189	188	0,05	377	23	21	
Zieloni Staw	22/08/93	0,2	2	148	16	19	5	71	69	29	6		188	175	3,71	363	22	20	
Zieloni Staw	02/09/93	0,2	2	150	17	17	5	79	73	28	6		191	185	1,56	376	22	21	
Zieloni Staw	13/09/93	0,2	1	148	16	19	5	79	71	29	8		188	187	0,34	375	22	21	
Zieloni Staw	23/09/93	0,1	0	155	16	12	5	83	73	28	8		188	192	-1,05	380	23	21	
Zieloni Staw	27/09/93	0,2	2	154	16	20	5	73	75	29	8		197	185	3,08	382	22	21	
Zieloni Staw	10/01/93	0,2	1	154	20	27	6		78	25	7		208	110	30,85	318	22	19	
Zieloni Staw	15/11/93	0,2		165	19	19	4	94	77	29	6		207	206	0,41	413	23	23	
Zieloni Staw	30/11/93	0,2	0	185	21	20	5	105	96	33	11		233	245	-2,64	478	27	26	
Zieloni Staw	14/12/93	0,2	1	196	22	24	5	109	90	35	8		249	242	1,50	491	26	27	
Zieloni Staw	**M 93**	**0,27**	**2**	**154**	**17**	**19**	**5**	**74**	**76**	**35**	**8**		**197**	**188**	**2,77**	**385**	**23**	**22**	
Zieloni Staw	01/01/94	0,2	1	177	20	22	5	96	79	61	6		225	214	2,44	439	3	24	2,66
Zieloni Staw	17/01/94	0,4	0	145	13	20	3	21	85	36	6		182	171	3,02	353	2	21	2,32
Zieloni Staw	01/02/94	0,2	4	169	20	26	6	94	75	61	8		225	214	2,49	439	3	24	2,67
Zieloni Staw	15/02/94	0,2	2	165	19	22	6	93	75	61	8		215	211	0,87	426	3	23	2,59
Zieloni Staw	28/02/94	0,3	4	163	17	19	5	94	75	60	8		208	212	-0,87	421	2	23	2,56
Zieloni Staw	14/03/94	0,3	1	164	18	20	4	92	73	62	8		208	208	-0,09	416	2	23	2,53
Zieloni Staw	29/03/94	0,4	1	163	19	22	4	87	73	66	8		209	207	0,43	417	2	23	2,54
Zieloni Staw	19/04/94	0,4	3	166	19	20	5	80	73	65	8		213	202	2,76	415	3	23	2,55
Zieloni Staw	04/05/94	0,7	7	137	15	17	4	55	73	69	8		180	177	1,07	357	2	20	2,26
Zieloni Staw	17/05/94	0,7	4	133	15	17	4	46	65	48	8		174	159	4,43	332	2	19	2,11
Zieloni Staw	22/05/94	0,4	1	128	14	17	4	66	65	44	6		165	169	-1,19	334	2	19	2,06
Zieloni Staw	31/05/94	0,3	0	130	14	17	4	73	62	42	6		165	183	-5,20		2	19	2,06
Zieloni Staw	20/06/94	0,1	0	152	12	17	4	88	67	39	6		186	199	-3,45		2	20	2,25
Zieloni Staw	04/07/94	0,2	1	129	9	17	4	72	71	35	6		160	184	-6,98		2	18	2,05
Zieloni Staw	18/07/94	0,2	1	125	12	17	4	67	69	34	6		159	175	-4,89		2	18	2,00
Zieloni Staw	25/07/94	0,3	2	127	14	19	4	65	77	38	8		166	188	-6,26		2	19	2,12
Zieloni Staw	16/08/94	0,2	2	132	15	18	4	73	79	40	6		172	198	-7,05		2	20	2,18

	Date	H+	NH4	Ca	Mg	Na	K	Alk	SO4	NO3	Cl	F	S Cat.	S An.	% Diff.	S Ions	Measured	Measured	Calculated
		µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l		µeq/l		µS/cm 25°C	25°C
Terianske Pleso	27/10/94	0,4	0	143	7	16	4	68	55	31	5		170	159	-6,79	329	19	18	
Terianske pleso	**M 94**	**0,4**	**0**	**143**	**7**	**16**	**4**	**68**	**55**	**31**	**5**		**170**	**159**	**-6,79**	**329**	**19**	**18**	
Dlugi Staw	23/09/93	1,1	0	110	8	7	3	-2	75	54	6		129	132	-1,20	262	19	18	
Dlugi Staw	GA-4		1	107	11	17	5		82		5		140	87	23,42	228	18	14	
Dlugi Staw	03/01/93	0,6		144	12	19	3	21	87	63	11		179	183	-1,00	362	23	21	
Dlugi Staw	19/01/93	0,4	0	147	16	20	5	61	81	41	8		189	192	-0,82	381	22	22	
Dlugi Staw	31/01/93	0,4	0	128	13	20	4	22	79	63	8		166	173	-1,90	339	22	20	
Dlugi Staw	01/03/93	0,3	0	137	12	20	4	27	85	63	11		174	187	-3,70	361	23	21	
Dlugi Staw	06/04/93	0,6		145	13	20	3	25	87	65	8		182	186	-0,88	368	23	22	
Dlugi Staw	15/04/93	0,6	0	148	13	20	4	23	75	64	8		186	170	4,45	356	23	21	
Dlugi Staw	20/04/93	0,4	1	155	12	21	4	21	92	67	14		193	194	-0,04	387	25	23	
Dlugi Staw	03/05/93	0,9	1	141	12	14	4	6	83	70	8		172	168	1,13	340	24	21	
Dlugi Staw	17/05/93	7,2		91	8	13	4	0	69	62	11		124	142	-6,84	266	21	18	
Dlugi Staw	01/06/93	6,0	2	76	7	7	3	3	60	48	8		101	120	-8,58	221	16	15	
Dlugi Staw	14/06/93	4,7	1	78	7	10	3	4	65	44	8		104	121	-7,74	225	16	15	
Dlugi Staw	01/07/93	3,7	1	82	7	11	3	0	60	45	8		107	113	-2,99	220	17	14	
Dlugi Staw	12/07/93	1,2	0	105	8	13	3	6	65	50	6		130	127	1,36	257	19	16	
Dlugi Staw	22/08/93	1,3	2	112	10	17	6	5	67	52	8		148	132	5,47	280	20	17	
Dlugi Staw	02/09/93	1,9	0	98	10	13	4	0	75	45	6		128	125	0,90	253	17	16	
Dlugi Staw	13/09/93	1,5	1	104	8	14	4		73	54	6		133	132	0,34	265	18	16	
Dlugi Staw	23/09/93	1,1	0	110	8	7	3	0	75	54	6		129	135	-1,95	264	19	16	
Dlugi Staw	27/09/93	1,2	0	112	9	16	4	18	77	54	8		143	157	-4,70	300	19	18	
Dlugi Staw	01/10/93												0	0		0	0	0	
Dlugi Staw	15/11/93	0,9	0	136	12	17	3	21	85	56	6		170	168	0,45	338	22	20	
Dlugi Staw	30/11/93	0,9	0	139	13	17	4	24	87	59	11		174	182	-2,14	356	23	21	
Dlugi Staw	14/12/93	0,4	0	150	12	20	4	20	87	62	8		186	177	2,49	364	23	22	
Dlugi Staw	**M 93**	**1,69**	**1**	**120**	**11**	**15**	**4**	**14**	**77**	**56**	**8**		**145**	**146**		**291**	**20**	**18**	
Dlugi Staw	01/01/94	0,6	0	146	12	21	3	20	87	61	6		183	173	2,73	357	2	21	2,35
Dlugi Staw	17/01/94	0,2	1	172	20	21	5	91	79	36	6		218	211	1,62	430	2	24	2,62
Dlugi Staw	04/02/94	0,2	0	143	13	22	4	24	85	61	6		182	176	1,75	358	2	21	2,34
Dlugi Staw	15/02/94	0,4	0	146	13	20	4	25	87	61	6		183	180	0,90	362	2	21	2,37
Dlugi Staw	28/02/94	0,7	0	144	12	19	3	26	96	60	8		179	191	-3,07	370	2	22	2,44
Dlugi Staw	14/03/94	0,7	0	142	12	20	4	23	85	62	6		178	176	0,75	354	2	21	2,33
Dlugi Staw	29/03/94	0,7	0	143	13	21	3	24	85	66	6		182	181	0,29	363	2	21	2,38
Dlugi Staw	19/04/94	0,7	0	158	14	21	4	31	83	65	8		198	188	2,59	386	2	23	2,51
Dlugi Staw	04/05/94	1,1	0	146	13	18	3	15	79	69	8		182	171	3,10	354	2	21	2,35
Dlugi Staw	17/05/94	2,1	3	102	10	15	3	4	62	48	8		134	123	4,42	257	2	16	1,77
Dlugi Staw	22/05/94	4,4	3	73	8	11	4	0	60	45	8		104	113	-4,34	218	2	14	1,61
Dlugi Staw	31/05/94	4,8	2	73	8	11	3	2	60	42	6		102	110	-3,68	212	2	14	1,57
Dlugi Staw	20/06/94	5,4	1	77	5	11	3	2	60	39	6		102	107	-2,02	209	2	14	1,57
Dlugi Staw	04/07/94	2,3	1	75	4	13	3	6	58	35	6		98	105	-3,59	203	2	13	1,43
Dlugi Staw	18/07/94	2,9	1	71	3	11	3	3	56	34	6		91	98	-3,77	190	1	12	1,36
Dlugi Staw	25/07/94	1,2	0	98	9	15	3	11	81	38	6		127	136	-3,32	263	2	16	1,79
Dlugi Staw	16/08/94	1,1	1	96	9	18	6	12	69	40	8		131	129	0,79	260	2	16	1,75
Dlugi Staw	29/08/94	1,4	1	91	7	11	4	12	67	42	6		117	127	-4,17	243	2	15	1,66
Dlugi Staw	19/09/94	1,2	2	96	9	17	4	10	67	51	9		127	136	-3,42		16	16	
Dlugi Staw	02/10/94	1,0	2	104	10	20	6	12	71	50	6		141	139	0,71		18	17	
Dlugi Staw	18/10/94	1,1	1	108	10	14	3	11	71	51	3		137	136	0,37		18	17	

	Date	H+	NH4	Ca	Mg	Na	K	Alk	SO4	NO3	Cl	F	S Cat.	S An.	% Diff.	S Ions	Measured	Measured	Calculated
		µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l	µeq/l		µeq/l		µS/cm 25°C	25°C
Zieloni Staw	29/08/94	0,2	3	130	14	14	5	80	69	43	6		166	197	-8,61		2	19	2,09
Zieloni Staw	19/09/94	0,2	3	143	9	17	4		67	51	9		176	127	16,23		20	18	
Zieloni Staw	02/10/94	0,1	3	144	10	20	6		71	50	6		183	127	18,09		20	19	
Zieloni Staw	18/10/94	0,2	2	150	10	14	3		71	51	3		179	125	17,82		21	18	
Zieloni Staw	01/11/94	0,3	1	147	11	17	4		73	52	6		180	131	15,84		20	19	
Zieloni Staw	15/11/94	0,3	1	144	11	14	3		73	56	6		173	135	12,42		21	19	
Zieloni Staw	**M94**	**0,29**	**2**	**146**	**14**	**19**	**4**	**75**	**72**	**51**	**7**		**186**	**179**	**2**	**395**	**6**	**20**	**2,31**
Laguna Cimera	mar-93												0	0		0	9	0	
Laguna Cimera	jun-93	1,5						25					1	25	-88,61	26	7	1	
Laguna Cimera	jul-93	0,7						25					1	25	-94,56	26	8	1	
Laguna Cimera	aug-93	1,1						26					1	26	-91,63	27	6	1	
Laguna Cimera	sep-93	0,9						29					1	29	-94,07	29	7	1	
Laguna Cimera	nov-93	3,6						13					4	13	-56,34	17	8	2	
Laguna Cimera	18/09/93	0,5		30	14	12	2	37	19	0	8		58	64	-5,17	122	7	6	
Laguna Cimera	18/09/93	0,9		31		30			16		10		62	26	41,45	88	7	5	
Laguna Cimera	**M 93**	**1,3**		**30**	**14**	**21**	**2**	**26**	**17**	**0**	**9**		**16**	**26**			**8**	**2**	
Laguna Cimera	22/01/94	1,7	0	7	12			9	8	23							3		
Laguna Cimera	16/10/94	2,6	0	20	6	30		25	14	17	9			65			6		
Laguna Cimera	**M 94**	**2,11**	**0**	**14**	**9**	**30**		**17**	**11**	**20**	**9**			**65**			**4**		
Chuna	R25.10.93	0,3	0	60	21	23	4	62	42	12	34		108	149	-16	257	17	16	
Chuna		0,3	1	80	21	46	2	60	42	12	31		152	144	2,42	296	17	18	
Chuna	**M 93**	**0,3**	**1**	**70**	**21**	**35**	**3**	**61**	**42**	**12**	**33**		**130**	**147**	**-7**	**277**	**17**	**17**	
Chuna	27/03/94	0,2	3	100	28	48	7	80	67	11	34		186	192	-1,61	377	25	21	2,29
Chuna	21/04/94	0,6	3	70	18	52	8	33	56	3	42		152	135	5,81	287	20	16	1,82
Chuna	17/08/94	0,4	0	45	11	22	1	23	37	2	17		79	80	-0,23	159	10	9	1,01
Chuna	17/08/94	0,4	1	47	13	21	1	24	35	3	17		84	79	2,52	163	10	9	1,03
Chuna	07/09/94	0,4	0	42	12	24	1	26	40	1	17		80	84	-2,21	164	10	9	1,03
Chuna	**M94**	**0,4**	**2**	**61**	**16**	**33**	**4**	**37**	**47**	**4**	**26**		**116**	**114**	**0,86**	**230**	**15**	**13**	**1,43**
Chibini	R25.10.93	0,1	0	19	5	261	38	251	66	6	26		323	349	-3,81	671	35	36	
Chibini		0,2		89	17	28	2	56	50	12	14		136	132	1,43	268	15		
Chibini	**M 93**	**0,1**	**0**	**54**	**11**	**144**	**20**	**154**	**58**	**9**	**20**		**229**	**240**	**-1,19**	**469**	**25**	**36**	
Chibini	10/07/94	0,0	0	35	6	252	40	234	58	19	23		333	335	-0,32	668	36	33	3,62
Chibini	10/07/94	0,0	0	32	6	245	38	190	52	14	23		322	278	7,22	600	32	29	3,27
Chibini	**M94**	**0,0**	**0**	**34**	**6**	**248**	**39**	**212**	**55**	**17**	**23**		**327**	**307**	**3,45**	**634**	**34**	**31**	**3,45**
Krisko jezero	31/08/93	0,0	1	783	0	43	12	737	146	8	0		841	891	-2,71	1732	105	95	
Krisko jezero	**M 93**	**0,0**	**1**	**783**	**0**	**43**	**12**	**737**	**146**	**8**	**0**		**841**	**891**	**-2,71**	**1732**	**105**	**95**	
Zgornje krisko jezero	27/07/94	0,0	2	744	66	5	1	467		14	6		817	694	8,12	1512	76	78	8,70
Zgornje krisko jezero	31/08/94	0,0	0	674	0	52	4	647	100	7	0	0	730	754	-1,58	1484	87	72	8,03
Zgornje krisko jezero	**M94**	**0,0**	**1**	**709**	**33**	**28**	**3**	**557**	**100**	**10**	**3**	**0**	**774**	**724**	**3,27**	**1498**	**81**	**75**	**8,37**

Figure 2. Position of the annual mean (1991-1994) for Lille Hovvatn, Ireland on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

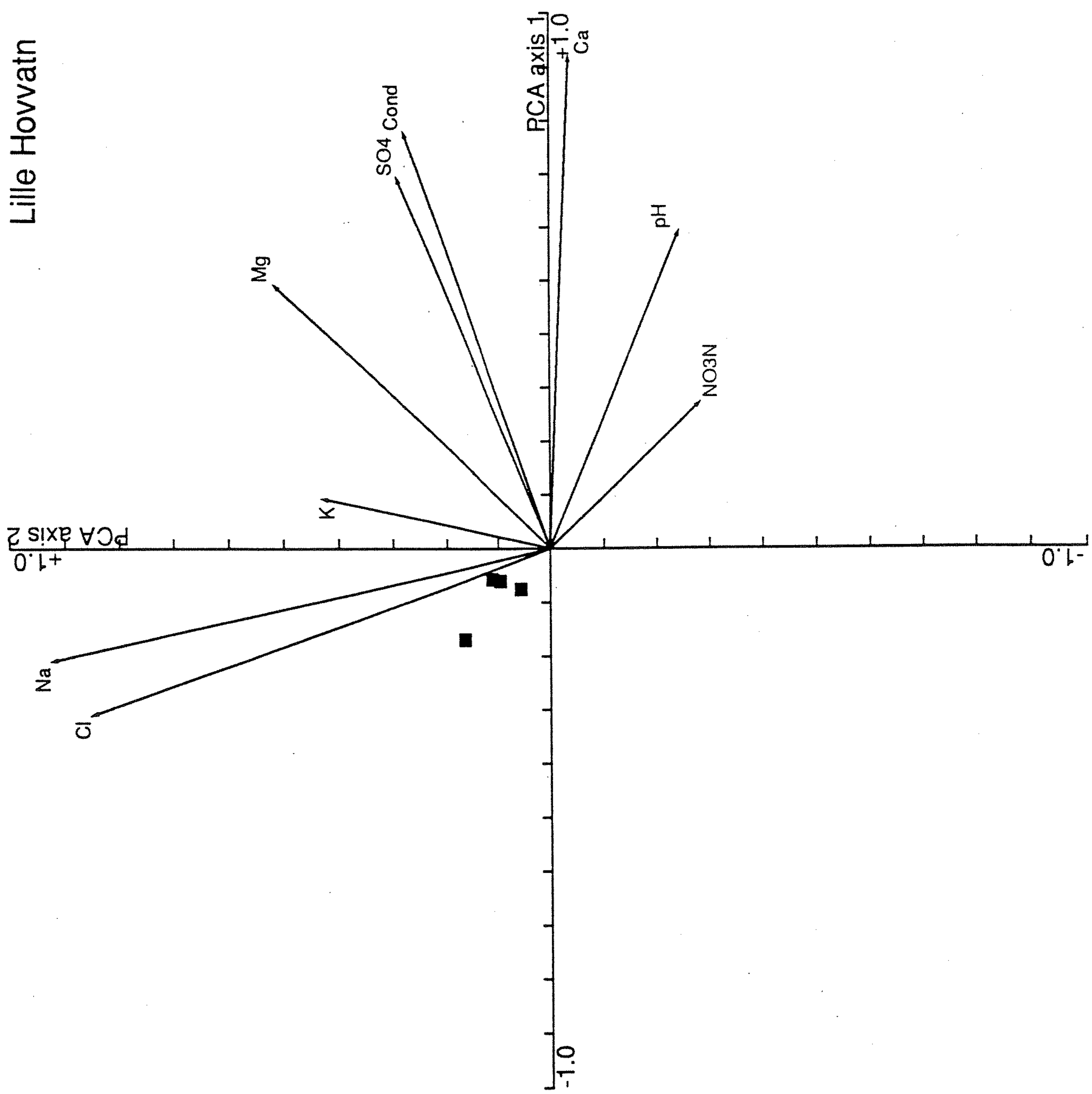


Figure 3. Position of the annual mean (1993) for Lough Maam, Ireland on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

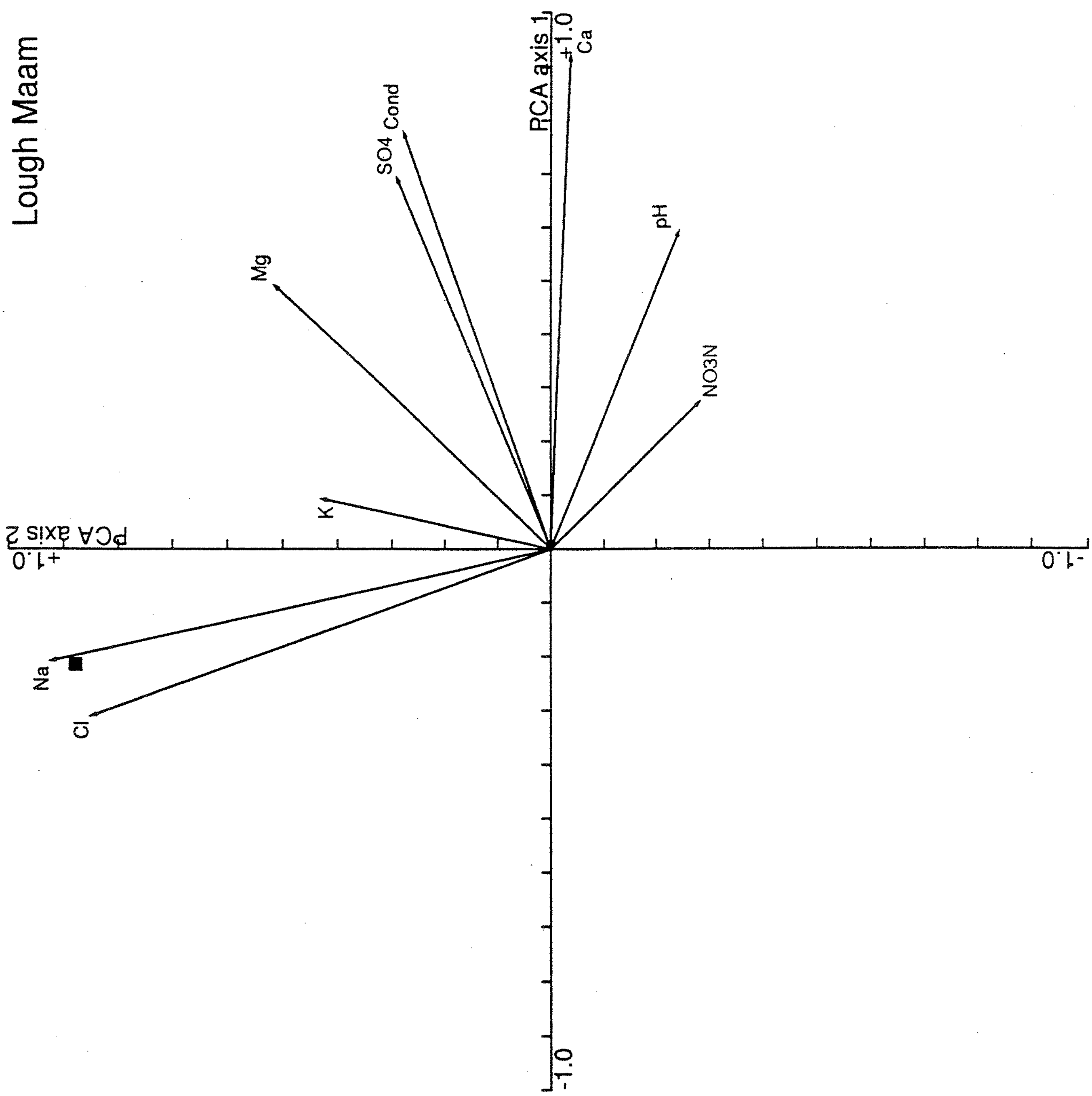


Figure 4. Position of the annual mean (1993 for Arresjøen, Spitsbergen on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

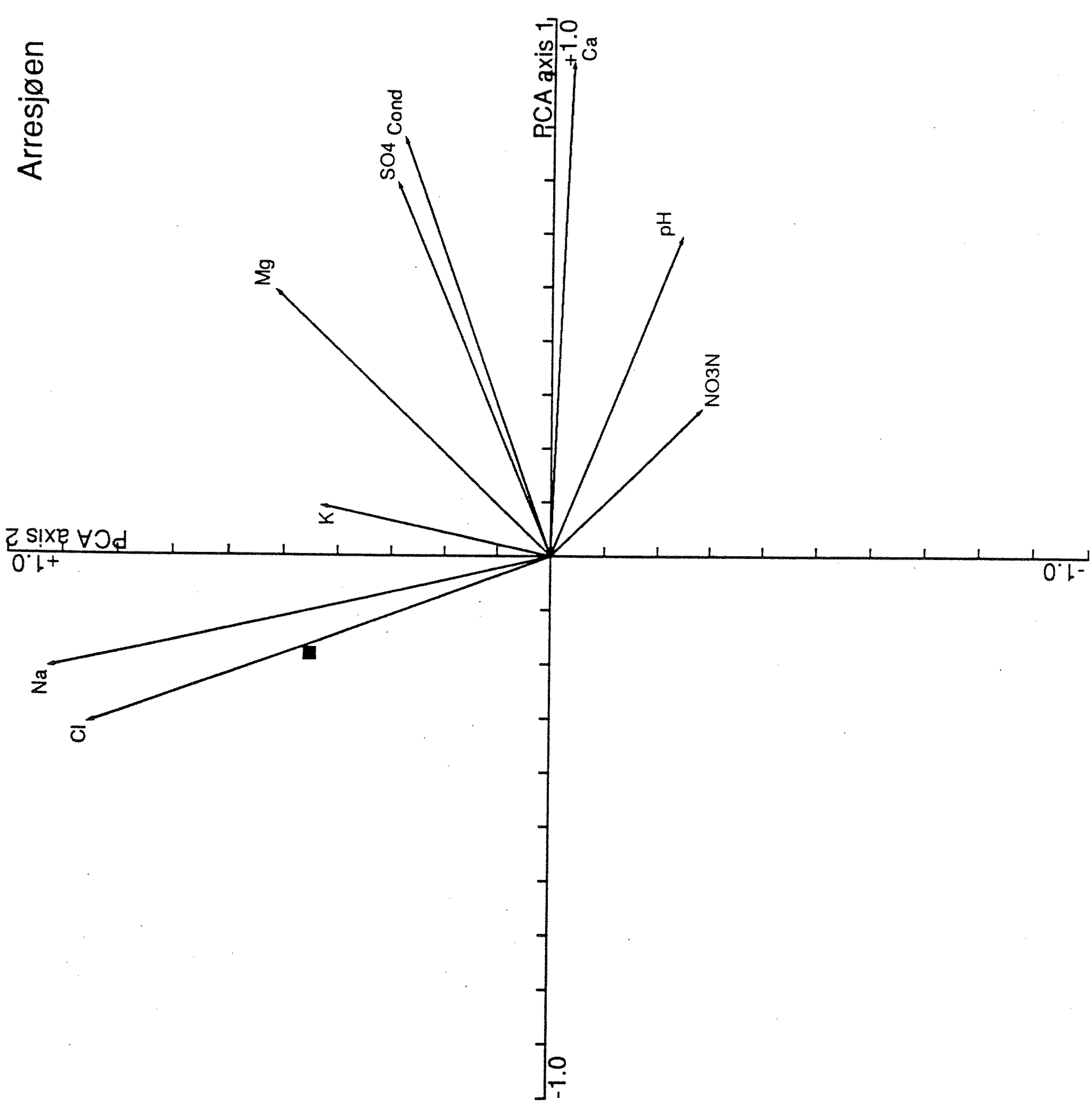


Figure 5. Position of the annual means (1991-1994) for Lochnagar, Scotland on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

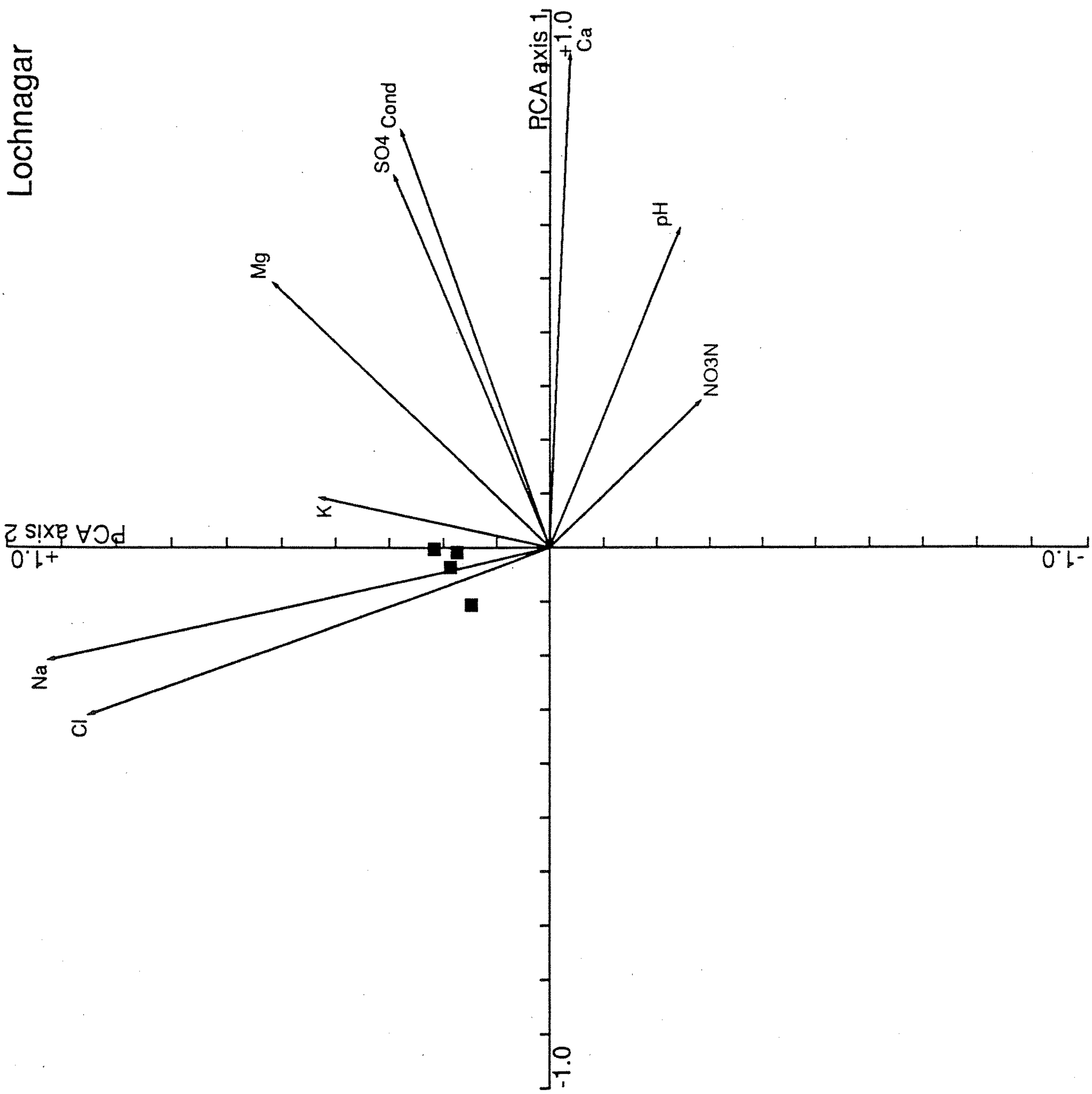


Figure 6. Position of the annual means (1991-1994) for Sandy Loch, Scotland on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

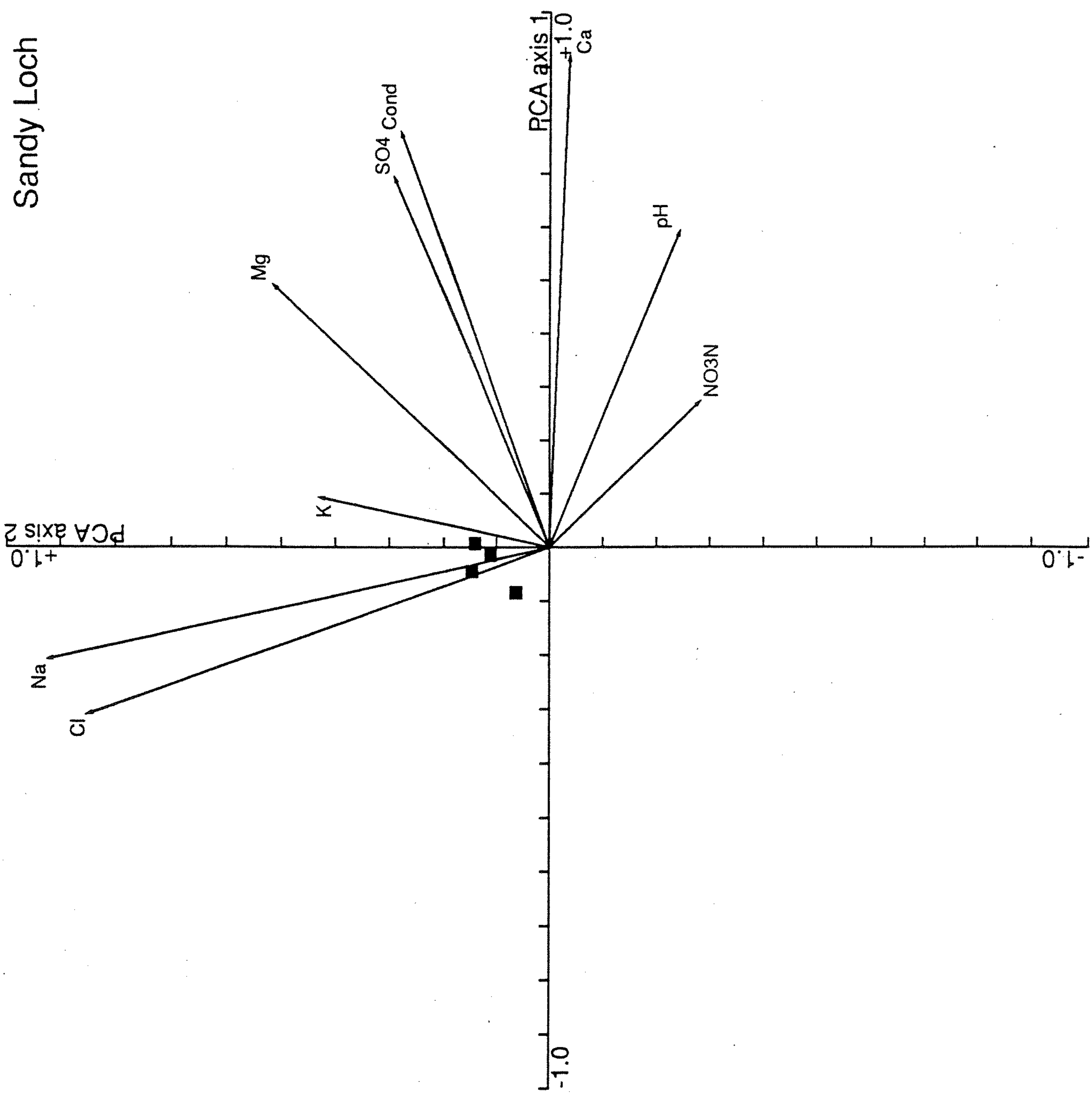


Figure 7. Position of the annual means (1991-1994) for Loch Nan Eun, Scotland on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

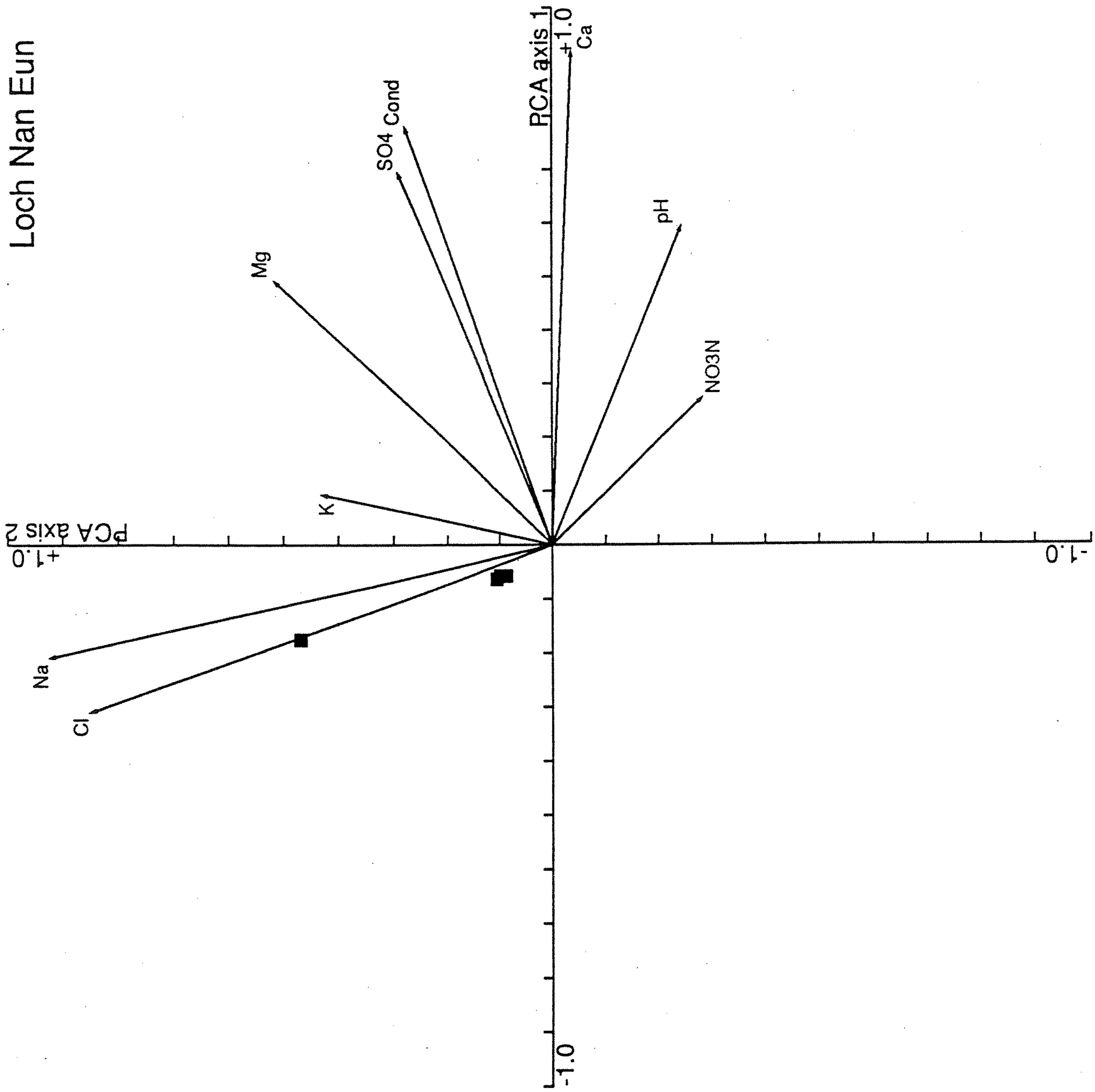


Figure 8. Position of the annual means (1993-1994) for Chibini, Kola on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

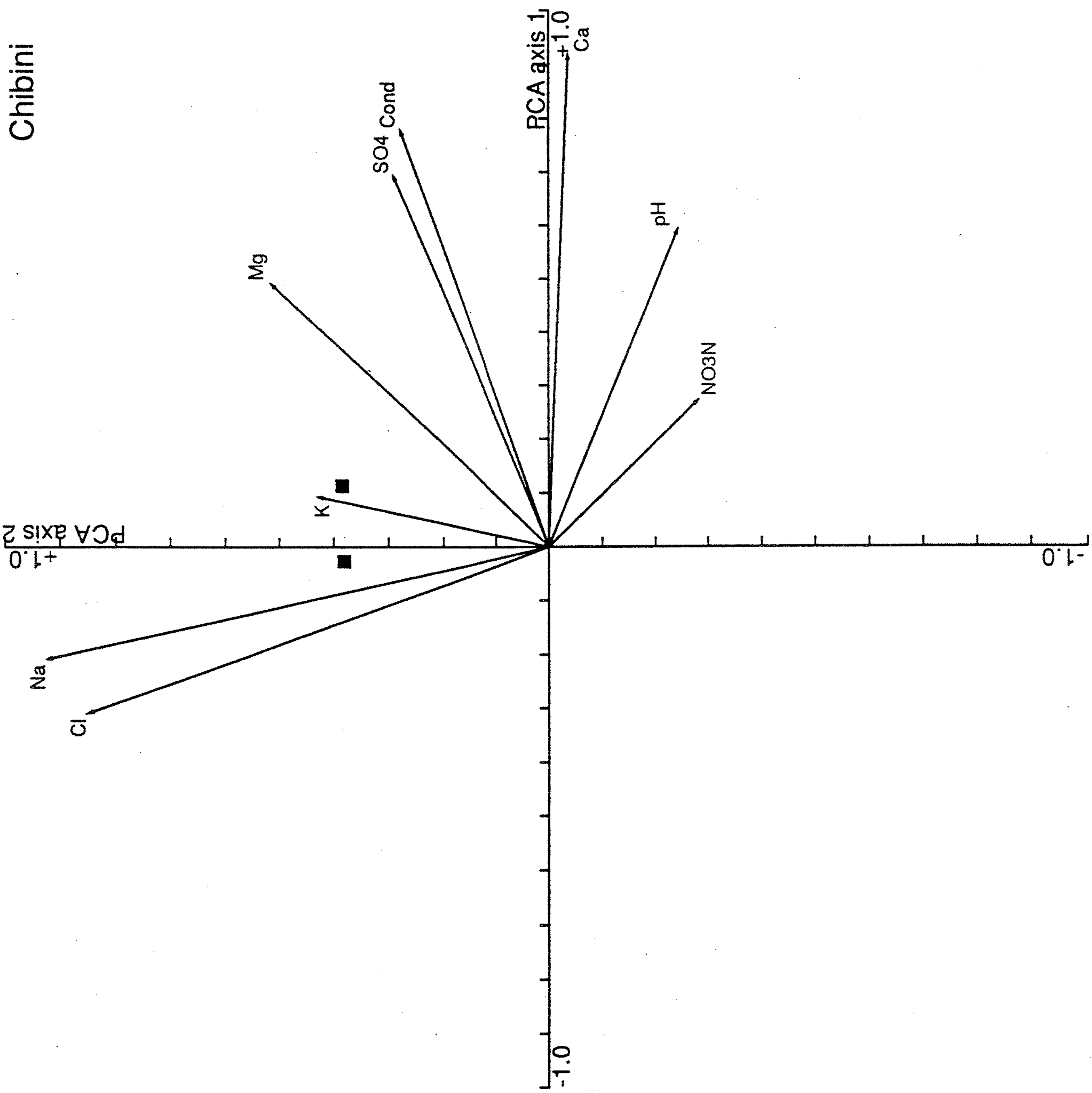


Figure 10. Position of the annual means (1993-1994) for Lago Escura, Portugal on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

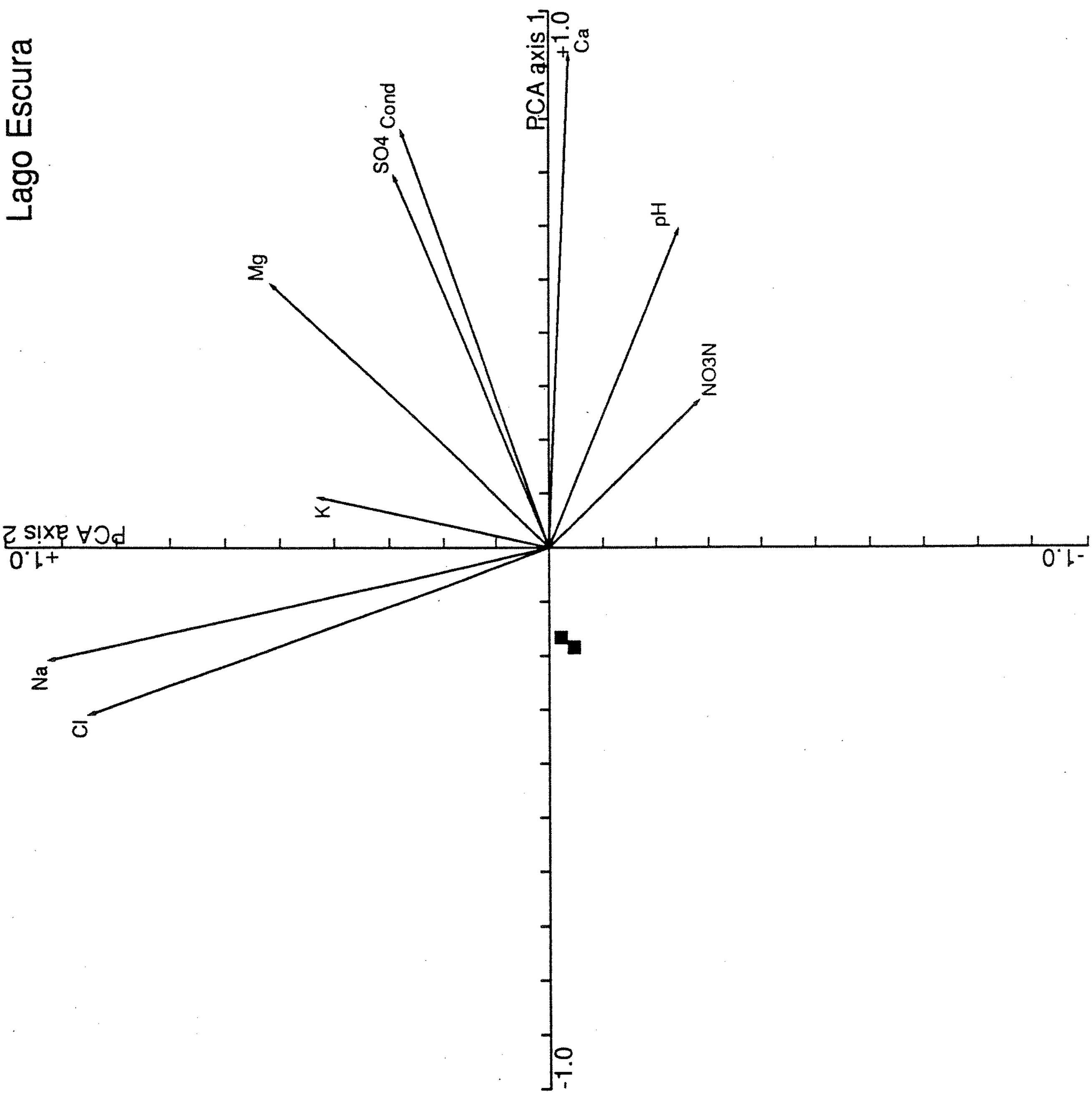


Figure 11. Position of the annual mean (1993) for Laguna Cimera, Spain on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

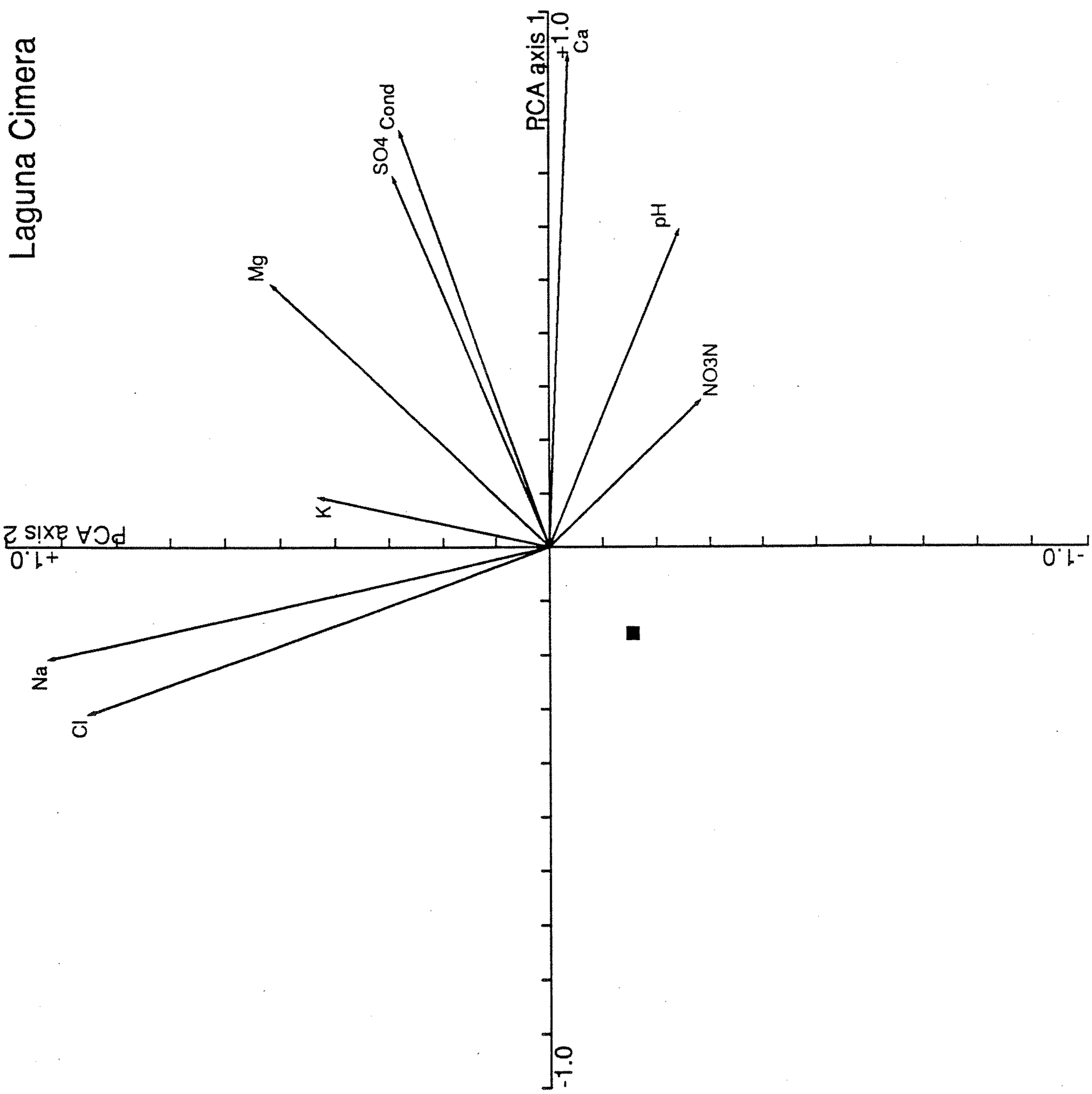


Figure 12. Position of the annual means (1993-1994) for Estany Redo, Spain on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

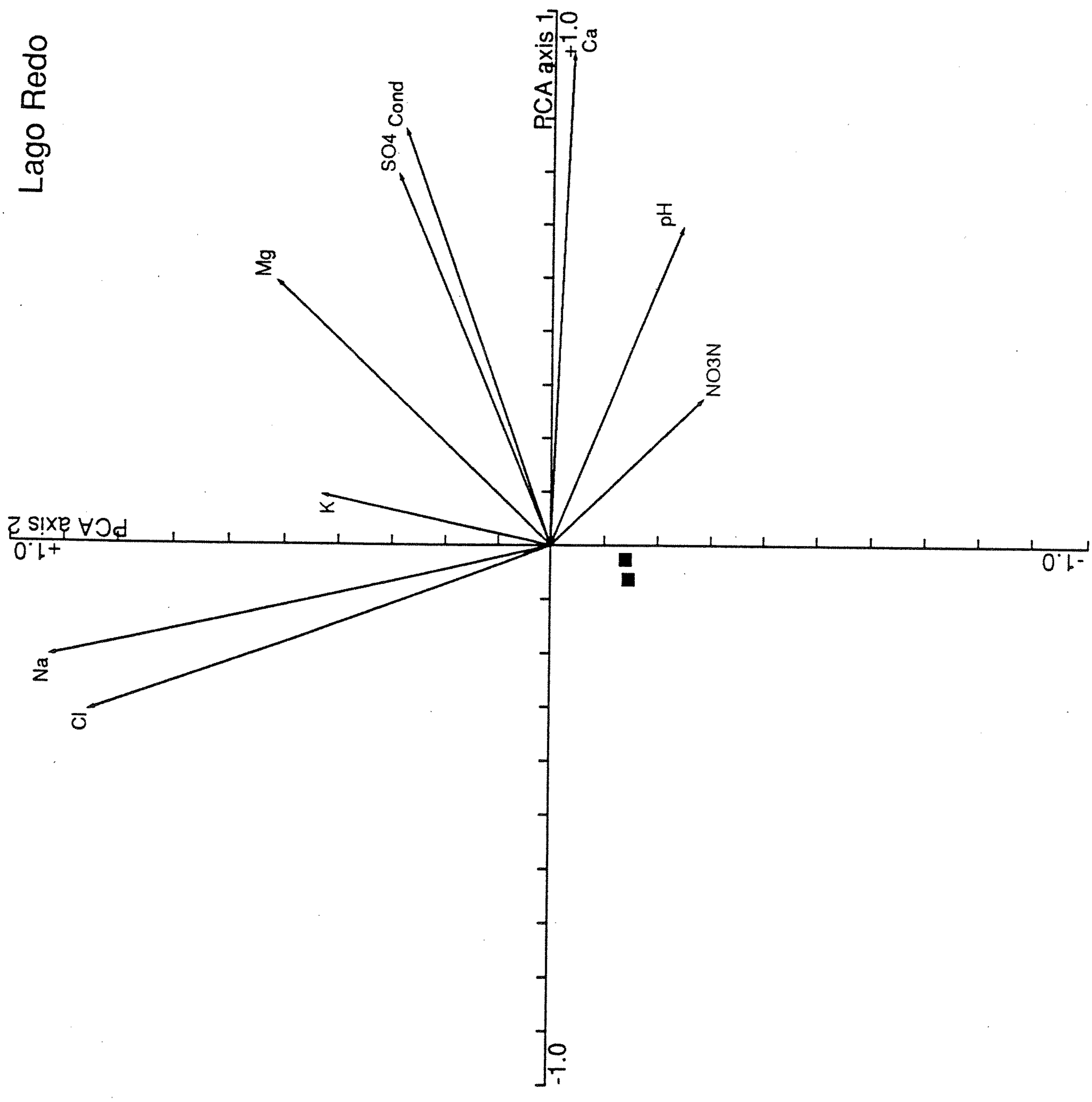


Figure 13. Position of the annual means (1993-1994) for Estany Aguiló, Spain on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

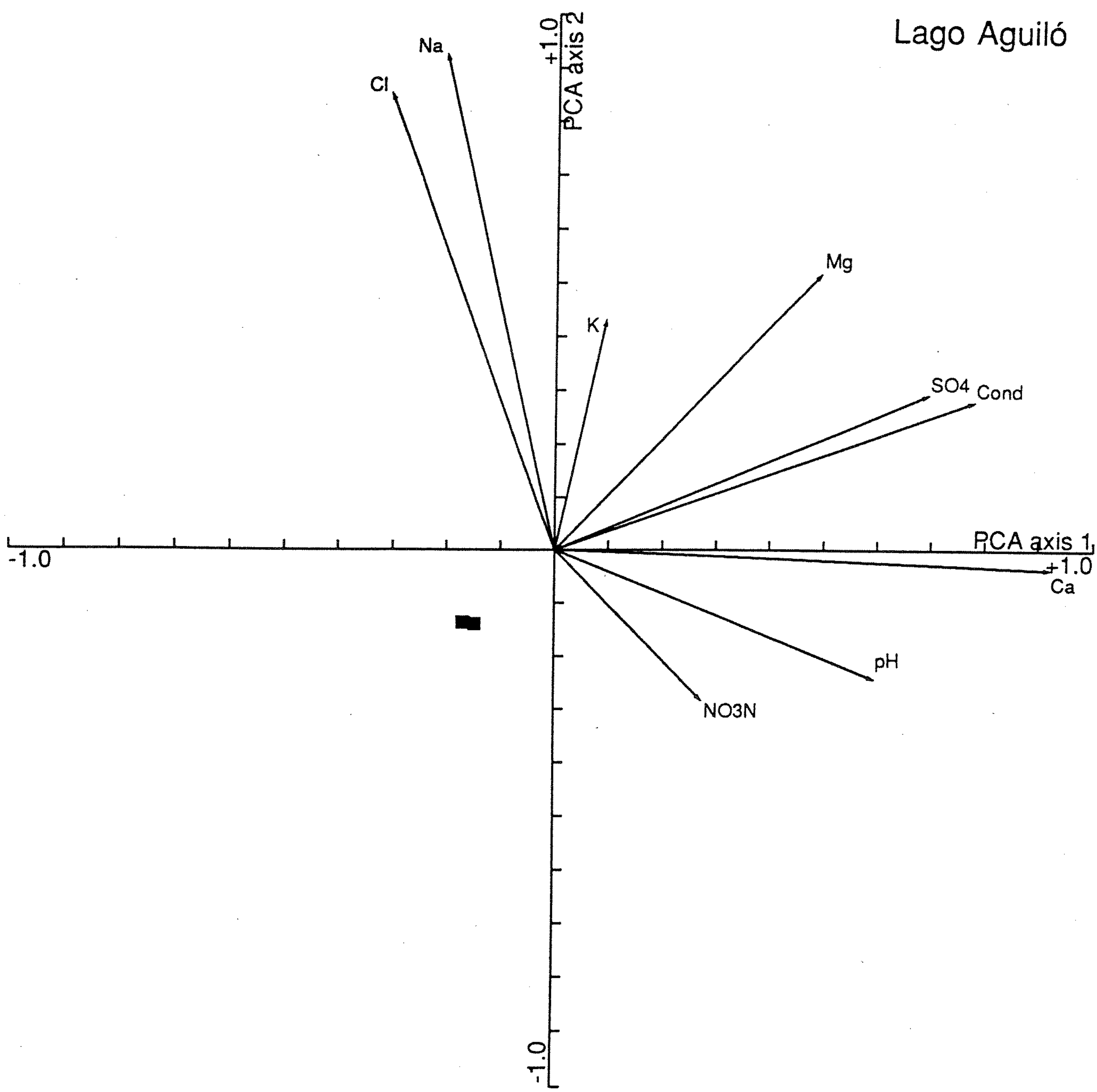


Figure 14. Position of the annual means (1991-1994) for Étang d'Aubé, France on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

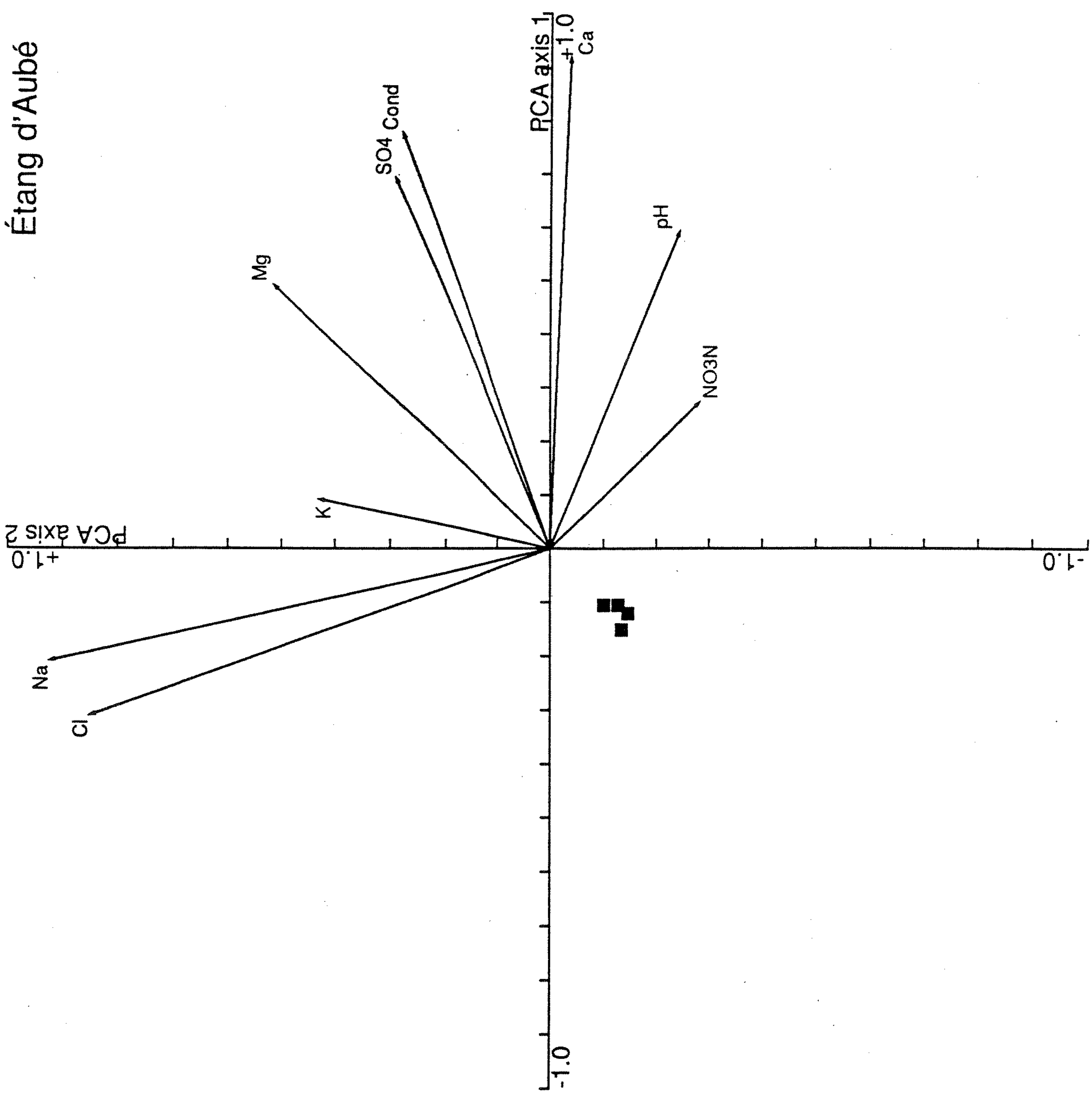


Figure 15. Position of the annual means (1991-1994) for Øvre Neådalsvatn, Norway or PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

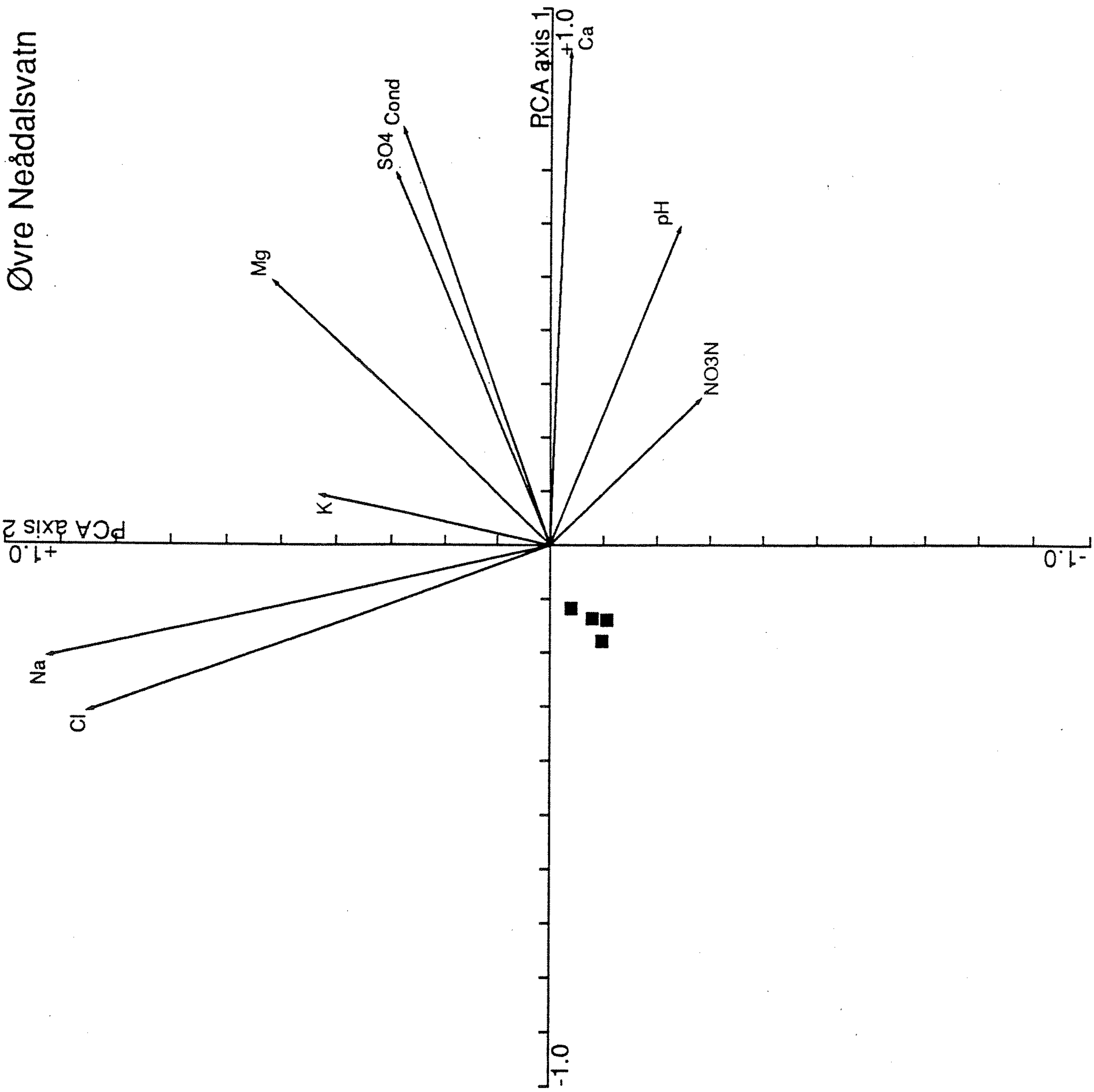


Figure 16. Position of the annual means (1991-1994) for Stavsvatn, Norway on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

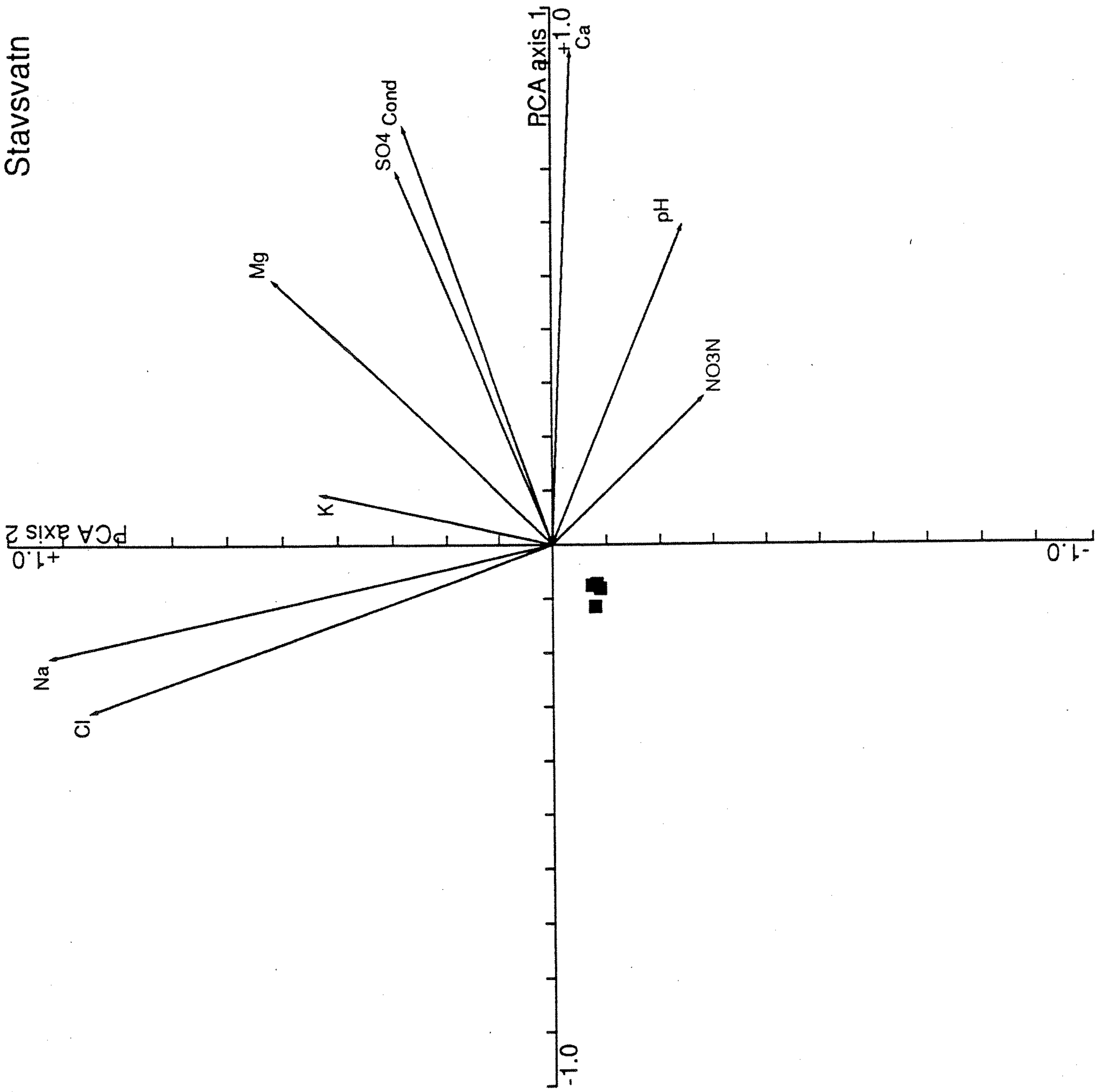


Figure 17. Position of the annual means (1991-1994) for Lago Paione Superiore on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

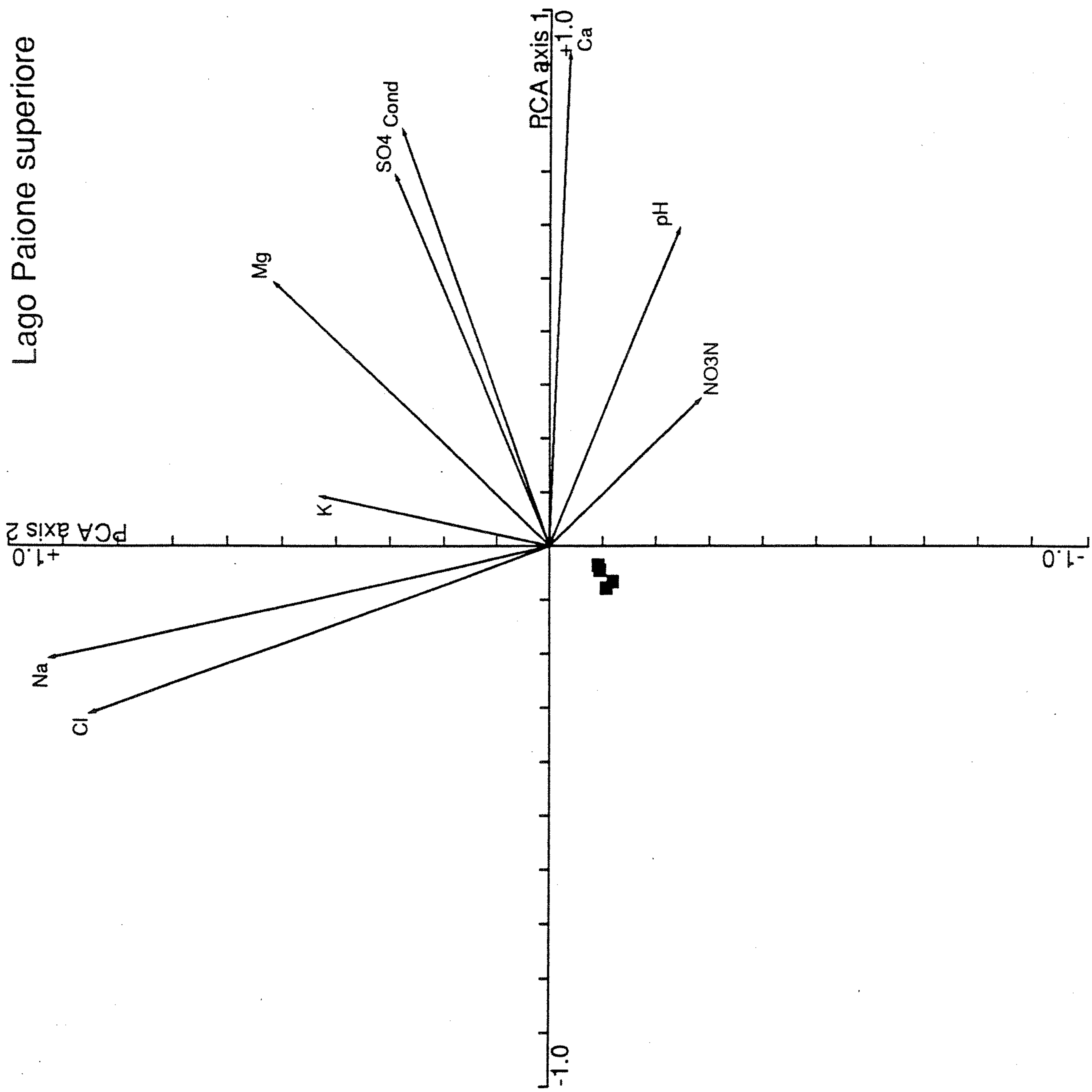


Figure 18. Position of the annual means (1993-1994) for Chuna, Kola on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

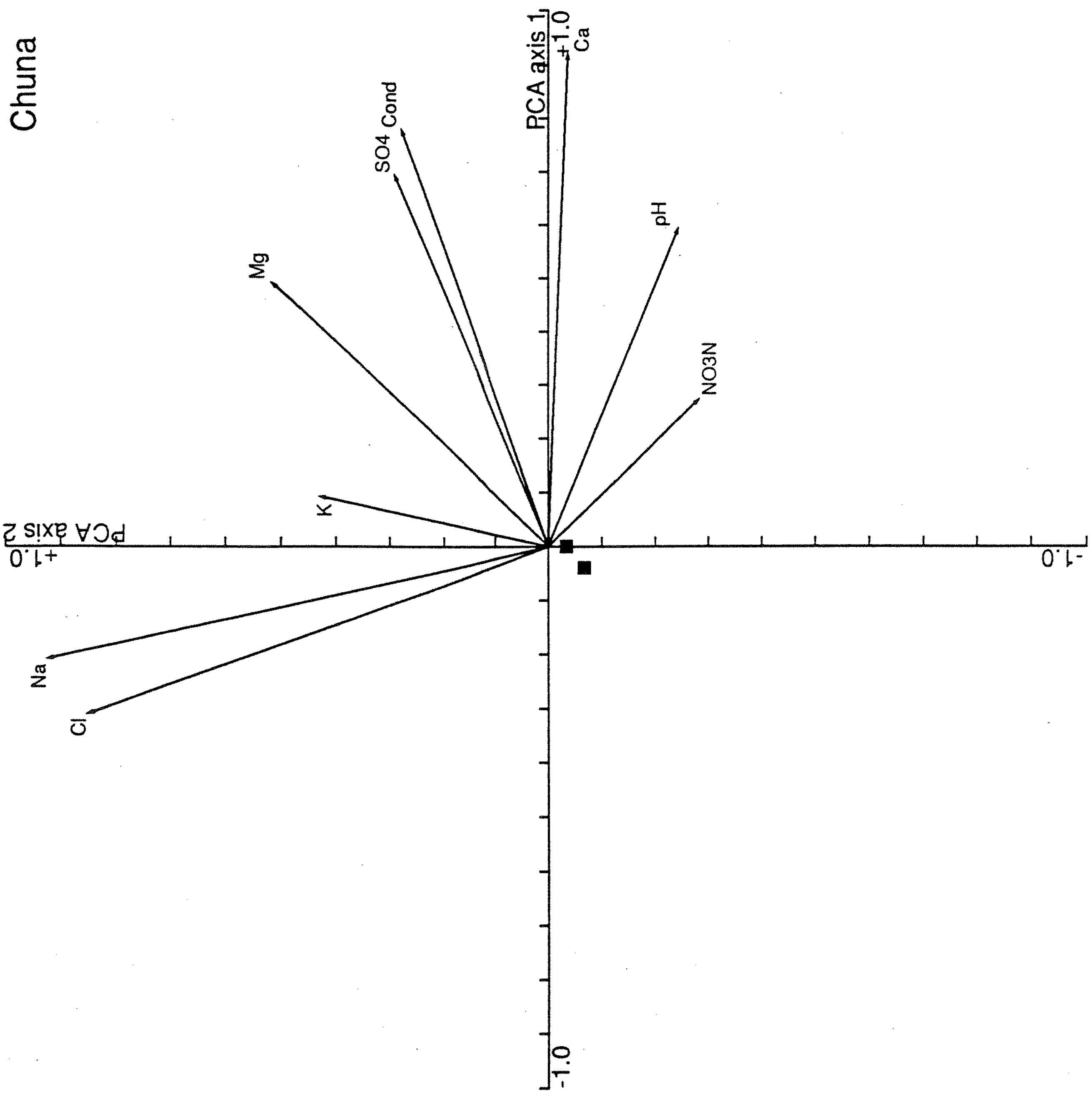


Figure 19. Position of the annual means (1993-1994) for Starolesnianske Pleso, Slovakia on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

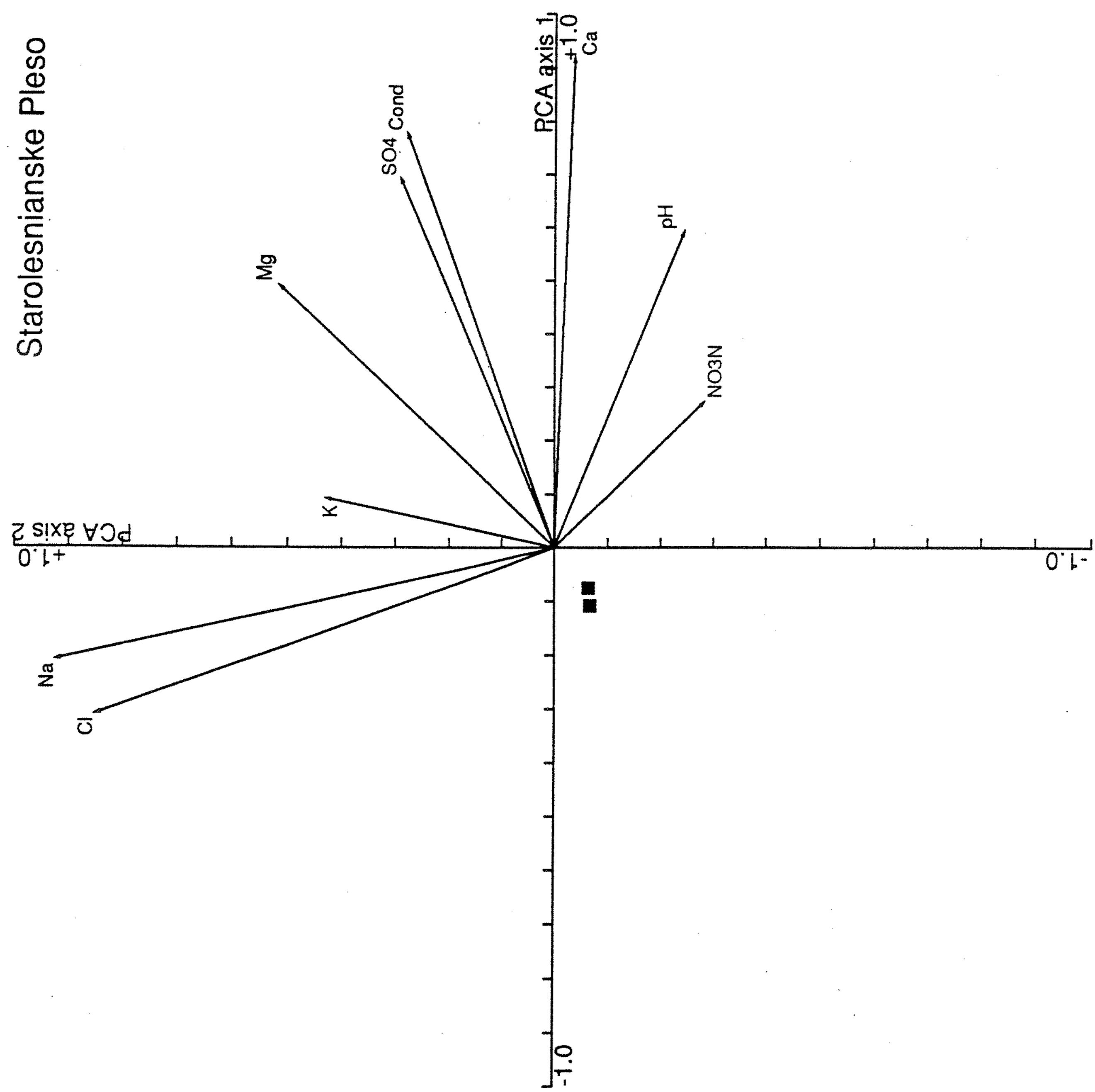


Figure 20. Position of the annual means (1993-1994) for Terianske Pleso, Slovakia on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

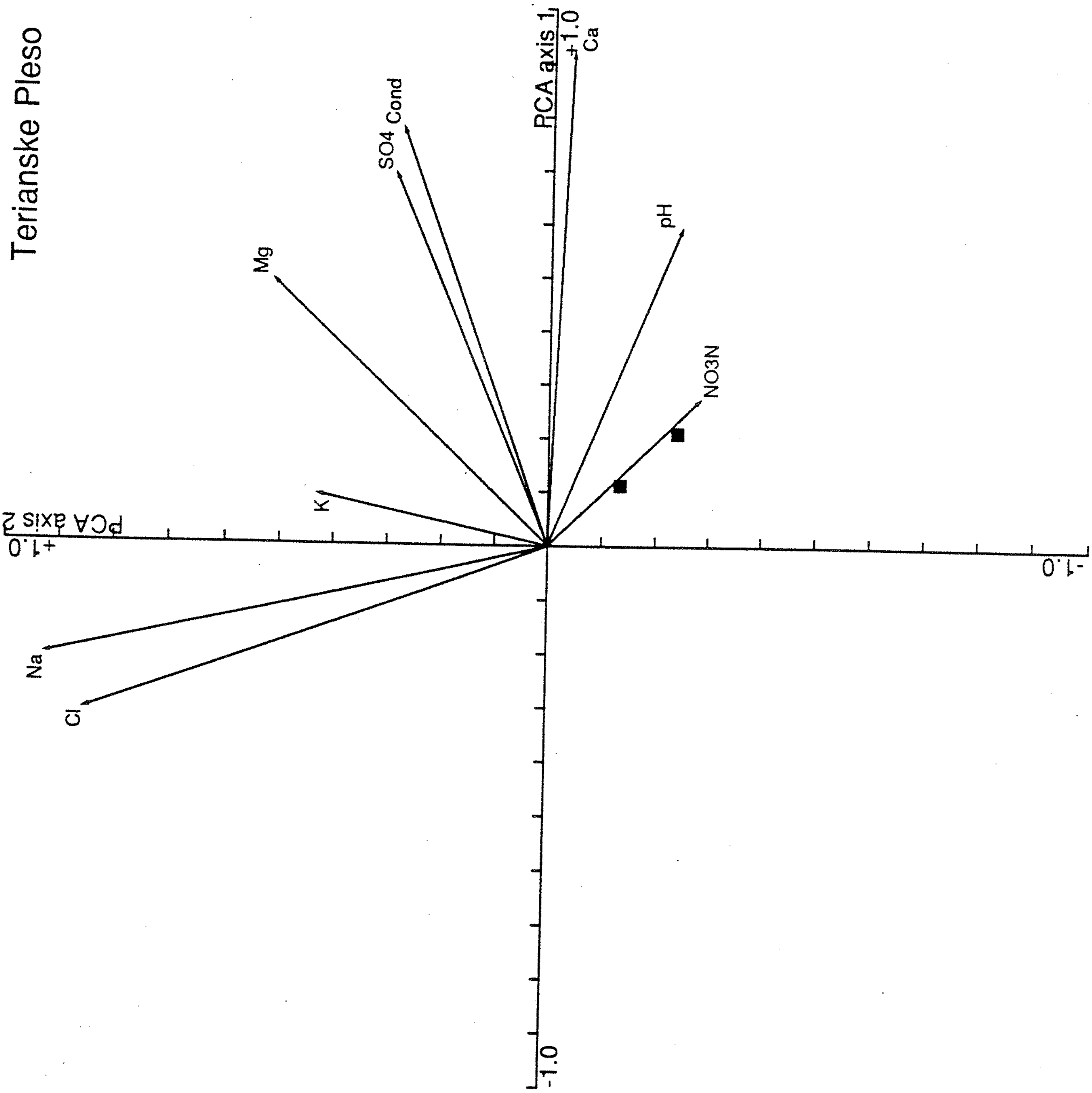


Figure 21. Position of the annual means (1993-1994) for Zieloni Staw, Poland on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

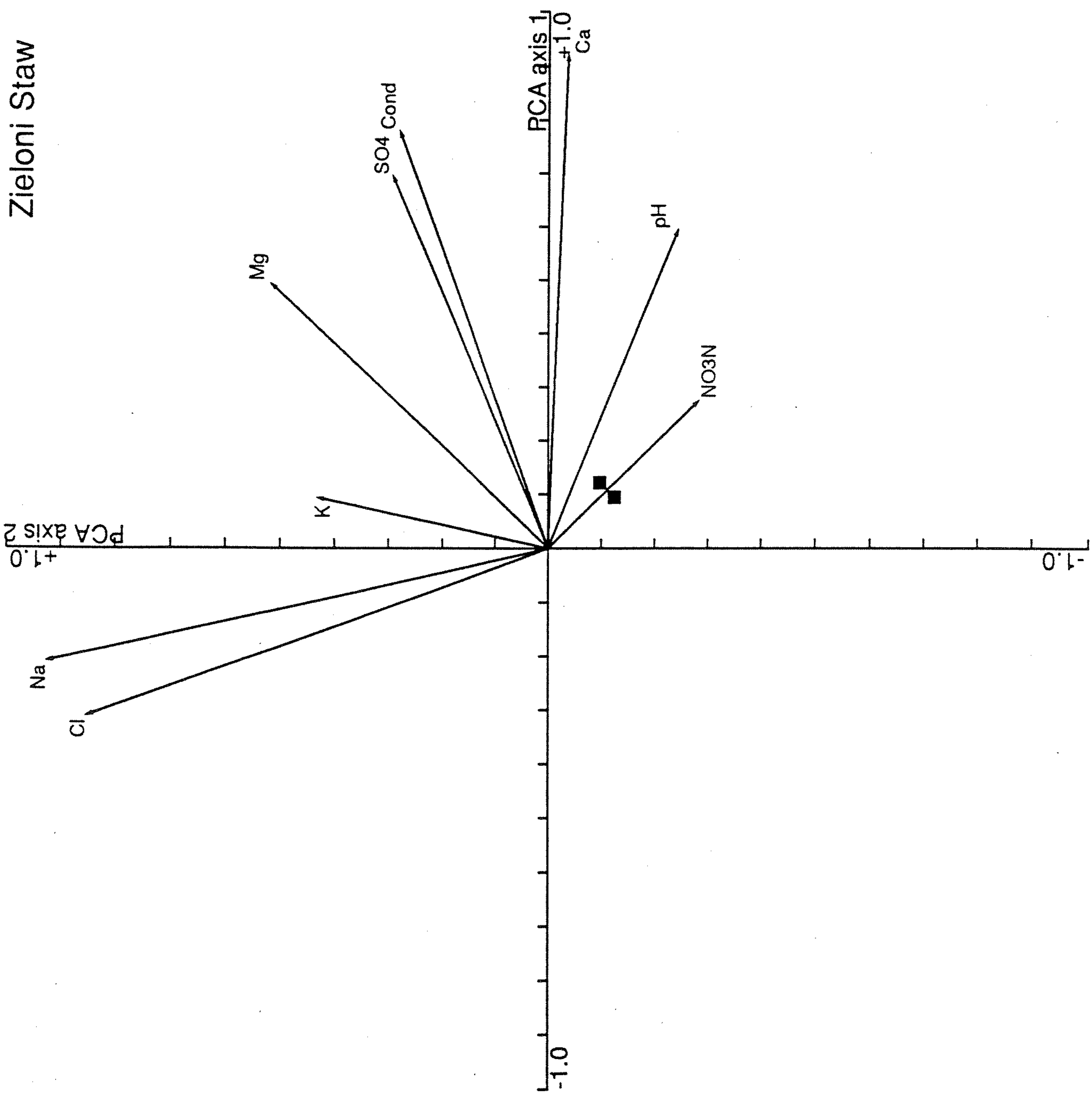


Figure 22. Position of the annual means (1993-1994) for Dlugi Staw, Poland on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

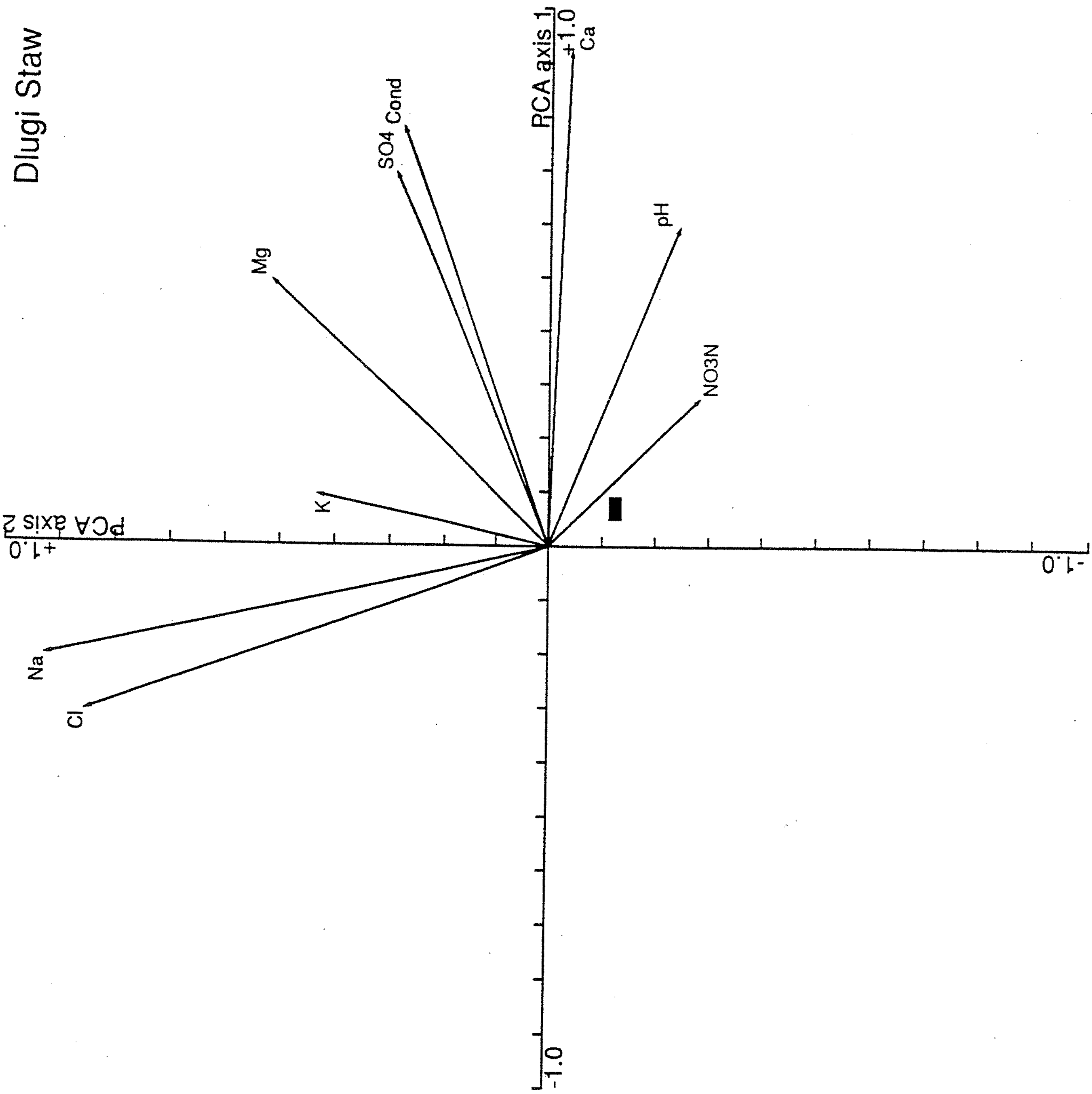


Figure 23. Position of the annual means (1993-1994) for La Caldera, Spain on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

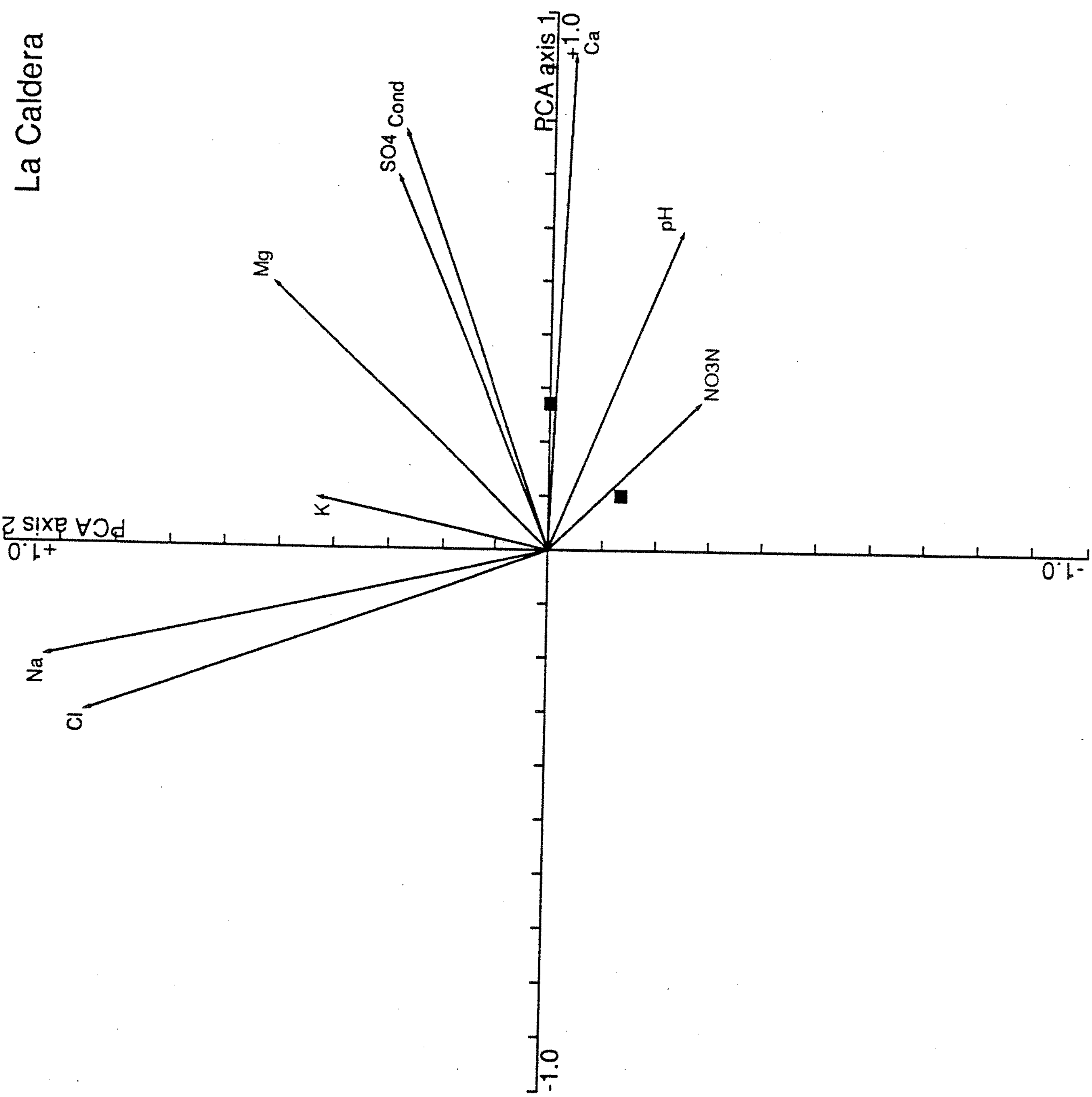


Figure 24. Position of the annual means (1991) for Combeynod, France on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

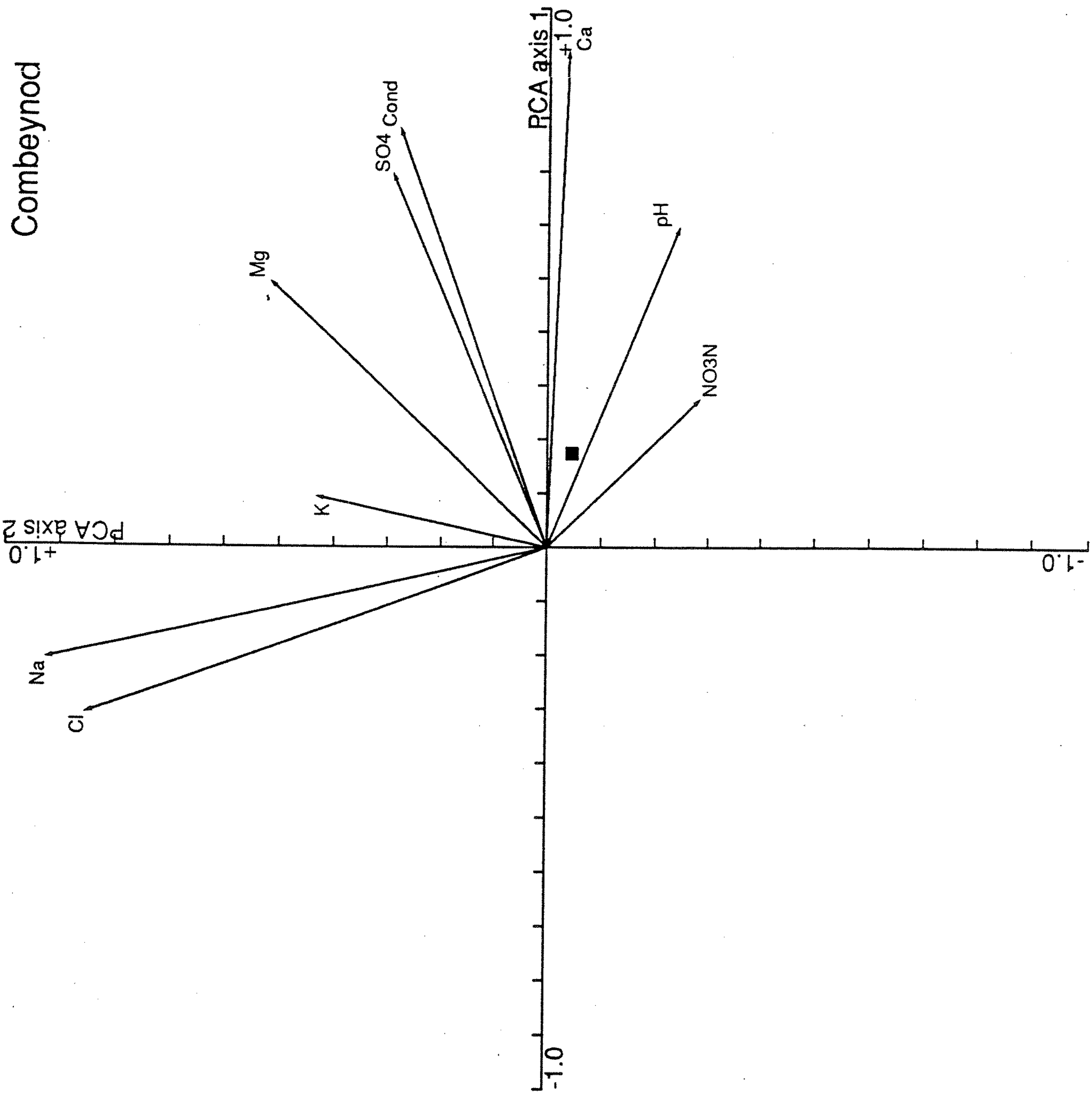


Figure 25. Position of the annual means (1992-1994) for Lac Noir, France on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

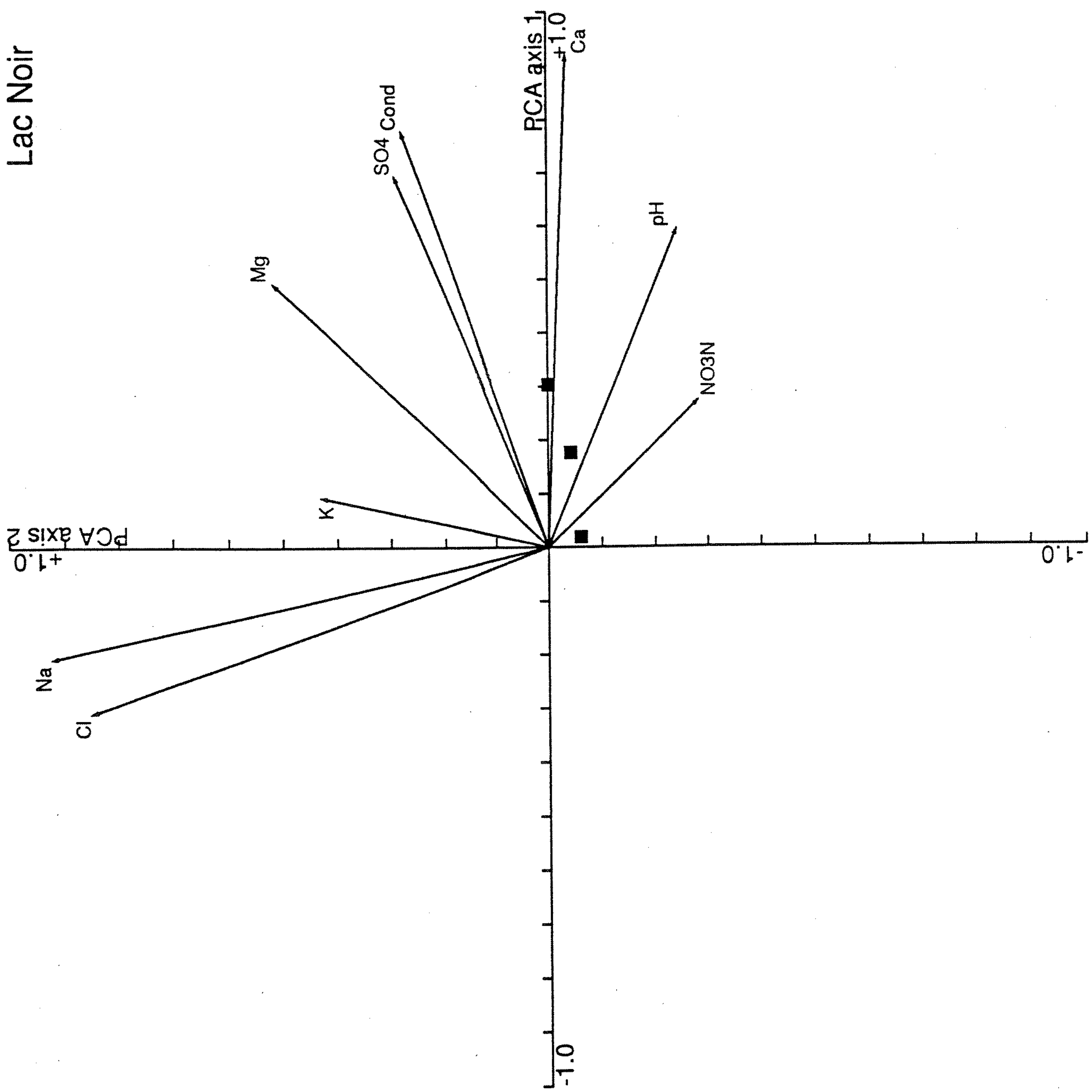


Figure 26. Position of the annual means (1992-1994) for Lago di Latte, Italy on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

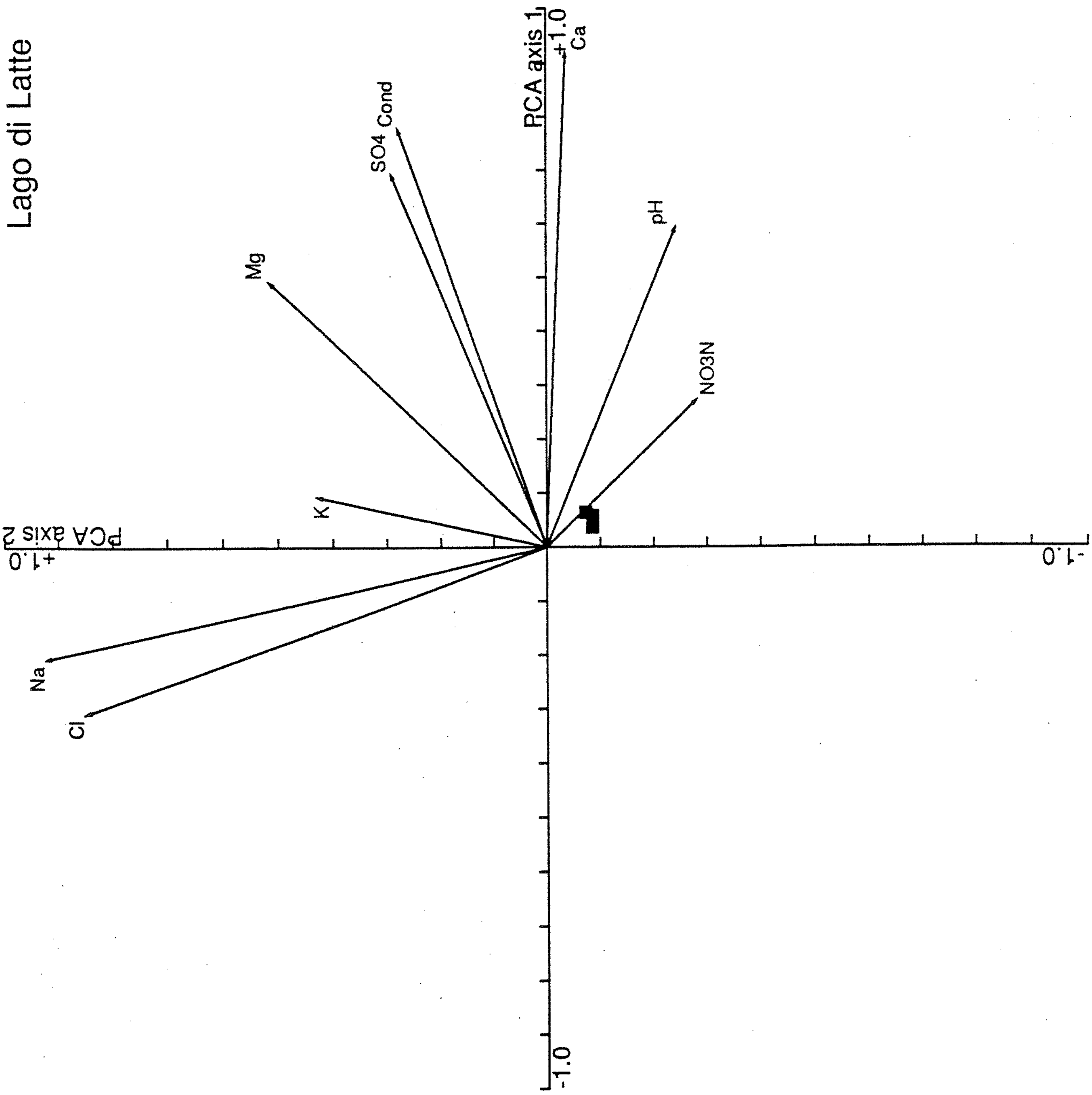


Figure 27. Position of the annual means (1991-1994) for Lago Paione Inferiore, Italy on PCA axes 1-2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

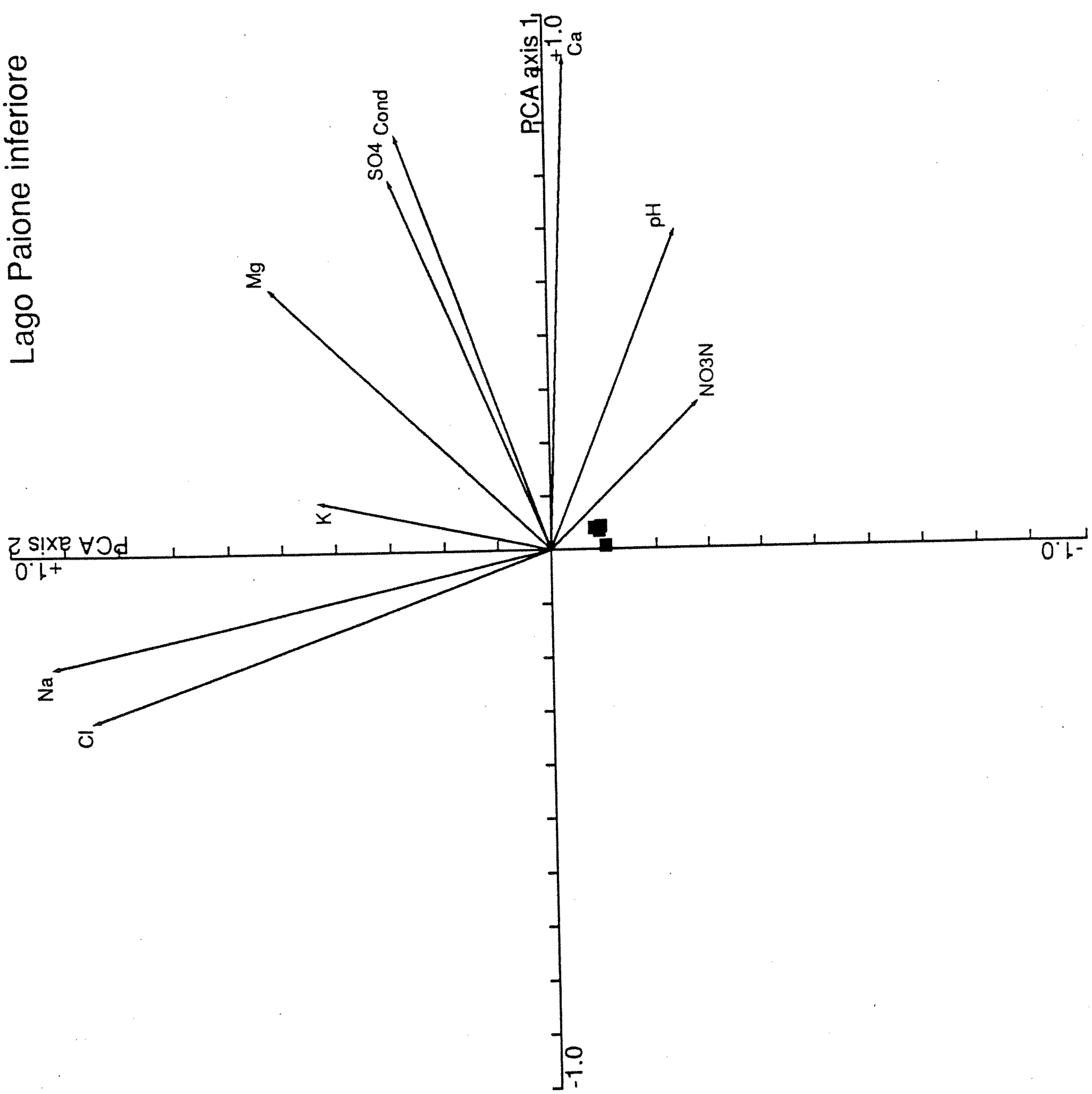


Figure 28. Position of the annual means (1991-1994) for Lago Lungo, Italy on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

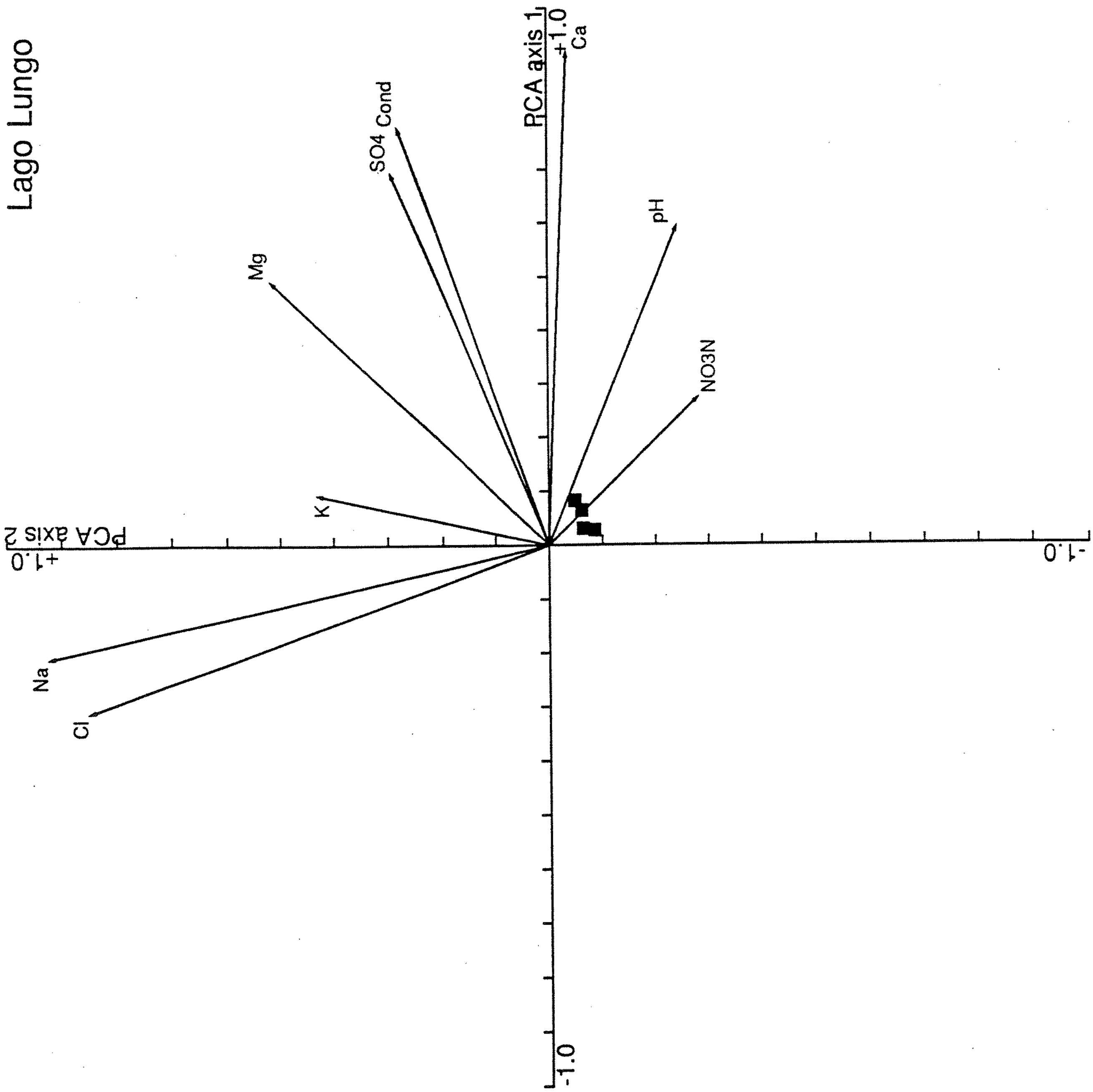


Figure 29. Position of the annual means (1991) for Lac Rond, France on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

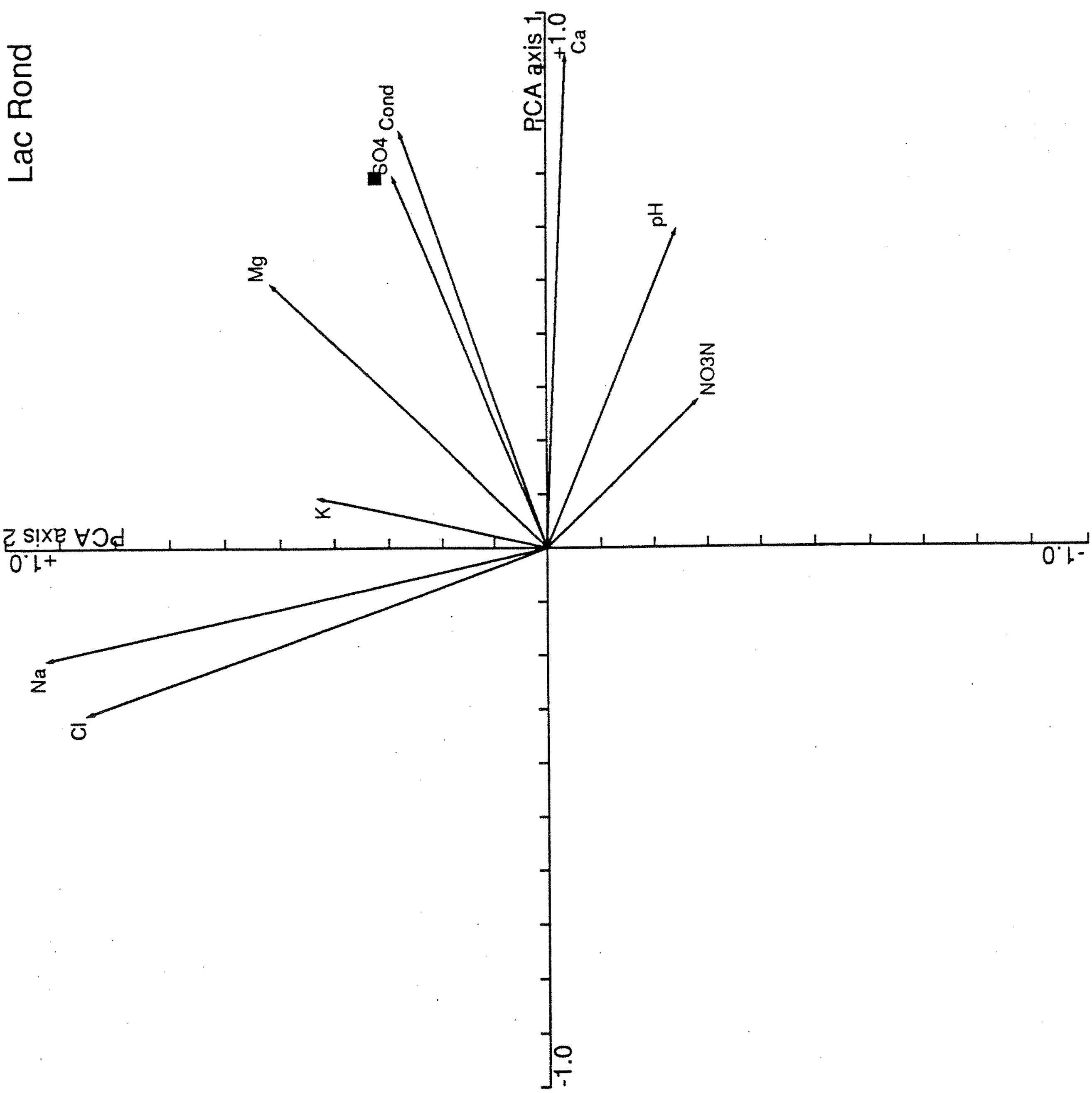


Figure 30. Position of the annual mean (1994) for Zgornje krisko jezero, Slovenia on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

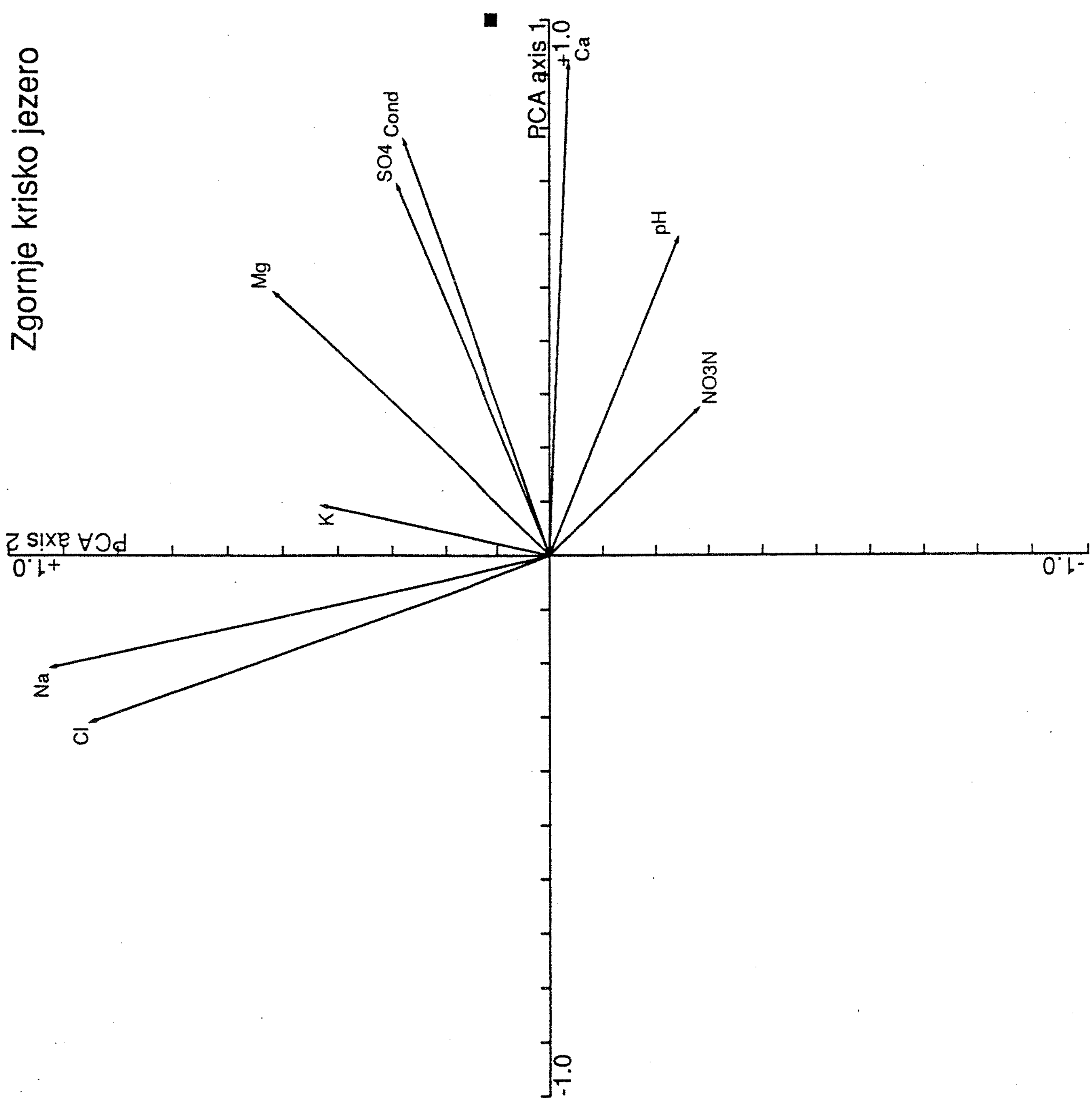


Figure 31. Position of the annual means (1992-1994) for Lac Blanc, France on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).

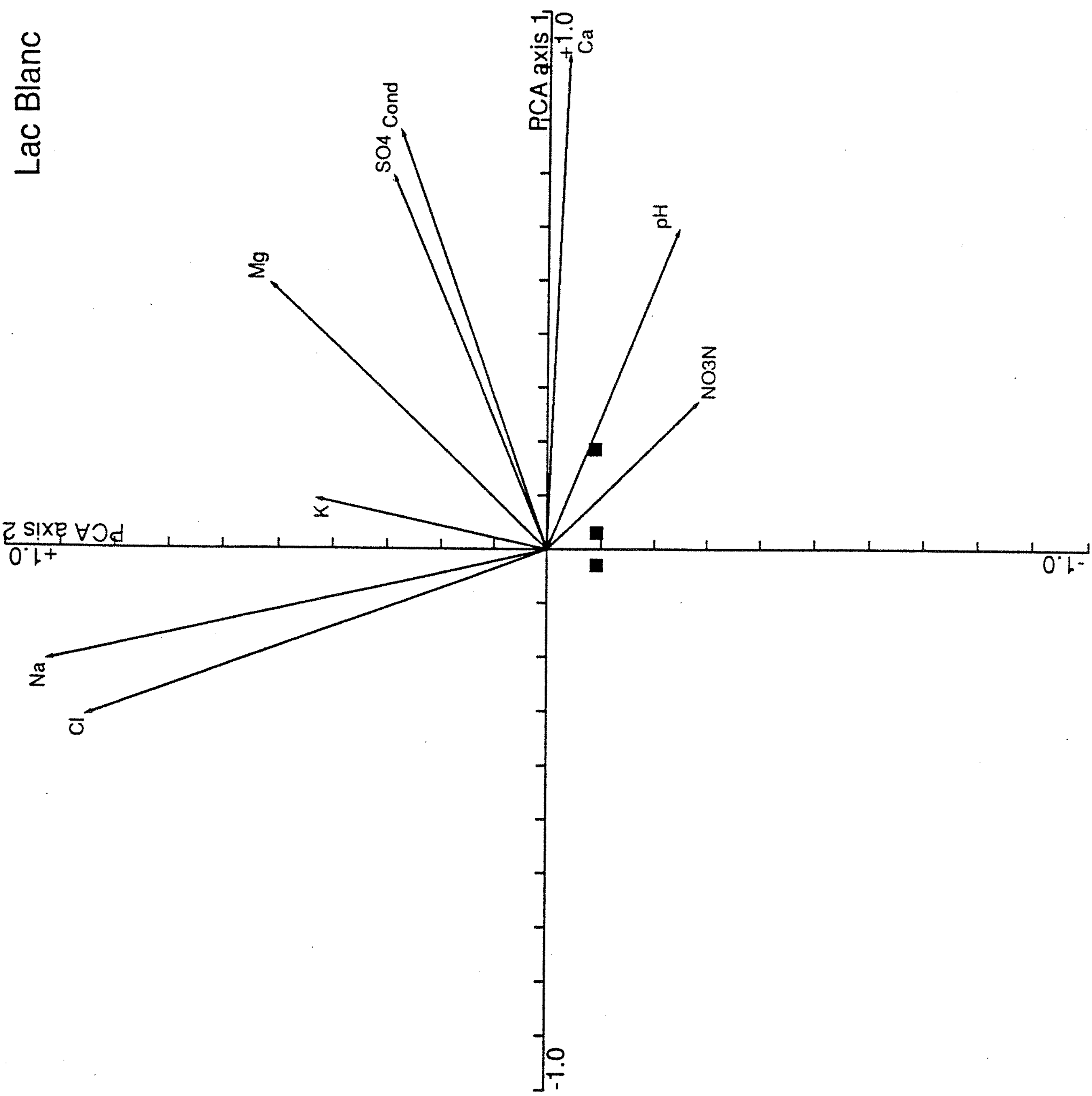
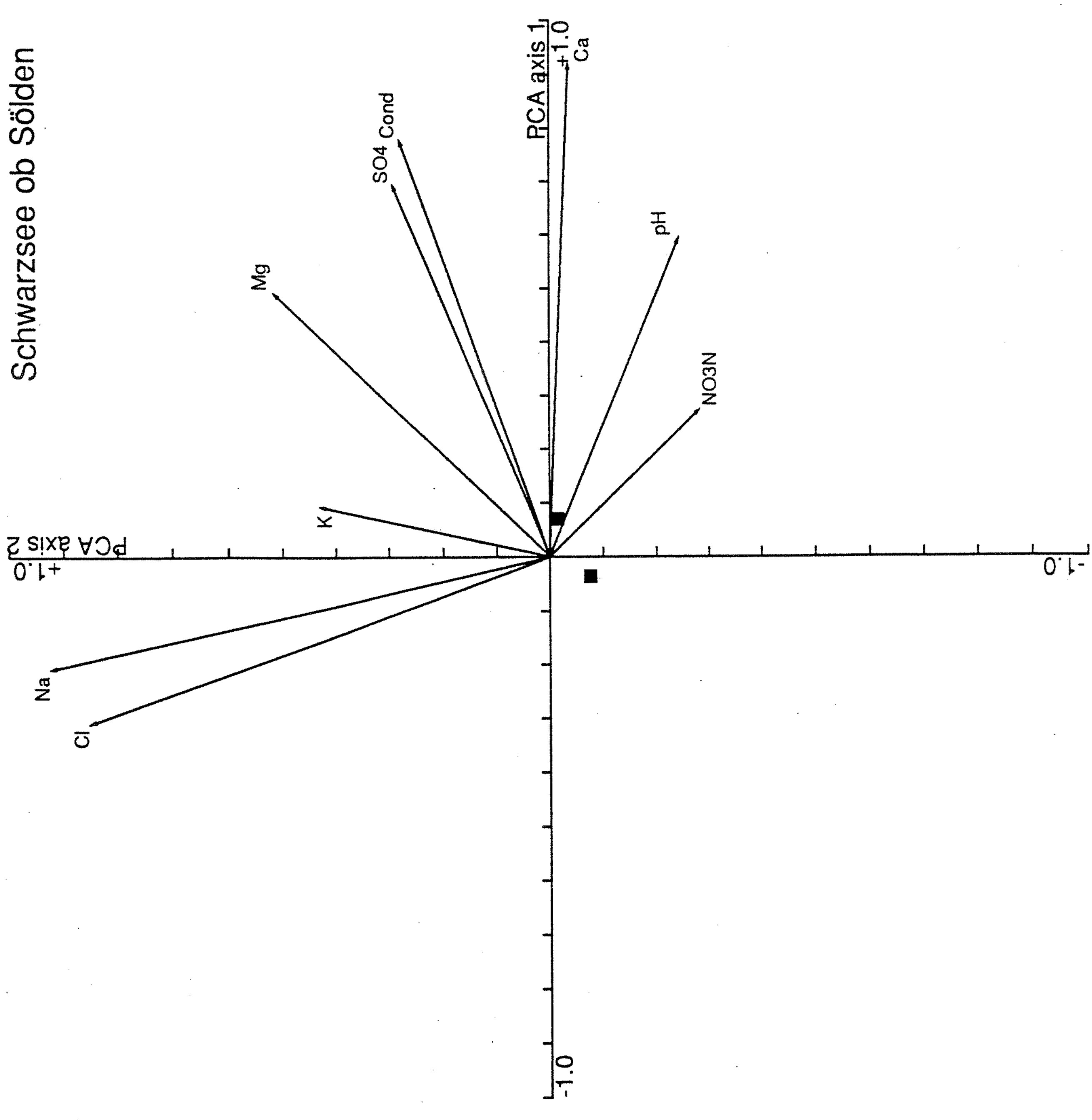


Figure 32. Position of the annual means (1993-1994) for Schwarzsee ob Sölden, Austria on PCA axes 1 and 2 in relation to the biplot arrows for the nine determinands (Figure 2.19).



Appendix 3. Water chemistry - Intercalibration exercises

Water Chemistry - Intercalibration exercises

INTERCOMPARISON EXERCISES PERFORMED IN THE FRAMEWORK OF THE AL:PE 2 RESEARCH.

Rosario MOSELLO(*), Aldo MARCHETTO(*), Herbert MUNTAU(+)and Giorgio SERRINI(+)
(*) C.N.R. Istituto Italiano di Idrobiologia, Pallanza (I)
(+) Environment Institute, Joint Research Centre, Ispra (I)

1. INTRODUCTION

Intercomparison exercises are an essential tool in ensuring data quality and comparability in research projects involving many laboratories. The activity already started with the AL:PE 1 project continued in 1993 and 1994 with two sets of intercomparisons. One was organized by the Norwegian Institute for Water Research, in the framework of the International Co-operative Programme on Assessment and Monitoring of Acidification in Rivers and Lakes. The second was organized by the C.N.R. Istituto Italiano Idrobiologia, in collaboration with the Environment Institute of the European Joint Research Centre, Ispra.

The variables examined were pH, conductivity and major cations and anions, alkalinity included. The fact that the two institutes are involved in other international scientific programs prompted the suggestion to enlarge the intercomparison exercise to other laboratories, in the context of three investigations:

a) the AL:PE 2 project

b) Environmental studies in the Mediterranean basin;

c) the International Commission for the Protection of Lake Leman.

This paper deals with the results obtained by the AL:PE laboratories in this second set of intercomparison exercises, run in 1993 and 1994. A complete presentation of the results obtained from all the laboratories (99 and 120 in 1993 and 1994, respectively) is given elsewhere (Mosello *et al.* 1994, in press). Methods used in sample preparation, data elaboration and the results concerning the laboratories involved in the AL:PE project will be presented and discussed. Special attention will be devoted to alkalinity, which is such an important variable in acidification studies.

2. SAMPLE PREPARATION

Two types of samples were prepared for the exercise: artificial rain-water and sodium bicarbonate solutions, stabilized with chloroform, for the measurement of alkalinity. Simulated rainwater (samples A, B) was prepared at the JRC-EI on the basis of the techniques already experimented for the yearly intercomparisons performed since 1989, which were adequate for the purpose (Mosello *et al.* 1990). Starting material is water of the highest quality (nanopure U.W.S. Barnstead) and the purest chemicals available. The carefully weighed chemicals were dissolved and water added to make up the master solution (1 l), which was then checked analytically for correctness of the envisaged analyte concentrations. The master solution was added to approximately 20 l of nanopure water in a 50 l polyethylene container, previously conditioned with the same quality of water for two weeks. The calculated quantity of Suprapure HCl required to reach the previously fixed pH value of the final solution was added and the solution made up to a total of 50 l. The solution was mixed by rolling the container.

Samples C and D, prepared specifically for alkalinity measurements, were dilute solutions of sodium bicarbonate, stabilized with chloroform.

Bottling was performed by hand, rinsing the previously conditioned 1 l polypropylene bottles (two weeks with nanopure water) with the samples and then filling them up to the top.

The concentrations of samples A and B were chosen in the upper and lower ranges of the concentration values most often measured in atmospheric deposition in northern Italy (Mosello *et al.* 1992). Alkalinity values were chosen in the range of those present in some episodes of atmospheric deposition; however, these values are in the same range as those measured in many high altitude lakes in the Alps, and areas characterized by poorly buffered water.

3. SAMPLE HOMOGENEITY AND STABILITY

The total variance measured on a number of samples representative of the whole population is the sum of the variances resulting from the analytical method used, the non-homogeneity of the samples and other random errors:

$$S^2_{tot} = S^2_{method} + S^2_{heterog.} + S^2_{random}$$

The estimation of S_{tot} was obtained by measuring the concentrations of ten randomly selected bottles for each of the four solutions. All the measurements were performed in one laboratory by the same analyst using the same analytical method. The variance due to the analytical method was estimated by repeating the measurement ten times on the same bottle. Results were expressed as relative standard deviation, i.e., ratio between standard deviation and mean value.

Heterogeneity was estimated as the square root of the difference of the squares of the standard deviations of samples and methods; it resulted below 1% for most of the variables of the four samples, with the few exceptions, giving results in any case lower than 2%.

To check the stability of the samples, analyses were performed by the two organizing laboratories over the period allowed for the exercise. During this time the samples were kept at room temperature, but shielded from light, and analysed approximately every four week. The results (Tab. 1) demonstrate the stability of the four solutions, and refer to the duration of the exercises only.

4. RESULTS

The concentrations of solutions were measured by the laboratories of the JRC-EI and CNR-III. Methods used are:

pH: potentiometry;
Ca, Mg: ion chromatography, atomic absorption spectrophotometry;
Na, K: ion chromatography, atomic absorption and atomic emission spectrophotometry;

sulphate, nitrate and chloride: ion chromatography; alkalinity: Gran's titration (Gran 1950); two end-points and single end-point titration (Rodier 1984).

Expected results are shown in table 2 and 3 for the two intercomparison exercises, together with the results obtained from the laboratories.

Tab. 1 - Intercomparison exercises 1993 and 1994. Stability tests of solution A, B, C, and D. Conductivity: µS cm^{-1} at 20 °C; alkalinity: meq l^{-1}; ammonium, nitrate: mg N l^{-1}; other ions: mg l^{-1}.

Date	pH	Cond.	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	NH_4^{+}	SO_4^{--}	NO_3^{-}	Cl^{-}	Alk.
Exercise 1993: Sample A (alkalinity from sample C)											
07.12.93	4.43	23.6	0.35	0.14	0.18	0.21	0.39	3.49	0.13	0.88	0.040
10.01.94	4.44	23.7	0.36	0.15	0.18	0.21	0.38	3.50	0.13	0.88	0.040
24.02.94	4.45	23.8	0.36	0.14	0.19	0.21	0.38	3.50	0.13	0.89	0.039
02.05.94	4.46	23.7	0.35	0.13	0.17	0.20	0.39	3.50	0.13	0.87	0.040
Exercise 1993: Sample B (alkalinity from sample D)											
07.12.93	3.72	104.5	1.10	0.34	0.70	0.46	1.40	14.50	0.96	1.92	0.133
10.01.94	3.73	104.6	1.11	0.35	0.71	0.48	1.38	14.40	0.97	1.92	0.134
24.02.94	3.73	105.0	1.11	0.34	0.71	0.47	1.38	14.50	0.97	1.91	0.134
02.05.94	3.76	104.0	1.09	0.34	0.71	0.45	1.40	14.38	0.95	1.92	0.136
Exercise 1994: Sample A (alkalinity from sample C)											
10.10.94	4.41	26.2	0.29	0.09	0.20	0.26	0.43	4.32	0.15	0.35	0.040
11.11.94	4.40	26.2	0.28	0.09	0.21	0.25	0.44	4.31	0.16	0.35	0.038
07.12.94	4.42	26.0	0.29	0.09	0.20	0.25	0.43	4.31	0.15	0.34	0.040
11.01.95	4.41	26.1	0.30	0.09	0.20	0.26	0.43	4.30	0.15	0.35	0.039
Exercise 1994: Sample B (alkalinity from sample D)											
10.10.94	3.84	96.1	1.34	0.30	1.67	0.46	1.20	13.80	1.16	1.95	0.120
11.11.94	3.82	96.0	1.32	0.29	1.68	0.44	1.18	13.82	1.17	1.96	0.118
07.12.94	3.83	95.8	1.33	0.29	1.68	0.46	1.21	13.82	1.16	1.97	0.120
11.01.95	3.85	96.0	1.33	0.29	1.69	0.46	1.19	13.78	1.16	1.95	0.121

Tab. 2 - Expected (E) and measured values for the 1993 exercise. Laboratories are referred to by numbers to preserve anonymity. Conductivity: µS cm^{-1} at 20 °C; alkalinity: meq l^{-1}; ammonium, nitrate: mg N l^{-1}; other ions: mg l^{-1}.

No.	pH	Cond.	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	NH_4^{+}	SO_4^{--}	NO_3^{-}	Cl^{-}	Alk.
Sample A (alkalinity from sample C)											
E	4.45	23.6	0.35	0.14	0.18	0.21	0.38	3.47	0.12	0.87	0.039
1	4.24	23.6	0.35	0.12	0.15	0.18	0.39	3.41	0.13	0.80	0.039
2	4.43	23.2	0.37	0.14	0.16	0.20	0.38	3.55	0.12	0.85	0.037
3	4.45	28.0	0.35	0.27	0.15	0.15	0.38	3.59	0.12	0.58	0.036
4	4.41	24.0	0.21	0.12	0.11	0.12	0.38	3.50	0.13	0.96	0.037
5	4.83	27.1	0.40	0.90	0.50	0.61	0.34	10.06	0.14	1.70	0.300
6	4.43	24.0	0.37	0.14	0.19	0.20	0.36	3.20	0.12	1.00	-
7	4.46	25.0	0.39	0.14	0.21	0.18	0.43	3.53	0.13	0.89	0.040
8	4.27	26.3	0.50	0.10	0.20	0.20	0.41	3.10	0.10	1.50	0.037
9	4.07	28.1	-	-	-	-	-	-	-	-	0.034
10	4.45	24.0	0.21	0.12	0.30	0.20	0.38	3.50	0.11	0.90	0.043
11	4.44	24.2	0.40	0.13	0.17	0.18	0.36	3.20	0.12	0.90	0.069
12	4.44	26.8	0.33	0.12	0.15	0.20	0.34	3.72	0.14	1.09	0.039
13	4.68	20.2	0.35	0.13	0.18	0.23	0.28	3.34	0.16	1.01	0.120
14	-	-	0.11	0.14	0.00	0.00	-	2.62	0.16	0.69	-
15	4.47	23.7	0.37	0.14	0.19	0.22	0.38	3.45	0.13	0.88	0.036
Sample B (alkalinity from sample D)											
E	3.73	104.1	1.08	0.34	0.70	0.45	1.40	14.5	0.97	1.91	0.134
1	3.63	102.0	1.12	0.31	0.66	0.42	1.37	14.8	0.86	2.37	0.132
2	3.72	104.0	1.06	0.33	0.68	0.43	1.38	14.7	0.99	1.84	0.137
3	3.72	117.6	1.05	0.69	0.61	0.36	1.43	14.4	1.00	1.72	0.111
4	3.70	101.0	0.80	0.30	0.42	0.30	1.35	14.5	0.92	2.10	0.128
5	4.35	92.1	0.20	0.90	0.50	0.52	1.31	19.2	1.10	0.90	0.275
6	3.70	105.0	1.10	0.33	0.71	0.43	0.69	12.8	0.98	1.92	-
7	3.76	107.0	1.12	0.32	0.74	0.43	1.48	14.4	0.99	1.81	0.136
8	3.57	116.3	1.10	0.30	0.70	0.40	1.30	14.1	0.80	2.20	0.131
9	3.47	117.0	-	-	-	-	-	-	-	-	0.108
10	3.73	105.2	0.90	0.31	0.83	0.32	1.30	14.1	0.90	1.96	0.137
11	3.74	106.4	1.17	0.32	0.73	0.40	1.32	13.2	0.97	1.80	0.162
12	3.72	115.3	0.98	0.27	0.50	0.35	1.25	16.8	1.12	2.40	0.132
13	3.68	99.1	0.98	0.34	0.61	0.42	1.02	13.5	0.92	1.97	0.250
14	-	-	0.82	0.42	0.60	0.82	-	14.4	0.90	1.59	-
15	3.74	104.9	1.11	0.34	0.73	0.48	1.33	14.5	0.97	1.94	0.134

Tab. 3 - Expected (E) and measured values for the 1994 exercise. Laboratories are referred to by numbers to preserve anonymity. Conductivity: µS cm^{-1} at 20 °C; alkalinity: meq l^{-1}; ammonium, nitrate: mg N l^{-1}; other ions: mg l^{-1}.

No.	pH	Cond.	Ca^{++}	Mg^{++}	Na^{+}	K^{+}	NH_4^{+}	SO_4^{--}	NO_3^{-}	Cl^{-}	Alk.
Sample A (alkalinity from sample C)											
E	4.42	25.9	0.29	0.09	0.20	0.25	0.42	4.32	0.15	0.35	0.039
1	4.47	25.9	0.32	0.10	0.21	0.27	0.40	4.33	0.15	0.35	0.039
2	4.37	23.5	0.30	0.09	0.06	0.30	0.46	4.60	0.13	0.30	0.042
3	4.45	21.9	0.31	0.09	0.19	0.23	0.42	4.10	0.18	0.20	0.075
4	4.35	25.0	0.29	0.09	0.20	0.23	0.41	4.15	0.15	0.36	0.040
5	4.38	29.0	0.42	0.11	0.22	0.27	0.34	4.37	0.15	0.30	0.044
6	4.33	28.0	0.18	0.08	0.09	0.21	0.49	4.32	0.16	0.18	0.036
7	4.43	26.0	0.26	0.17	0.18	0.22	0.48	3.93	0.16	0.14	0.046
8	4.35	26.3	0.28	0.09	0.20	0.26	0.40	5.10	0.18	0.34	0.040
9	3.22	23.0	0.30	0.10	0.20	0.30	0.20	4.32	0.18	0.36	0.044
10	4.08	29.9	-	-	-	-	-	-	-	-	0.047
11	4.56	21.3	0.20	0.08	0.16	0.22	0.33	4.13	0.15	0.30	0.088
12	4.34	25.1	0.22	0.09	0.19	0.23	0.43	4.20	0.15	0.35	0.041
13	4.38	24.3	-	-	-	-	0.34	6.87	0.15	-	0.087
14	-	-	0.23	0.06	0.10	0.24	-	4.20	0.76	0.30	-
Sample B (alkalinity from sample D)											
E	3.85	95.5	1.33	0.29	1.67	0.45	1.15	13.8	1.16	1.95	0.121
1	3.90	95.8	1.34	0.28	1.65	0.47	1.12	13.8	1.16	1.95	0.121
2	3.80	94.7	1.28	0.29	1.70	0.44	1.28	14.1	1.10	2.00	0.123
3	3.87	81.9	1.36	0.28	1.74	0.43	1.16	13.1	1.17	1.90	0.157
4	3.78	96.0	1.28	0.28	1.65	0.43	1.14	13.3	1.15	2.10	0.116
5	3.80	107.0	1.45	0.30	1.70	0.55	1.13	13.6	1.18	1.83	0.142
6	3.76	100.0	1.20	0.28	1.91	0.40	1.30	13.3	1.09	1.71	0.116
7	3.84	104.0	1.22	0.57	1.40	0.40	1.24	12.0	1.18	2.06	0.119
8	3.78	95.5	1.29	0.28	1.68	0.48	1.13	14.4	1.15	1.70	0.116
9	2.94	93.0	1.30	0.30	1.80	0.60	0.50	14.0	1.21	1.80	0.132
10	3.63	110.0	-	-	-	-	-	-	-	-	0.116
11	3.86	82.0	1.24	0.25	1.52	0.42	0.91	14.0	1.23	2.31	0.168
12	3.78	94.0	0.13	0.28	1.61	0.42	1.13	13.4	1.22	2.00	0.120
13	3.88	96.8	-	-	-	-	1.09	21.8	1.25	-	0.170
14	-	-	1.22	0.28	1.56	0.59	-	14.4	5.42	1.90	-

Altogether 99 and 120 laboratories participated in the intercomparisons in 1993 and 1994, respectively. The AL:PE laboratories are listed below:

Norwegian Institute for Water Research, Oslo, (N)
Laboratorio Biologico Provinciale, Laives, (I)
CNR Istituto Italiano di Idrobiologia, Pallanza, (I)
Freshwater Fisheries Laboratory, Faskally, Scotland (GB)
Dept. Hydrobiology, Charles University, Praha (CS)
Czech Geological Survey, Praha (CS)
Inst. Hydrobiology, Academy Sciences, Ceské Budéjovice (CS)
Inst. Zoologie, University Innsbruck (A)
Dept. Ecologia, University Barcelona (E)
Dept. Ecologia, Universidad Autonoma Madrid (E)
Inst. Agua, University Granada (E)
Inst. Biology, Dept. Freshwater Ecology, Ljubljana (SLO)
Inst. Ecology Problems, Kola Science Centre, Apatity (SU)
Inst. Ecology Industrial Areas, Katowice (PL)
Centro Ciencias Medioambientales, Madrid (E)

5. DATA ELABORATION

As a first presentation, the data for each solution and each variable are plotted in distribution graphs, in comparison with the expected values and with a range of ±20% of the expected values (±0.2 units for pH). This range has no statistical meaning nor does it represent a goal to be reached, but is only an aid to seeing the data distribution. Results are divided according to the analytical methods, if several techniques were used.

Outliers were identified by means of the method used at the Norwegian Institute for Water Research (NIVA), Oslo, for the inter-comparisons performed in the framework of the 'Convention on long-range transboundary pollution' (Hovind 1989). This technique excludes data outside the range of ±50% of the expected values, then calculates the mean and standard deviation of the remaining results, excluding values outside the range ±3 standard deviations.

A further graphical presentation of the data is given using the Youden's plot (Youden & Steiner 1975). This procedure uses the data relative to two samples, analysed with the same method, which are plotted in a scatter diagram, in comparison with the expected values or, alternatively, the median values of the results. This graphical presentation makes it possible to distinguish between the random and systematic errors affecting the results. The diagram is divided into four quadrants by the two straight lines representing the expected values for the two samples. In a hypothetical case, when the analysis is affected by random errors only, the results will be spread randomly over the four quadrants. However, the results are usually located in the lower left and the upper right quadrant, forming a characteristic elliptical pattern along the line passing through the origin and the expected value. This is due to systematic errors, which underestimate or overestimate the concentrations in both samples.

The 20% range around the expected values is represented by a circle with its centre at the expected values, i.e. at the intersection of the two straight lines in the diagram. The distance between the centre of the circle and the mark representing the laboratory is a measure of the total error of the results. The distance along the line passing through the origin and the expected values gives the magnitude of the systematic error, while the distance perpendicular to the same line indicates the magnitude of the random error. In conclusion, the location of the laboratory in the Youden's diagram gives important information about the size and type of analytical error, which assists in the identification of the causes of the error.

Examples of distribution graphs and of the Youden plot are reported for alkalinity (Fig. 1 and 2).

6. RESULTS AND DISCUSSION

Both artificial and natural stabilized samples resulted adequate for the aims of the intercomparisons, as they were chemically stable over the period of the exercise and no significant heterogeneity among bottles was detected.

The chemical results obtained by the AL:PE laboratories are reported in Tab. 2, compared with the expected values. For the whole set of results see Mosello *et al.* (1994, in press). Only a minor number of outlier data were present among the results of the AL:PE laboratories, although some results appear significantly different from the expected values. Furthermore some data were lacking, indicating that the laboratories were unable to perform all the analyses.

The main observation emerging from the elaboration of the whole set of data is the prevalence of systematic over random errors. This is well shown in Fig. 2 in the case of alkalinity, but it is true for most of the determinations, pH included. pH measurements resulted critical in the samples with low solute concentrations, which are poorly buffered.

Special attention was paid to alkalinity because of its importance in studies dealing with freshwater acidification. The results of both intercomparisons show a wide scatter of values, and a high number of different methods used. This is partially explained by the fact that not all the laboratories involved were used to analysing low alkalinity solutions. In the case of the AL:PE laboratories the results are good, even though they could be improved (Tabs 2 and 3). A substantial improvement was observed from the first intercomparisons, performed in 1991, to the 1994 exercise. The improvement in the case of alkalinity is largely explained by the fact that manual acid titration, with dye as indicator of the equivalence point, has been replaced by titration performed with an automatic burette, using the Gran titration or the two end-point titration.

Part of the dispersion of the results is explained by the fact that titrations consider different end-points; these aspects are extensively discussed in the reports of the whole set of results (Mosello *et al.*, 1994, in press).

7. CONCLUSIONS

Our results confirm the importance of intercomparison exercises in testing and improving analytical quality. The solutions used proved stable enough for the duration of the exercise, and there were no problems with results from samples sent by mail.

For all variables, the use of Youden plots clearly indicates the prevalence of systematic errors over random errors. The calibration technique and standard solutions used may be responsible for such results.

Compared with the first exercise, the second revealed an improvement in the overall performance of the laboratories; the conclusion is that regular intercomparison exercises are an important tool for assuring analytical quality and comparability of the results produced in international scientific and monitoring programmes.

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Mosello, R., M. Bianchi, H. Geiss, A. Marchetto, G.A. Tartari, G. Serrini, G. Serrini Lanza and H. Muntau. In press. AQUACON-MedBas Subproject 6. Acid Rain Analysis. Intercomparison 1/94. *Documenta Ist. Ital. Idrobiol.*.

Rodier, J. 1984. *L'analyse de l'eau*. Dunod. Orleans: 1365 pp.

Youden, W.J. and E.H. Steiner. 1975. *Statistical manual of the Association of Official Analytical Chemists*. Statistical Techniques for Collaborative Tests. Arlington.

Fig. 1-Distribution plot of alkalinity in exercise 1994. Unit: meq l^{-1}. Lines indicate expected values ± 20%

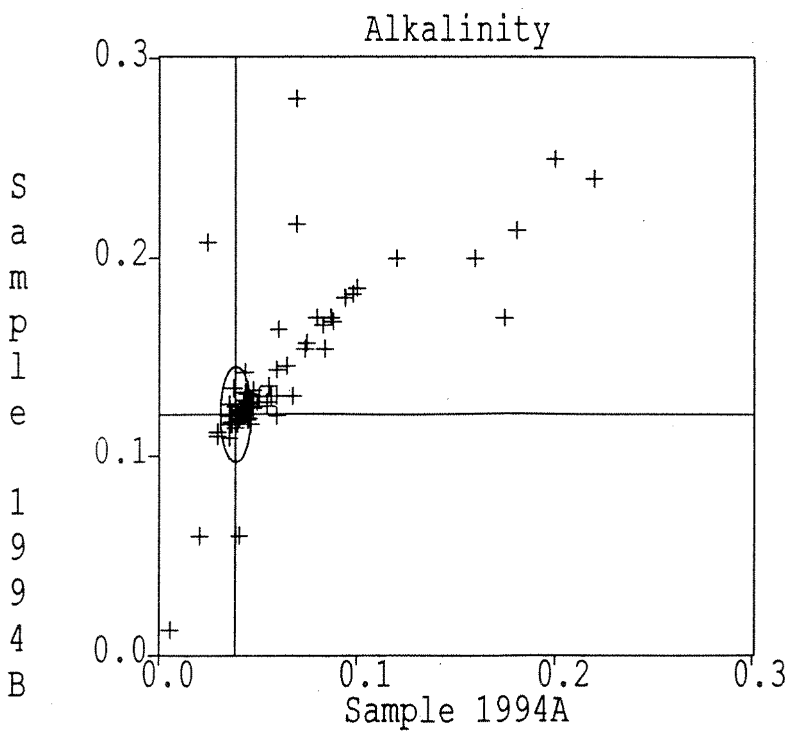
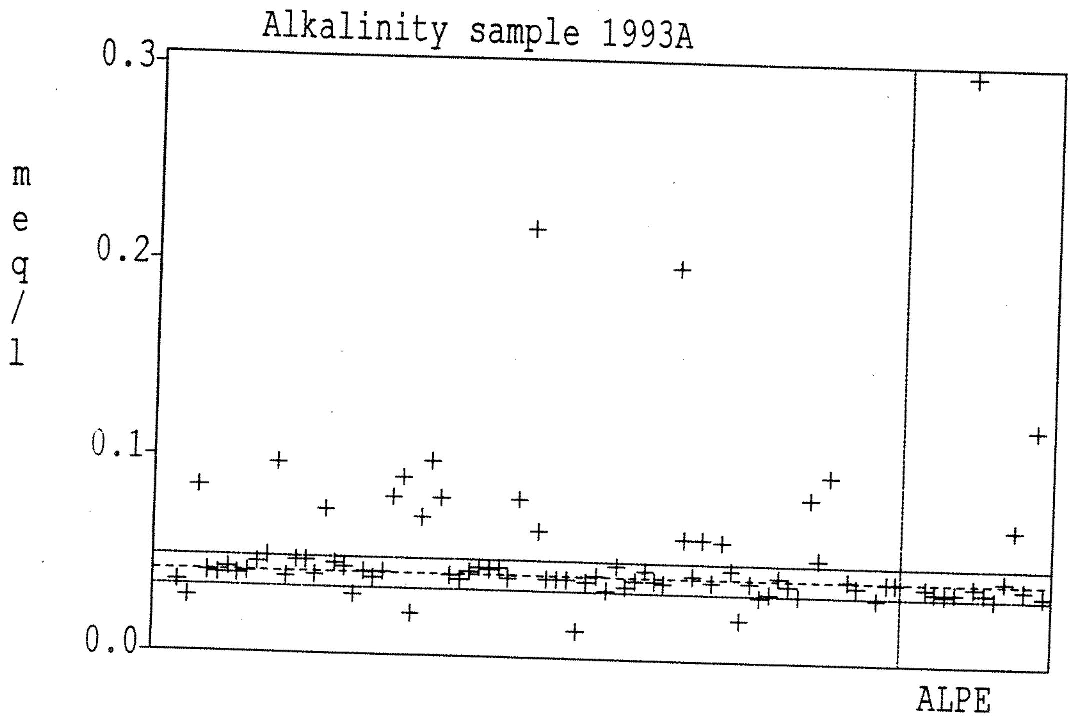
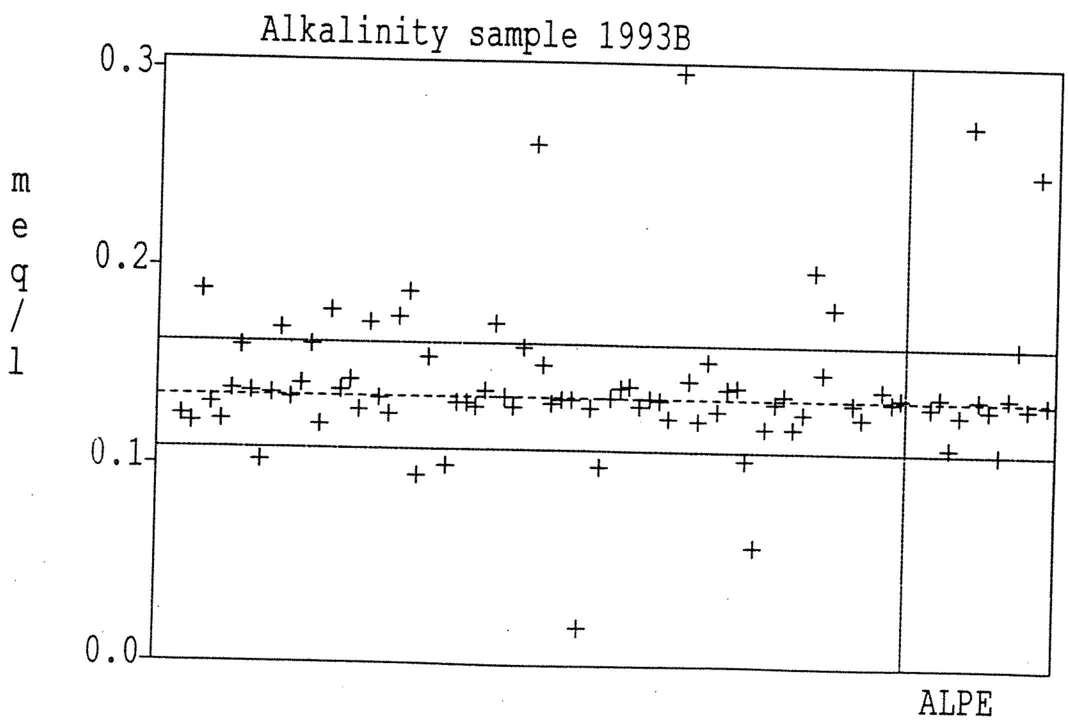
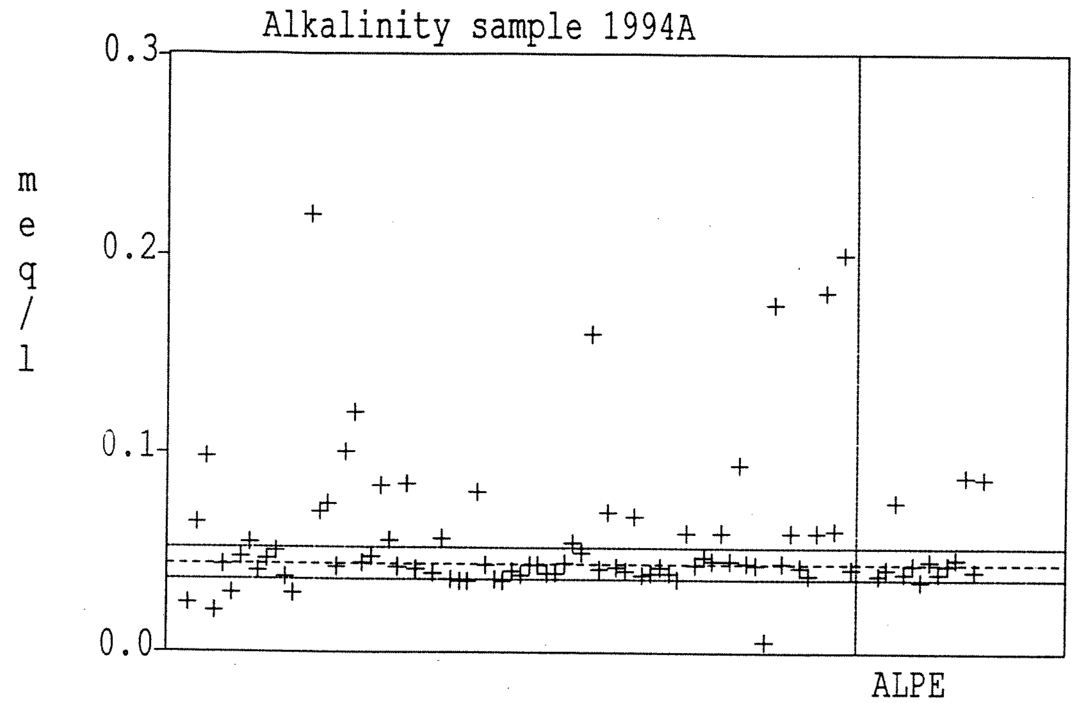
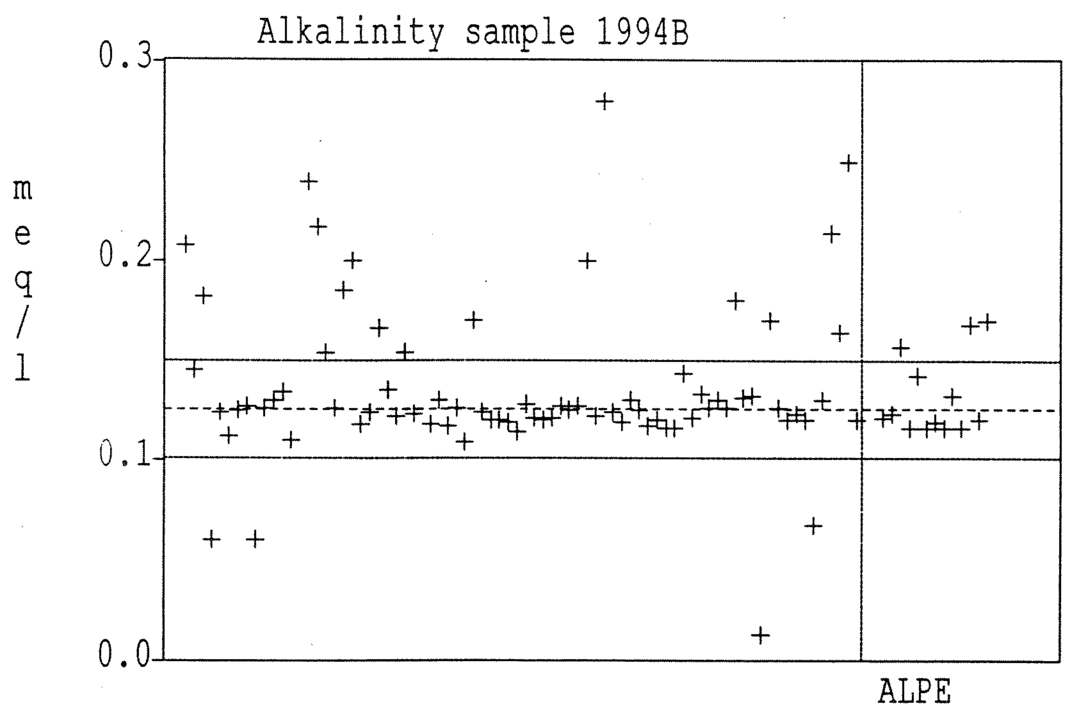


Fig. 2 - Youden's plot of alkalinity in exercise 1993 and 1994. Straight lines indicate expected values, the ellipses an interval of ± 20% of the expected values.






Alkalinity sample 1994A
0.3
0.2
0.1
0.0
meq/l
ALPE


Alkalinity sample 1994B
0.3
0.2
0.1
0.0
meq/l
ALPE

Vedlegg C. Fish - Population Structure and Concentrations of Heavy Metals and Oragnic Micropollutants

AL:PE 2 - Acidification of Mountain Lakes: Paleolimnology and Ecology. Remote Mountain Lakes as Indicators of Air Pollution and Climate Change

AL:PE 2 report for the period January 1993 - June 1995.

Fish

Population Structure and Concentrations of Heavy Metals and Organic Micropollutants

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EXECUTIVE SUMMARY FISH

Seventeen lakes have been testfished in the AL:PE 1 and 2 project to define the population structure. In addition, lakes that had been testfished during the AL:PE 1 project, as well as the new lakes in AL:PE 2, has been sampled for analyses of heavy metals and organic micropollutions in fillet and liver.

During resampling for analyses of heavy metals and organic micropollutants, new species were found in two lakes. In Étang d'Aubé, France, Arctic charr (*Salvelinus alpinus*) and minnow (*Phoxinus phoxinus*) was found for the first time, and in Zielony Staw, Poland, a population of brown trout (*Salmo trutta*) was found. The outlet stream of Lochnagar, UK, is the only locality over the whole period who has annually been testfished (by electrofishing).

NIVA has analysed the heavy metals in all lakes, except Schwarzsee ob Sölden where the University of Innsbruck, Austria, has done the analyses. The concentrations of heavy metals were compared to the locality of capture and to the length, weight, age, sex, state of sexual maturity, and the condition factor of the fish. Organic micropollutants, organochlorinated compounds in tissue and lipids of fish (HCB, HCHs, DDTs and PCBs) have been analysed by CID-CSIC, Spain. As the fish which were sent to NIVA for heavy metals analyses also were age determined here, discrepancy between age determination was found between some institutes. Age determination in fish thus needs inter-calibration practices.

The lowest concentrations of Hg were registered in Øvre Neådalsvatn, Zielony Staw, Lago Paione Inferiore, Laguna Cimera and Étang d'Aubé, while the highest concentrations of Hg were found in Arresjøen, and Lagoa Escura.

The concentrations of Hg and Pb were below the acceptable levels for human consumption in all of the AL:PE sites except for Schwarzsee Ob Sölden. Cd were too high for most of the sites, except the lakes Øvre Neådalsvatn, Lough Maam, Lagoa Escura, Étang d'Aubé and Chibiny.

When the concentration of the metals Hg, Pb, and Cd are arranged according to geographical positions of the AL:PE sites and according to accumulations of the metals in the fish , the geographical distributions are quite pronounced. Hg seems to have the highest concentrations in the western localities close to the Atlantic ocean. The highest contaminations appeared in Arresjøen (Svalbard) and Lagoa Escura (Portugal), and also quite high value in the Irish Lough Maam.

Pb showed low concentrations in the northern sites, higher values in the western localities, and the highest figures in the central, south-east Europe. Cd shows more or less the same pattern as for Pb, but with generally higher concentrations, especially compared to acceptable limits for human consumption. Both for Pb and Cd, the concentrations in Lochnagar (Scotland) were higher than expected from its geographical position. Øvre Neådalsvatn showed the lowest or second lowest values for all three metals. This site is therefore also well suited as a reference locality concerning accumulation of heavy metals in fish.

For some of the lakes, correlation was seen between the size of the fish (length, age, weight) and the concentration of Cd and Pb. For the whole material (not separating between species), however, no significant correlation was identified between the measured fish parameters and concentration of Cd and Pb. For Hg, correlation was seen between the size (length, age) of the fish and the Hg concentrations for the whole material. However, site identity demonstrated the strongest controlling variable for the examined heavy metals in fish. Principal components analysis showed high covariance for Cd and Pb (e.g. high concentrations of Cd and Pb in the same lake), but no covariance with Hg.

The results of PCB and DDE/DDT in the fish analyses are in good agreement with the concentrations observed in the sediments. Thus, they exhibit approximately the same geographical distribution in terms of higher and lower polluted sites. The fish analyses also show a general good correspondence between PCB and DDE/DDT concentrations, usually the two compounds are observed to increase or decrease alike in the lakes.

The PCB distribution found in the fish tissues is similar to that present in the sediments although it shows a clear enrichment in the heavier congeners. This effect probably reflects the different bioaccumulation factor of each of these compounds. HCB and HCH seem to be distributed following the influence of local sources.

There is a group of lakes with very low levels (almost blanks): Lagoa Escura, Lough Maan, Lochnagar and Laguna Cimera. Some lakes with moderate pollution levels were Stavsvatn, Zielony Staw and Estany Redo, whereas lakes with relative high pollution were Arresjoen and Lago Lungo. The highest pollution was found in Schwarzsee ob Sölden.

This classification among low, moderate, high pollution corresponds to the concentrations of the major chlorinated compounds, the PCBs and DDTs. The concentrations of these compounds change alike. These results show a higher concentracion in Central Europe.

4. FISH

4.1 INTRODUCTION

Because of the good empirical relationship between water chemistry and fish population changes, information about fish populations, both the historical and present status, has been of great importance in the AL:PE projects. High mountain lakes represents some of the most extreme environments for fish; low ionic concentration, long ice-cover period, low annual mean temperature, short period with food abundance etc. In such areas, few changes toward a less favourable water quality might immediately be reflected in fish population characteristics. As fish are long lived, 20 to 40 years in some alpine areas, fish populations acts as integrators of pollutants, a.o. for heavy metal and organic micro pollutant contamination. Likewise will reproduction failure, found by missing yearclasses, pinpoint the years when extreme water quality no longer provided the environment for survival of the most sensitive life history stages. Such changes might therefore act as an early warning for environmental changes, or as a confirmation of the historical changes which have taken place in the environment.

4.2 METHODS

Both in the AL:PE 1 and 2 project, information about the historical changes and stocking programme in the lakes has been collected by interviews (see Wathne *et al.* 1995). In lakes where the fish population are undergoing negative changes due to acidification, such information about present status has in many cases been shown to underestimate the degree of damage (Hesthagen *et al.* 1993). Test fishing, using standard gill net series and sampling procedures to describe fish population size, age composition, growth pattern, food organisms etc., has since the start of the monitoring programme in Norway (Rosseland *et al.* 1980) demonstrated its relevance to give a true picture of the present fish status. These same methods have been used in the AL:PE 2.

4.2.1 Test fishing.

Gillnet series

In AL:PE 1 and 2, the gillnet series that was design for the Norwegian monitoring programme (Rosseland *et al.* 1979) has been used (Wathne *et al.* 1995). Eight individual bottom gillnets of different mesh sizes (Table 1) or a set of three gillnets, each as a combination of these 8 mesh sizes (SFT 1983), has been used either alone or in combination. In cases where national laboratories have deviated from the standard (France, Austria and Russia), the used gillnets are given for the specific lakes.

Gillnet-setting.

The gillnets are set perpendicular to the shore, avoiding steep-slope shore to bottom areas.

Both in the AL:PE 1 and 2 projects, the period between August 15 to October 15 have been selected for testfishing, for reasons given in Wathne *et al.* (1995).

Table 4.1. The standardised gillnet series, containing 8 gillnets of given mesh size and thread thickness. (After: Rosseland *et al.* 1979). In the series of 8 single nets, each individual gillnet is 26 m long, 1.5 m deep, and have a dark red colour. In the series of 3 nets, each net contains a combination with 4 m of each mesh size, each of the 3 nets having the individual mesh sizes in different order. The catchability of the 8 single nets are 1.0, compared to 0.46 of the 3 net series. The gillnets are produced by Lundgrens Fiskredskapsfabrik AB, Stocholm, Sweden.

Mesh size mm.	10	12.5	16.5	22	25	30	38	46
Thread thickness mm.	.15	.15	.15	.15	.15	.15	.15	.17

Analytical program

Each fish have been given a specific number which follow all subsamples to be analysed. Data from individual fish has been sent to NIVA.

For each individual fish, the following parameters have been noted:

- lake
- date
- species
- length, in mm, measured from snout to lower part of tail.
- weight, in gram.
- sex and gonadal maturation, from stage I - VII
  - I - II juveniles
  - III - V recruit spawners
  - VI spawning
  - VII/.. postspawners
- flesh colour; white, pink or red.
- stomach fullness, classified from 0 - 4.
- stomach content (if possible), conserved in 70% alcohol and classified in main invertebrate groups (not fully analysed in AL:PE 2).
- scale samples for age determination, taken from the area between the sideline organ and dorsal and pectoral fin.
- otolith samples for age determination (all species), using the "burning technique" described by Christensen (1964). If age differ when determined by otolith and scales, otolith age is considered as the true age.
- growth, determined by:
  - length at catch as a function of true age.
  - back calculation of growth, using the methods of Dahl (1910) and Lee (1920).

Analytical programme for the electrofishing (Lochnagar, UK) includes length and age (by scales). Analytical work as well as testfishing at sites in Norway and Italy has been performed by NIVA. Lake In all other countries, practical and analytical work has been performed at the national laboratories. The results are processed in databases at NIVA

4.2.2 Heavy metals, Cd and Pb in fish liver, and Hg in fillet

Analyses

The liver and fillet were digested, and Pb and Cd were analysed by graphite furnace (Perkin-Elmer 2380), and Hg were determined by cold-vapour atomic absorption spectrometry (Perkin-Elmer 1100 B with gold trap used with helium as carrier gas). All methods are described in Green, 1993. Except for the fish from Schwarzsee ob Sölden, where the University of Innsbruck has done the metal analyses, NIVA has analysed the heavy metals in all other lakes.

Statistics

The concentrations of heavy metals were compared to the locality of capture and to the length, weight, age, sex, state of sexual maturity, and the condition factor of the fish. The statistical handling of the material (Principal component analysis, Analysis of variance, and Analysis of co-variance) was done by John Birks (UiB) and Eirik Fjeld (NIVA).

Multivariate numerical methods of data analysis have been applied to these data in an attempt to detect the major patterns of variation within the data-sets. Such patterns highlight the principal gradients of variation, help to generate hypotheses about the underlying causal processes, and define new research questions.

The Pb, Cd, and Hg concentrations in livers or muscle of arctic charr, brook trout, rainbow trout, and brown trout have been measured from 73 fish from 15 lakes in the AL:PE project. The lakes are Arresjøen (Spitsbergen), Lago Lungo (Italy), Lago di Latte (Italy), Schwarzsee ob Sölden (Austria), Lake Chibini (Kola), Étang d'Aubé (France), Laguna Cimera (Spain), Zieloni Staw (Poland), Lagoa Escura (Portugal), Lago Paione Inferiore (Italy), Stavsvatn (Norway), Estany Redo (Spain), Lochnagar (Scotland), Lugh Maam (Ireland), and Øvre Neådalsvatn (Norway).

Numerical analyses

The data have been analysed by principal components analysis (PCA) (ter Braak, 1987) using a correlation matrix between the three chemical variables. Because the chemical variables come from fish of different species, length, age, weight, sex, and growth stage, all of which could cause variations in the observed heavy metal concentrations, the effects of these variables were removed statistically by treating these variables as covariables and partialling out their effects in a partial PCA (ter Braak and Prentice, 1988).

The results of the PCA and of the partial PCA are presented as correlation biplots (ter Braak, 1983, 1994).

In an attempt to partition how much of the observed variation in the heavy-metal concentrations can be explained by all the potential predictor variables (site, fish species, sex, length, weight, age, and growth stage), and by site alone when the effects of different sets of biological variables are allowed for statistically, a series of (partial) redundancy analyses (RDA) were done using different sets of predictor variables and covariables. RDA is a constrained or canonical form of PCA (ter Braak, 1994) in which the patterns of variation in the response variables, in this case heavy-metal concentrations, are modelled as linear combinations of the predictor variables so as to give the lowest possible residual sum-of-squares (ter Braak, 1987, 1994). The statistical significance of each RDA model was assessed by a Monte Carlo permutation test (ter Braak, 1990) using 249 unrestricted permutations.

4.2.3 Organochlorinated compounds, PCBs PAH and DDT in fish fillet and lipid

The organochlorinated compounds, PCBs, PAH and DDT from fillet and lipid of fish has been analysed by CID-CSIC, Spain. In two Norwegian lakes, however, NIVA has in parallel analysed for total PCB.

The parameters analysed by CID-CSIC were:

- Water and lipid content in muscle tissue
- Organoclorinated pesticides compounds.
  Hexachlorobencene
  Hexachlorocyclohexanes (à, ë and isomers)
  DDTs (pp'-DDE, pp'-DDT)
- Industrial organochlorinated products:
  Polychlorobiphenyls (Congeners Nos. 28+31, 52, 101, 118, 153, 138 and 180)

The muscle tissues were freeze-dried and Soxhlet extracted with (4:1) *n*-hexane-dichloromethane for 18 hours. This extract was used to measure total extractable lipid weight after evaporation to dryness. The extract was then redissolved in 2 ml of *n*-hexane and cleaned up with agitation with sulphuric acid (three times). Instrumental analysis of the cleaned extracts was performed by gas chromatography with splitless injection and electron capture detection. The instrument was equipped with a 5% phenyl-95% methylpolysiloxane capillary column. Quantitation was performed with reference to authentic standards. Calibration curves were performed with each of these standards to ensure that all compounds were quantified within the linear range of the detector.

Results from the different lakes are shown in Appendix 7 (Table 7.2 - 7.16). These Tables report the concentrations per total wet weight and total extractable lipids. No significant covariation is observed between content of any of the chlorinated products and fish weight, length or lipid content. In these conditions the normalisation of the concentration to total extractable lipids is not necessary (Hebert and Keenleyside, 1995). The results referring to lipid weight are therefore only given for comparative purposes. In the present evaluation, only the concentrations per wet weight will be considered.

All the lakes considered in this study are oligotrophic (total N < 1000 µg/L and total P < 7 µg/L) and the concentration of humic materials in their waters is also low (TOC < 3.3 mg/L). Thus, the small influence of lake productivity and water concentration of humic substances in the uptake of organochlorinated pollutants by fishes observed in other studies (Larsson et al., 1992) is not probably significant in the context of the lakes selected for study.

4.3 RESULTS

Lakes not previously testfished in the AL:PE 1 project, was testfished and the population structure and contamination levels was determined. In lakes from AL:PE 1, a selective gillnet fishing for collecting tissue samples for determination of heavy metals and organic micropollutants have been performed. NIVA has analysed the metals (Cd and Pb in liver, and Hg in tissue) in five fish from all lakes, except the Austrian Lake Schwarzsee ob Sölden who was analysed by the University of Innsbruck (Hofer). The concentrations of HCB, HCH, DDT and PCBs was analysed from five other fish by CID-CSIC (Grimalt). The size of the fish and concentration of the different components are shown in Appendix 7.

4.3.1 SVALBARD

Arresjøen (9)

Arresjøen, Svalbard, was testfished by the University of Tromsø in 1990 (Svenning 1992, Svenning and Borgstrøm 1995) and by NIVA in 1993. The population of Arctic charr (*Salvelinus alpinus* L.) is typical for the arctic lakes at Svalbard being landlocked and isolated from sea migration. The fish has a slow growth the first 10-12 years, until they shift their feeding habits and becomes cannibals around the age of 12, Figure 4.1. This shift in feeding, is reflected in the bimodal growth curve, Fig 4.2. Charr up to the age of 31 years was found, Figure 4.3.

On August 16, 1993, NIVA performed a restricted testfishing to get data on micropollution in the charr population. Five fish, age from 17 to 31 years, were analysed. Cadmium and lead in liver ranged from 0.45 - 0.91 and 0.00 - 0.03 µg/g wet weight, respectively. Mercury in fillet ranged from 0.14 to 0.27 µg/g wet weight, se Table A7.1. As for Stavsvatn, total PCB concentration in the fish from Arresjøen has been analysed both by NIVA and CID-CSIC. The concentration was found by NIVA to be between 12 to 59.2 µg/kg wet weight (mean and SD = 24.7 $\pm$ 17.8) for the five fish, the oldest fish (31 years) having the highest concentration (Table A7.1).The body weight, length, tissue water, lipid content and concentrations of HCB, HCH, DDT and PCBs in the five charr analysed by CID-CSIC, are shown in Table A7.2.1-3. The body weight ranged from 27 to 440 g, ranging in total PCBs between 1.86 to 35.8, mean 17.0 $\pm$ 16.1 µg/kg wet weight (Table A7. 2.2).

Region summary - Svalbard

The fish population at Arresjøen is typical for a lake at Svalbard having a landlocked and isolated Arctic charr population. The old fish in these lakes make them ideal for studying pollutants concentrating as a function of exposure time (age dependant). Of the heavy metals, some of the highest concentrations of Hg in the AL:PE lakes were found in Arresjøen. Although not exceeding the acceptable limits for food consumption (>0.3 ppm Hg), the level for Cd in liver, however, was exceeded (> 0.5 ppm Cd). Pb, on the other hand, showed a low concentration (<0.1 ppm).

The concentrations of organochlorinated compounds in Arresjøen are low but they are not the lowest in the AL:PE series. This observation is a bit surprising taking into account large distance of this lake from the European continental sites were organochlorinated compounds are produced and/or used. Furthermore, the results from the sediment analyses show that the lower concentrations of these compounds are effectively found in this lake. One important feature of the fishes collected in this lake is that two specimens are among the largest collected in the whole study. They have been excluded from the average values described in Figures 4.18 - 4.21. The most abundant compounds are the PCB congeners. The DDT derivatives are also significant.

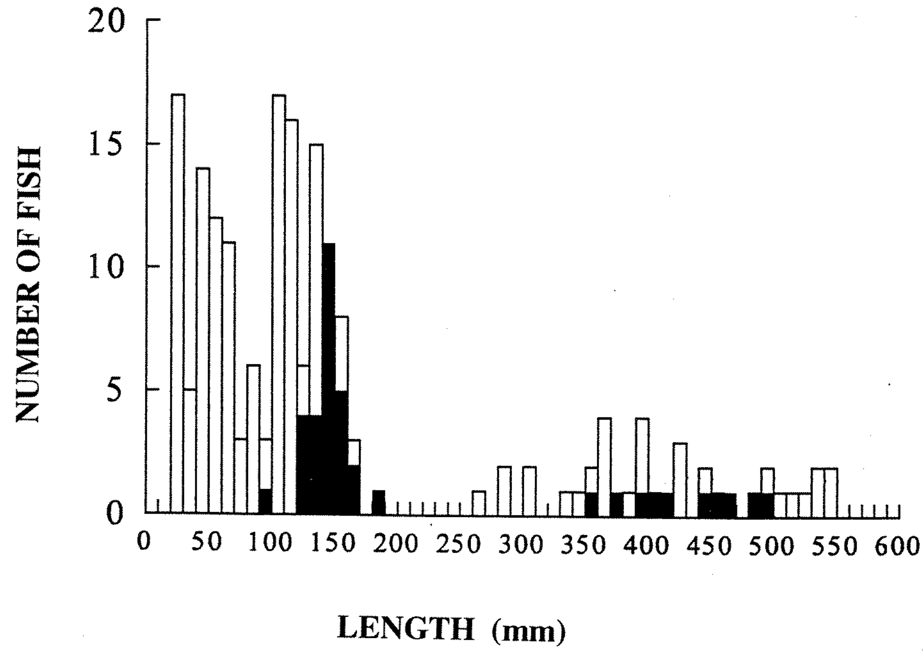


Figure 4.1. The length distribution of Arctic charr from Arresjøen in August 1990. Closed columns indicate spawners (stage IV-V or VII/IV-V). Data from Svenning (1992)

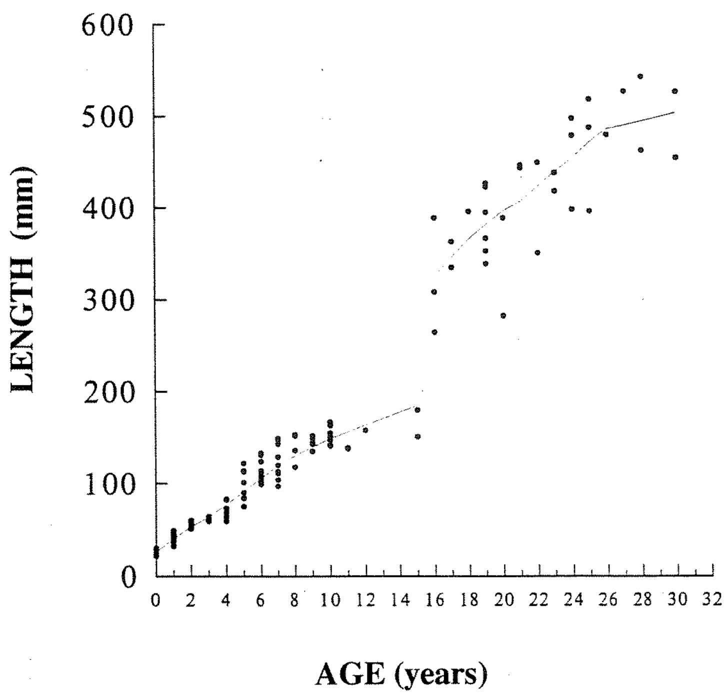


Figure 4.2. The bimodal growth curve of the Arctic charr from Arresjøen. Data from Svenning (1992).

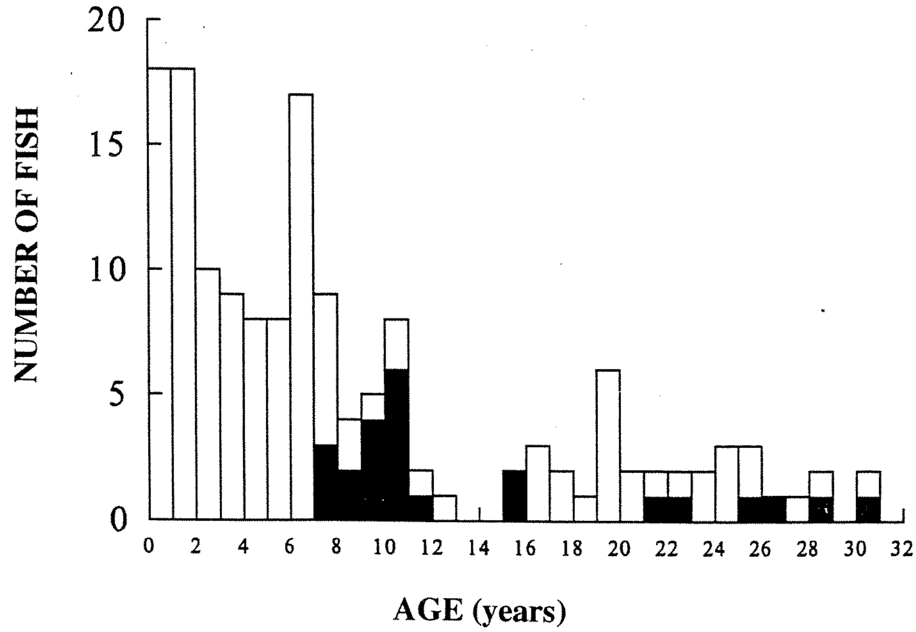


Figure 4.3. The age composition of the Arctic charr population in Arresjøen 1990. Closed columns indicate spawners (stage IV-V or VII/IV-V). Data from Svenning (1992).

4.3.2 KOLA

Chuna (17)

Chuna was testfished with one standard gillnet series on September 24, 1994. The lake contained a population of brown trout. Pathological and morphological examinations were performed, and symptoms of fish diseases and parasitic infections were examined visually. Detailed information on the results from Chuna is given by Moiseenko *et al.* (1995).

The 49 trout represented year classes between 1 to 7 years. The length and age distribution are shown in Figure 4.4. No signs of disease were found on the brown trout.

Based on the age determination, the length at age 1+ (mean 16.7 cm) seems extraordinary good, more comparable with a well grown 2+ fish. The brown trout population has a good growth up to the age of 5 years, and a marked growth reduction at higher age. Although the condition factor is good and around K = 1 even for the oldest fish, the data reflects a population of moderate to high density (Moiseenko *et al.* 1995).

No fish has been analysed for heavy metals and organic compounds.

Chibiny (18)

Chibiny was testfished with one standard gillnet series on September 30th, 1993, and 25 Arctic charr were captured. Detailed information on the results from Chibiny is given by Moiseenko *et al.* (1995).

Year classes between 1 to 7 years were found. The length, age distribution and condition factor are shown in Figure 4.5. The good growth and high condition factor (increasing with age), indicates a sparse fish population with abundance of food. The pathological studies showed some changes

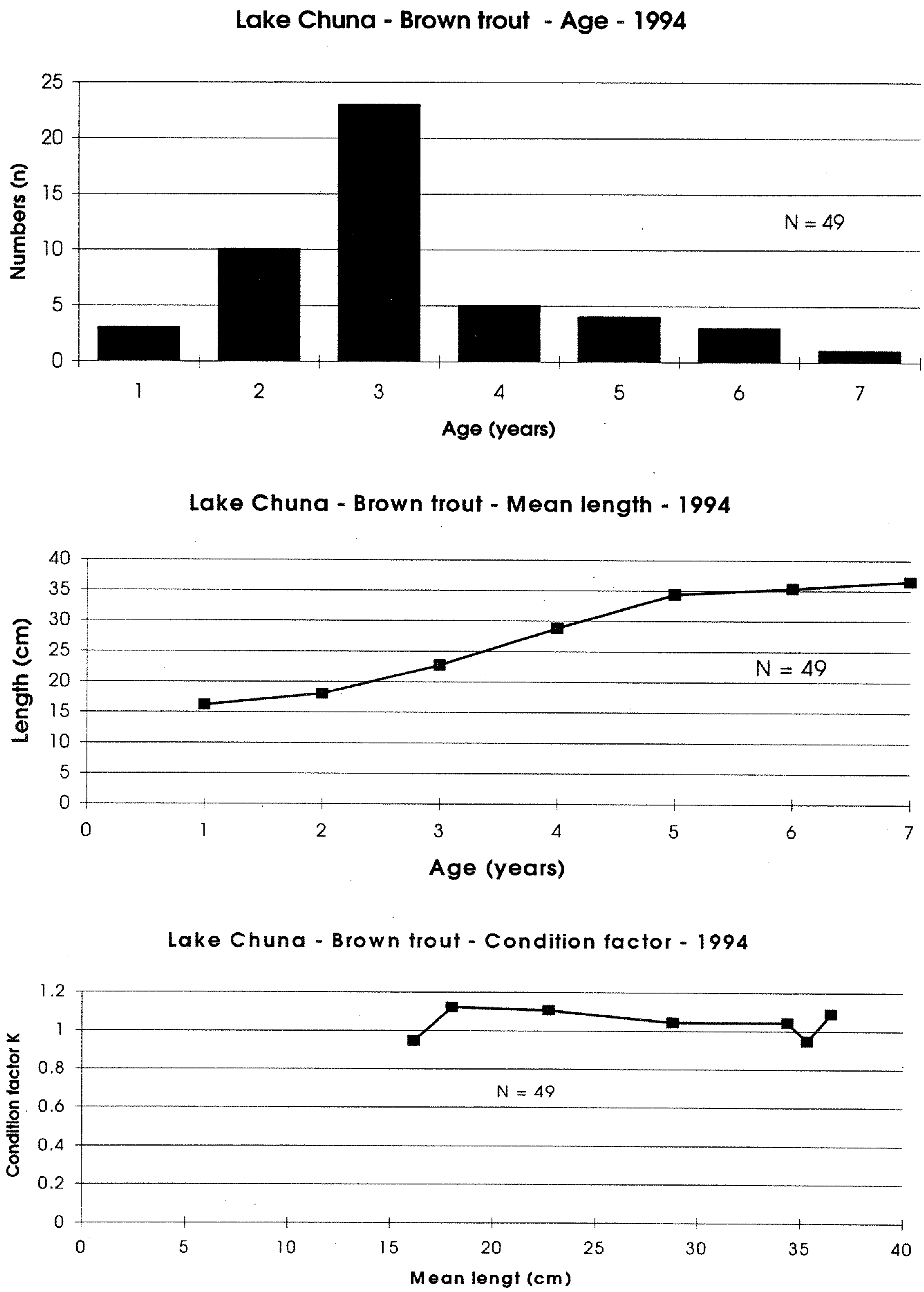


Figure 4.4. Chuna was testfished in September 1994. The length (upper), age (middle) and condition factor distribution (lower) for the brown trout are shown.

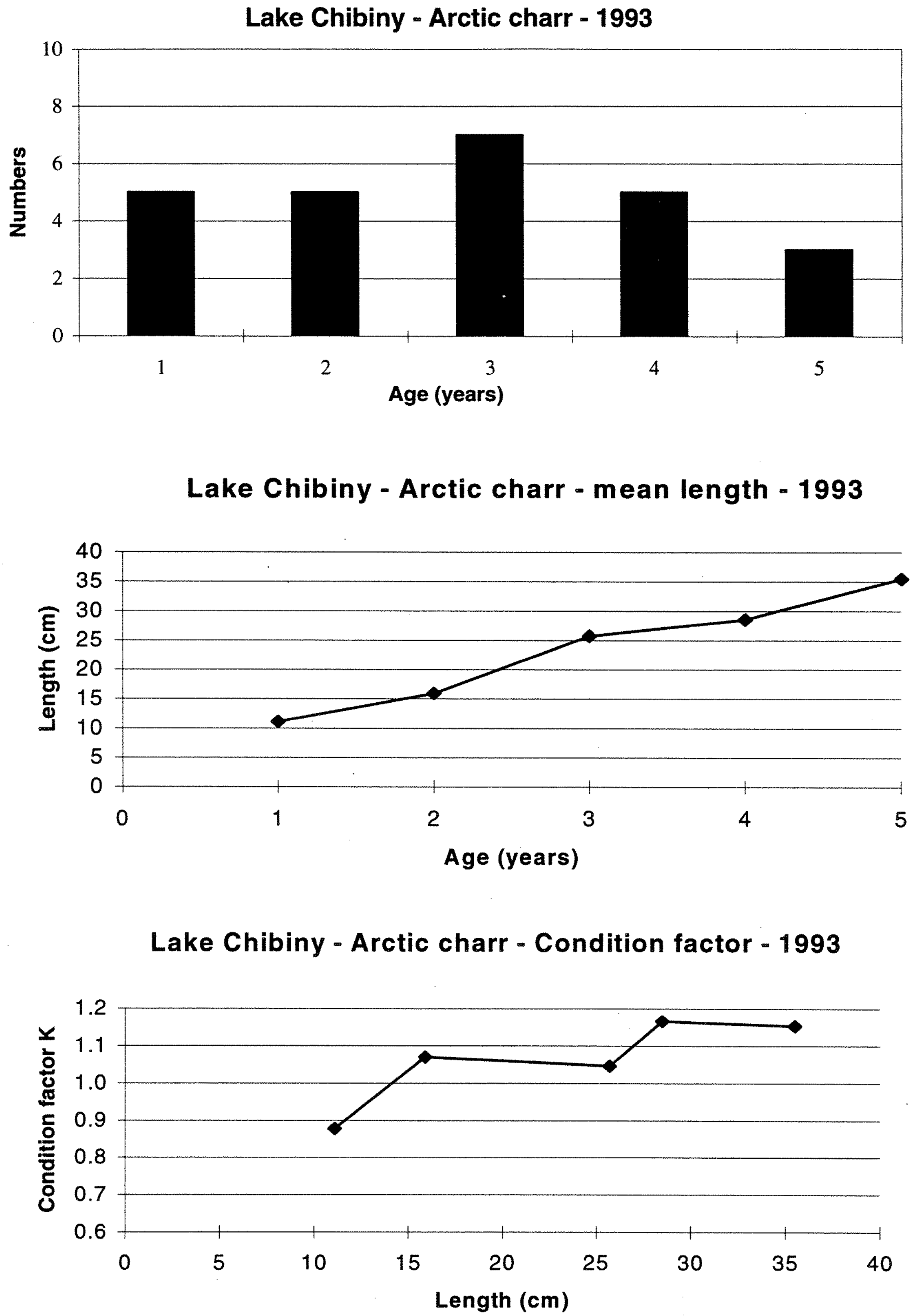


Figure 4.5. Chibiny was testfished in September 1993. The age (upper), length (middle) and condition factor distribution (lower) for the Arctic charr are shown.

relative to controls. Some unevenness colour of liver was observed in 24 % of the charr, and these livers were "flabby". Some charr (16%) had connective tissue expansions in kidney, and in most charr, initial stages of anaemic rings were found on gills.

Five fish between 5 and 8 years (weight 55 - 285), were sent to NIVA for analyses of heavy metals. Cadmium and lead in liver ranged from 0.024 - 0.042 and 0.03 - 0.07 µg/g wet weight, respectively. Mercury in fillet ranged from 0.031 to 0.062 µg/g wet weight, se Table A7.1 for comparison of levels between lakes. Metals in liver, muscle, gills, skeletal and kidney were also analysed by the Institute of the North Industrial Ecology problems (INEP). The concentrations of Cu, Ni, Co, Zn, Mn, Al and Sr (mg/g dry weight) are shown in Table A7.3.

Four fish were analysed by CID-CSIC (Table A7.4.1-3.), body weight from 79 to 233 g, ranging in total PCBs between 0.76 to 2.83, mean 2.08 $\pm$ 1.06 µg/kg wet weight , and between 55.1 to 166, mean 120 $\pm$ 61 µg/kg lipid weight.

Region summary - Kola

The fish populations in Chuna and Chibiny seemed both to be naturally reproducing. The age structure and general growth are considered to be typically for the region.

Only fish from Chibiny were analysed for heavy metals and organic micropollutants. Heavy metal concentrations were generally low, and well below acceptable limits for food consumption. The concentrations are also very low for all organochlorinated compounds. The PCB congeners are those present in higher abundance although their concentrations range among the lowest of the whole AL:PE series.

4.3.3 NORWAY

Øvre Neådalsvatn (1)

Øvre Neådalsvatn was testfished in 1978 and in August 1991 in the AL:PE 1 project. The lake contain a healthy, self reproducing brown trout population, which are carefully but extensively exploited by the owners. In 1991, six year classes was found, and the fish demonstrated a rapid growth with a high condition factor (mean around K = 1.1), Wathne *et al.* (1995).

A minor testfishing was performed on August 12, 1994. One five year old and four 3 year old trout (weight 298 - 524 g) was analysed for micropollutants (µg/g wet weight). Cadmium and lead in liver ranged from 0.063 - 0.084 and 0.03 - 0.05, respectively. Mercury in fillet ranged from 0.028 to 0.034 µg/g wet weight, see Table A7.1 for comparison of levels between lakes.

Five fish was analysed by CID-CSIC (body weight from 75 to 237 g) for HCB, HCH, DDT and PCBs, ranging in total PCBs between 0.69 to 3.29 mean 1.50 $\pm$ 1.08 µg/kg wet weight, and between 25.4 to 82.7 mean 51.2 $\pm$ 29.3 µg/kg lipid weight, respectively (Table A7.5.1-3).

In general, Øvre Neådalsvatn exhibits low concentrations of organochlorinated compounds, where the most abundant compounds correspond to the mixture of PCBs.

Stavsvatn (2)

Stavsvatn was testfished in August 1991, in the AL:PE 1 project. The population of brown trout suffered from reproduction failure due to acidification, and the sparse population has been kept by repeated stocking over 20 years (Wathne *et al.* 1995). In 1991, age classes between 2 and 6 years were represented, having a low condition factor ($K < 1$) and growth rate.

In September 1993, five trout from Stavsvatn, one at 5 and four at 7 years of age, was captured and analysed for micropollutants. Cadmium and lead in liver ranged from 0.67 - 1.84 and 0.12 - 0.30 µg/g wet weight, respectively. Mercury in fillet ranged from 0.05 to 0.11 µg/g wet weight, se Table A7.1. As for Arresjøen, PCB concentration in the trout from Stavsvatn has been analysed both by NIVA and CID-CSIC. The pooled total PCB concentration in the five fish from Table A7.1 (weight 374 - 768 g) was found by NIVA to be 14.6 µg/kg wet weight. Five fish analysed by CID-CSIC (weight between 258 to 675 g) had a concentration of total PCBs between 2.19 to 16.23, mean 6.57 ± 5.74 µg/kg wet weight, and between 176 to 896, mean 426 ± 302 µg/kg lipid weight Table A7.6.1-3.

The pollution level of major chlorinated compounds in Stavsvatn is considered to be low.
The most abundant compounds correspond to those included in the DDT mixtures (Table A7.6.2-3).

Region summary - Norway

The Norwegian lakes represents a reference lake with a healthy selfreproducing brown trout population (Øvre Neådalsvatn), and an acid lake dependant on repeated stockings to provide fishing (Stavsvatn). Øvre Neådalsvatn is a true reference lake for Europe, with very low values for the heavy metals. The concentrations of organochlorinated compounds in these lakes are also very low. The two lakes, however, exhibit significant differences in the concentrations of organic micro pollutants (less in Øvre Neådalsvatn) which probably reflect local influences or inhomogeneous deposition trends in this area.

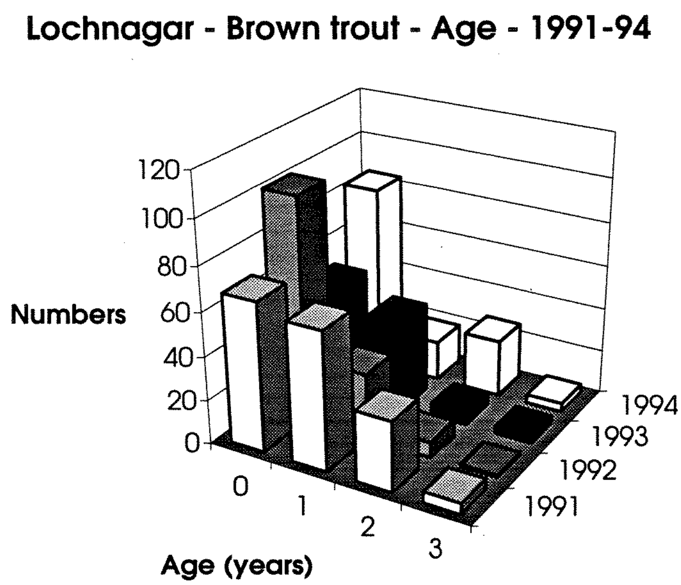
4.3.4 BRITISH ISLES

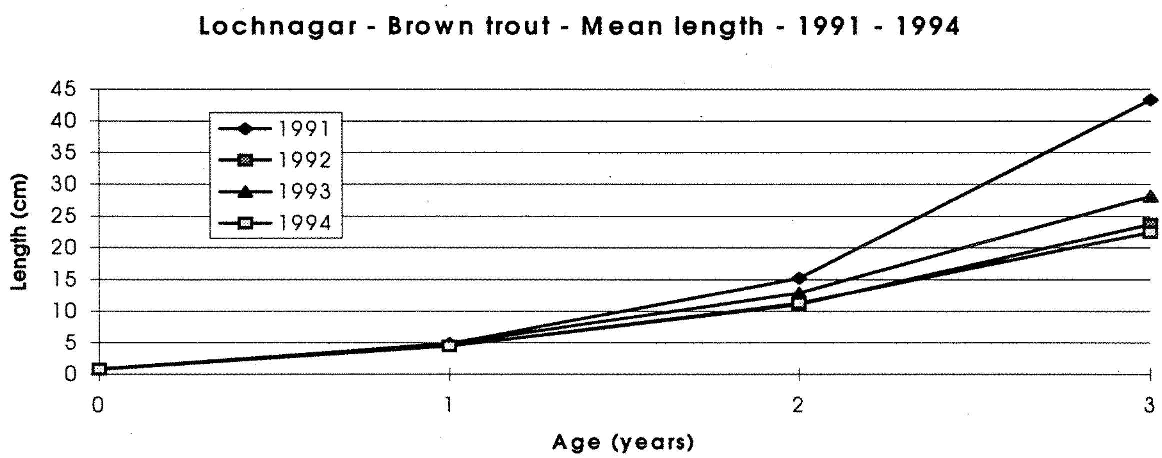
Lochnagar (4.1)

Each autumn, the Freshwater Fisheries Laboratory, Pitlochry, has estimated the fish population in the outlet river of Lochnagar by electrofishing. The stream is divided into three stretches which are testfished three times. The pooled samples for all stretches and the three samples are used in Figure 4.6. The number of fish in the years 1991-94 has been 168, 140, 100 and 132, respectively.

The age composition in the stream is shown in Figure 4.6 (upper). The 0+ generation in 1993 was smaller than in the other years, being reflected as a small 1+ yearclass in the catches in 1994. The results thus seems to reflect the real situation in the outlet stream from Lochnagar, still providing recruitment in spite of a marginal water quality. The growth, represented by length at catch, is shown in Figure 4.6 (middle). Except for the size of the 3+ in 1991 (N= 5), no difference exist between the other yearclasses over the four year period. The condition factor for the fish sampled in 1991 (Figure 4.6 lower), illustrates good growth conditions.

In July 1993, a testfishing took place in the lake itself, and ten fish were sent to analyses; five for heavy metals and five for organic compounds. In the 2-4 year old fish, weighting from 41 to 296 g, the cadmium and lead in liver ranged from 1.33 - 2.58 and 0.52 - 0.77 µg/g wet weight, respectively. Mercury in fillet ranged from 0.04 to 0.08 µg/g wet weight, se Table A7.1.





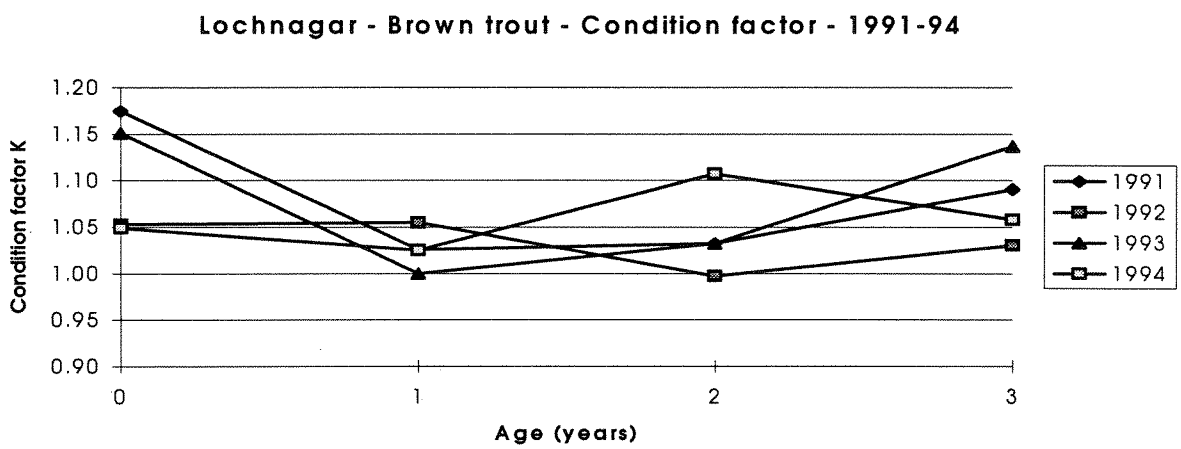


Figure 4.6. Results from electrofishing in the outlet stream of Lochnagar, pooled samples from three stations, each being electrofished three times. The age composition of the brown trout in the period 1991 to 1994 (upper), empirical length at testfishing (middle) and condition factor K for all three stations in 1991.

The concentrations of HCB, HCH, DDT and PCBs was analysed by CID-CSIC from five other fish, weight between 108 to 211 g. The fish size and concentration of the different components are shown in Table A7.7.1-3. The fish had a concentration of total PCBs between 2.01 to 5.77, mean 3.48 ± 1.84 µg/kg wet weight, and between 134.8 to 289, mean 187 ± 82 µg/kg lipid weight, Table A7.7.1-3.

The pollution level of major chlorinated compounds in Lochnagar is low. As in the previous cases the most abundant compounds are PCBs. The concentrations of total DDTs range among the lowest in the whole AL:PE series.

Lough Maam (10)

Lough Maam, Ireland, was testfished on September 10, 1993 by the Freshwater Fisheries Laboratory, Pitlochry. Out of 22 brown trout caught, ten fish were sent to analyses; five for heavy metals and five for organic compounds. In the 4 and 5 year old fish, weighting from 185 to 299 g, the cadmium and lead in liver ranged from 0.19 - 0.56 and 0.14 - 0.20 µg/g wet weight, respectively. Mercury in fillet ranged from 0.07 to 0.09 µg/g wet weight, se Table A7.1.

The concentrations of HCB, HCH, DDT and PCBs was analysed from five other fish, weight between 187 to 270 g, by CID-CSIC. The fish size and concentration of the different components are shown in Table A7.8.1-3. The fish had a concentration of total PCBs between 1.20 to 6.88, mean 3.16 ± 2.72 µg/kg wet weight, and between 48.7 to 365, mean 198 ± 164 µg/kg lipid weight, Table A7.8.1-3.

The pollution level of major chlorinated compounds in Lough Maam is very low, and close to what can be considered to be "blanks".

Region summary - British Isles

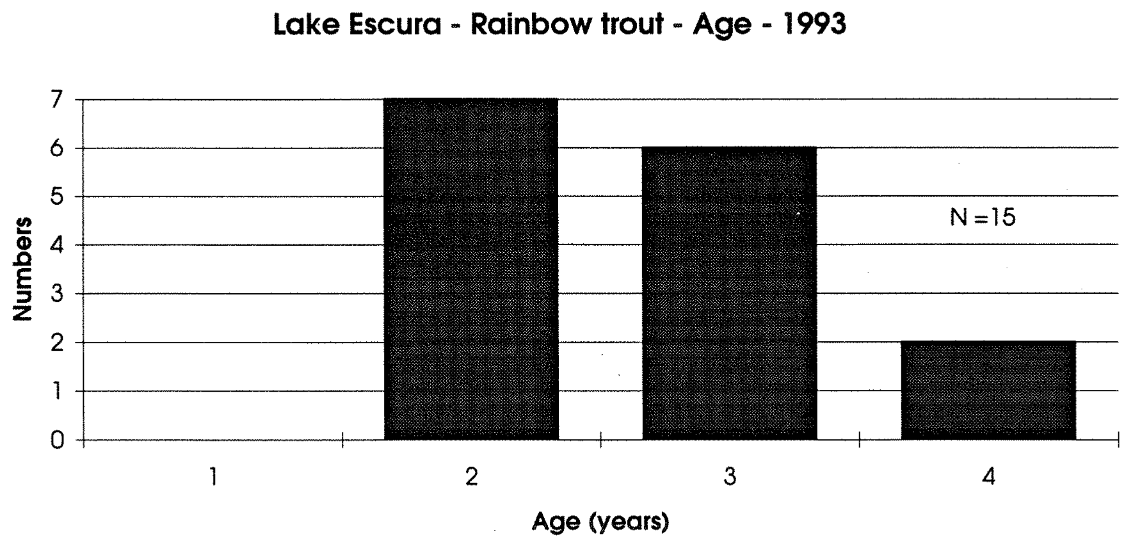
The brown trout population in the outlet stream of Lochnagar, Scotland, has not changed during the AL:PE 1 and 2 project period, demonstrating only small annual variations in yearclass composition, growth etc.

The levels of heavy metals are generally high, when compared to reference areas, both in Lochnagar and Lough Maam, Ireland. However, the geographical distributions of metals are quite pronounced, and Hg seems to have the highest concentrations in the western localities close to the Atlantic ocean. For this reason, there were quite high values of Hg in Lough Maam. Both for Pb and Cd, the concentrations in Lochnagar were higher than expected from its geographical position.
The concentrations of organochlorinated compounds are low and rather uniform between the two lakes. The most abundant products correspond to the PCB congeners. These lakes range among those showing lowest concentrations of total DDTs.

4.3.5 IBERIA

Lagoa Escura (14)

Lagoa Escura was testfished on October 7, 1993. A small population of rainbow trout was found, represented by 2 - 4 year old fish. This small population presented a good growth and a mean condition factor of 1.35, Figure 4.7.



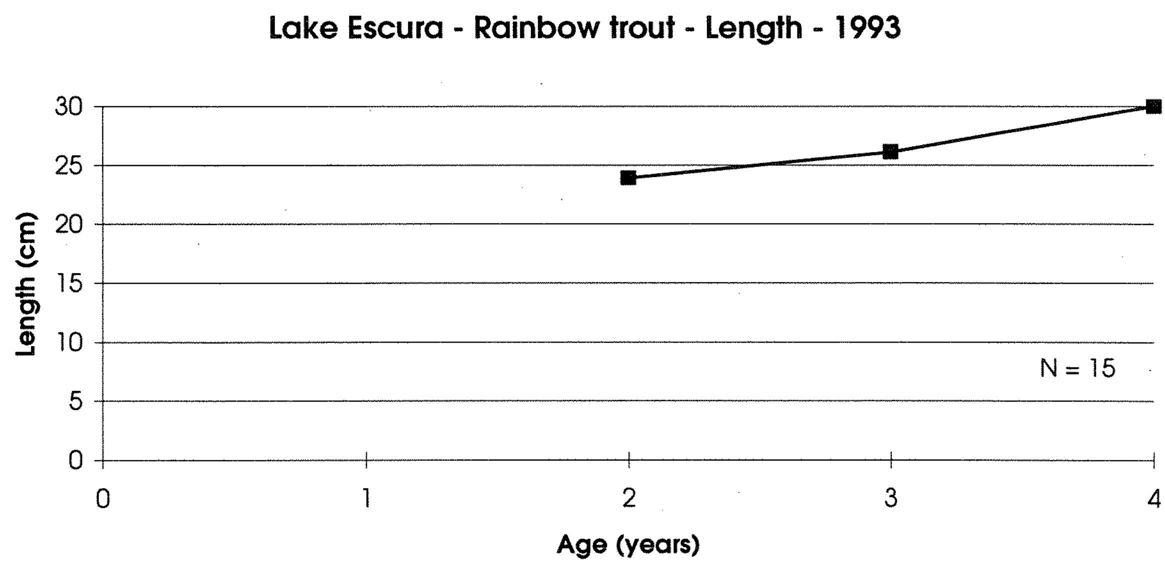


Figure 4.7 Lagoa Escura: Age of rainbow trout caught by testfishing in October 1993 (upper), and empirical length according to age (below).

Six rainbow trout were sent to analyses; three for heavy metals and three for organic compounds. In the 3 year old fish , weight between 185 to 277 g, the cadmium and lead in liver ranged from 0.07 - 0.09 and 0.22 - 0.39 µg/g wet weight, respectively. Mercury in fillet ranged from 0.09 to 0.13 µg/g wet weight, se Table A7.1.

The concentrations of HCB, HCH, DDT and PCBs were analysed from three other fish, weight between 174 to 264 g, by CID-CSIC. The fish size and concentration of the different components are shown in Table A7.9.1-3. The fish had a concentration of total PCBs between 1.19 to 2.17, mean 1.76 ± 0.61 µg/kg wet weight, and between 91.6 to 142, mean 110 ± 35.6 µg/kg lipid weight, Table A7.9.1-3.

The pollution level of major chlorinated compounds in Lagoa Escura is very low, and considered to range among the lowest of the whole series of lakes studied. The dominant compounds are PCBs although their concentration, 1.8 µg/kg, is the lowest observed. This lake is also that showing lowest concentrations of total hexachlorocyclohexanes

Laguna Cimera (16)

Laguna Cimera was testfished on October 16, 1994, catching 48 brook trout. Age groups from one to six years was found, and the population had a relative good growth and condition factor, Figure 4.8.

Ten brook trout was sent to analyses; five for heavy metals and five for organic compounds. In the 2 to 3 year old fish , weight between 152 to 259 g, the cadmium and lead in liver ranged from 0.16 - 0.88 and 0.07 - 0.18 µg/g wet weight, respectively. Mercury in fillet ranged from 0.017 to 0.042 µg/g wet weight, see Table A7.1.

The concentrations of HCB, HCH, DDT and PCBs were analysed from five other fish, weight between 140 to 230 g, by CID-CSIC. The fish size and concentration of the different components are shown in Table A7.10.1-3. The fish had a concentration of total PCBs between 2.37 to 4.90, mean 3.73 ± 1.65 µg/kg wet weight, and between 216 to 507, mean 354 ± 181 µg/kg lipid weight, Table A7.10.1-3.

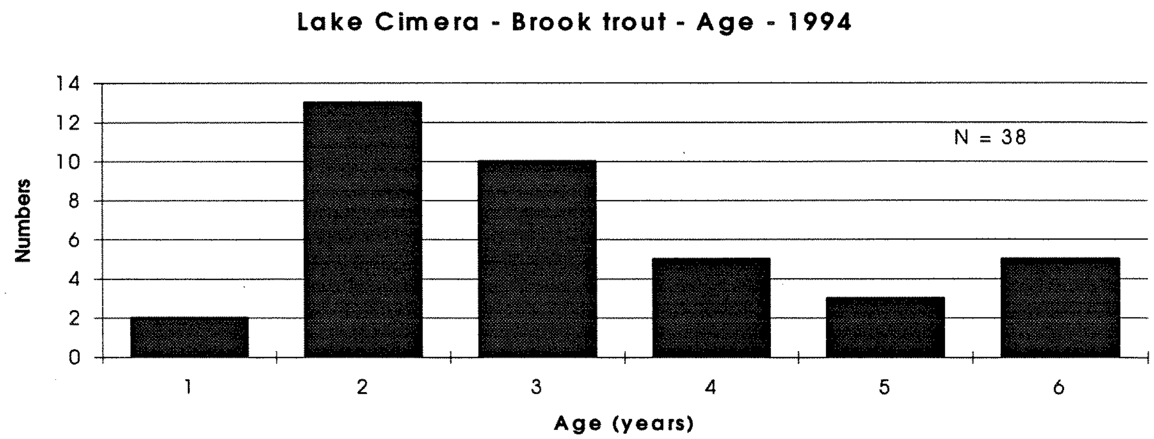
Although the concentrations of PCBs are higher in Laguna Cimera than Lagoa Escura, the two lakes range among the lowest of the whole series of lakes studied. The only exception to this trend is the relatively high amount of DDT derivatives in Lake Cimera, 14 µg/kg, which is important when compared to other AL:PE lakes (see Table A7.10.1-3).

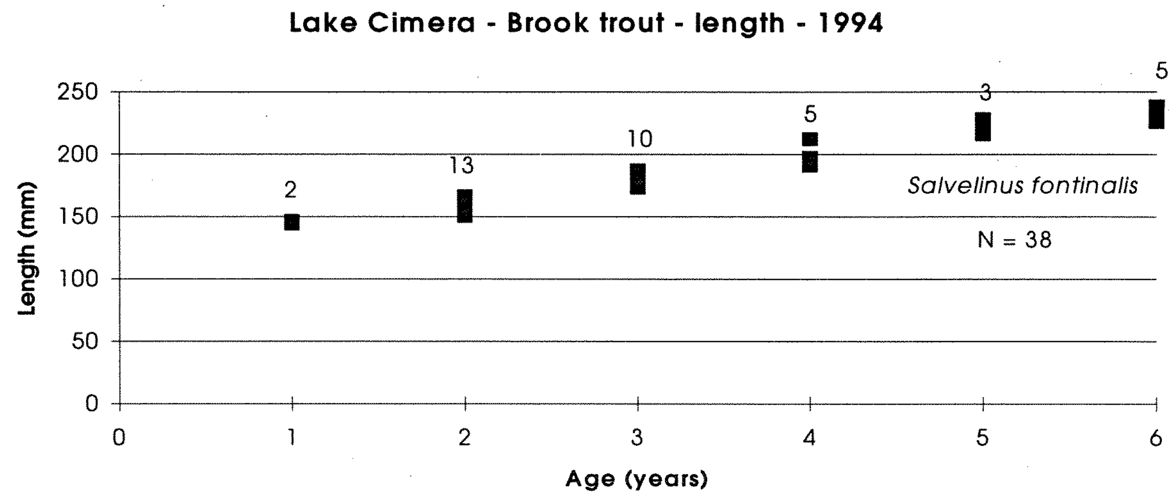
Region summary - Iberia

This region is represented by Lagoa Escura, Portugal, and Laguna Cimera, Spain. Both have introduced salmonid fish populations, rainbow trout and brook trout, respectively. The brook trout population seems to be self reproducing. Both populations have good growth conditions.

The levels of heavy metals differ in the region. Hg concentrations were among the highest of the AL:PE lakes in Lagoa Escura, while it was among the lowest in Laguna Cimera. Pb was low, and did not differ much, but Cd was highest in Laguna Cimera, exceeding the acceptable levels for human food consumption.

The concentrations of organic micropollutants in these two lakes range among the lowest of the whole series of lakes studied. The only exception to this trend is the relatively high amount of DDT derivatives in Laguna Cimera.





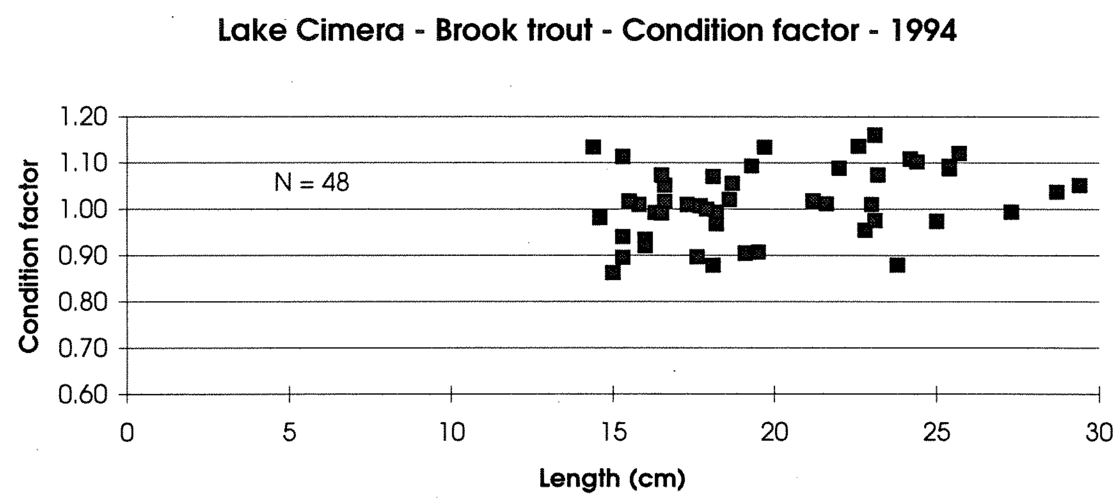


Figure 4.8 Laguna Cimera: Age of brook trout caught by testfishing in October 1994 (upper), empirical length according to age (middle), and the condition factor (below)

4.3.6 PYRENEES

Étang d'Aubé (8)

Étang d'Aubé was test fished in September 1991 as a part of AL:PE 1. Three species of fish were found; brown trout, lake trout (*Salvelinus namaycush*) and dace (*Leuciscus leuciscus*) (introduced as bait), see C.4.5. in Wathne *et al.* (1995). To sample for heavy metals and organic micropollutants, another test fishing took place between August 30 and September 2, 1994. Both floating nets and bottom gill nets were used (not standard SNSF-series), Table 4.1.

Table 4.1. Gillnets used in Étang d'Aubé in 1994.

Floating nets :

Mesh size(mm)	Length(m)	Height(m)
10	19	2
15	19	2.1
20	20	2.6
27	40	3.8
35	50	4

Bottom nets :

Mesh size(mm)	Length(m)	Height(m)
10	20	2
15	20	2
20	20	2
27	50	3
35	50	3

Three species were found, brown trout (n = 13), Arctic charr (n = 65) and minnow (*Phoxinus phoxinus*, (introduced as bait) n = 2), while only brown trout had been captured in 1991. The lake thus contains (or had contained) five species of fish. It was not possible to do proper age determination of the brown trout. Most of the Arctic charr had been stocked in 1992, as 1+, 5 - 7 cm long, and were therefore considered to be 3 years at catch in 1995. The five charr that were sent to NIVA for analyses, were determined as 5, 6, 6, 7 and 21 years of age, respectively (Table A 7.1). A re-determination of Arctic charr age by otoliths was performed by B. Riviera, CNRS, who confirmed 3 years as the correct age. The catch per unit effort (CPUE), converted from the used series to a comparative standard SNSF-series is shown in Table 4.2. In 1993, the CPUE for the three species was 8.6 (brown trout = 7.5, lake trout 1.0, dace 0.1), compared to a total of 8.38 for the three species caught in 1994. Although the CPUE was in the same range in the two years, Arctic charr was dominating in 1994, in contrast to the brown trout dominance in 1993. The condition factor (K) for the three species in 1994 were: 0.99, 1.06 and 1.35 for Arctic charr, brown trout and minnow, respectively. The comparative value for brown trout in 1993 was 1.14, slightly higher than in 1994.

Five old Arctic charr was sent to NIVA for heavy metal analyses. In the 5 to 21 year old fish, weight between 163 to 246 g, the cadmium and lead in liver ranged from 0.26 - 0.5 and 0.11 - 0.15 µg/g wet weight, respectively. Mercury in fillet ranged from 0.019 to 0.041 µg/g wet weight, se Table A7.1.

No fish was sent to CID-CSIC for analyses of organic micropollutants.

Table 4.2. The catch per unit effort, converted to a standard SNSF-series, for the three species caught in Étang d'Aubé in 1995.

Species	Number/UE	Weight/UE(g)
Salvelinus alpinus	6.81	1277.49
Salmo trutta	1.36	508.38
Phoxinus phoxinus	0.21	1.67
Total	8.38	1787.54

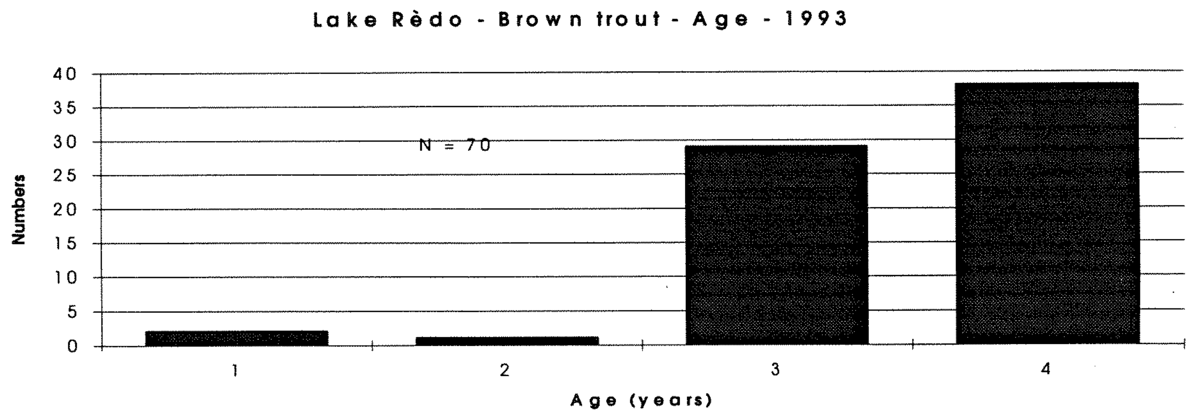
Estany Redo (12.2)

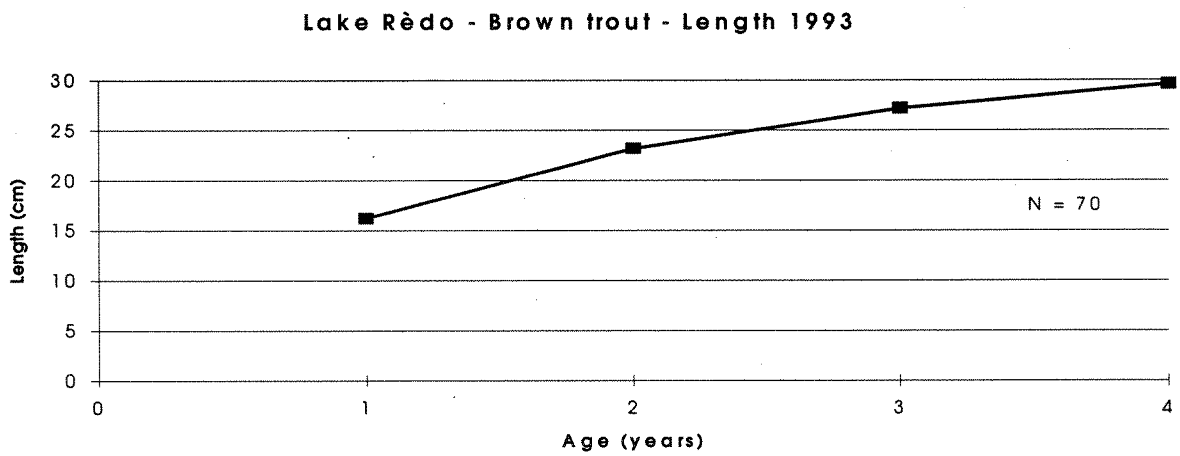
Estany Redo was testfished on October 17, 1993, and contained a population of brown trout. Fish from 1 to 4 years were represented in the material which was analysed in Spain. The five largest fish which were sent to NIVA for metal analyses, however, were six years old. The trout became recruit spawners at the age of three. The trout population showed a good growth, with a mean condition factor of 1.2 , Figure 4.9.

Ten brown trout, the largest captured, was sent to analyses; five for heavy metals and five for organic compounds. In the 6 year old trout (oldest found, not represented in the ordinary catch data, see Figure 4.9), weight between 240 to 351 g, the cadmium and lead in liver ranged from 0.57 - 0.82 and 0.10 - 0.16 µg/g wet weight, respectively. Mercury in fillet ranged from 0.05 to 0.16 µg/g wet weight, se Table A7.1.

The concentrations of HCB, HCH, DDT and PCBs was analysed from five other fish, weight between 200 to 295 g, by CID-CSIC. The fish size and concentration of the different components are shown in Table A7.11.1-3. The fish had a concentration of total PCBs between 7.82 to 12.21, mean 9.91 $\pm$ 2.31 µg/kg wet weight, and between 104 to 306, mean 215 $\pm$ 101 µg/kg lipid weight, Table A7.11.1-3.

Estany Redo is the one lake showing highest concentrations of total hexachlorocyclohexanes and hexachlorobenzene. The concentration of the former is more than one order of magnitude higher than any other concentration observed in the AL:PE series. The concentration of hexachlorobenzene is also very high when compared with most AL:PE lakes. The other chlorinated products, total DDTs and PCBs, also exhibit important concentrations, the highest in the Iberian Peninsula, but they are found even in higher levels in the fishes from other European lakes.





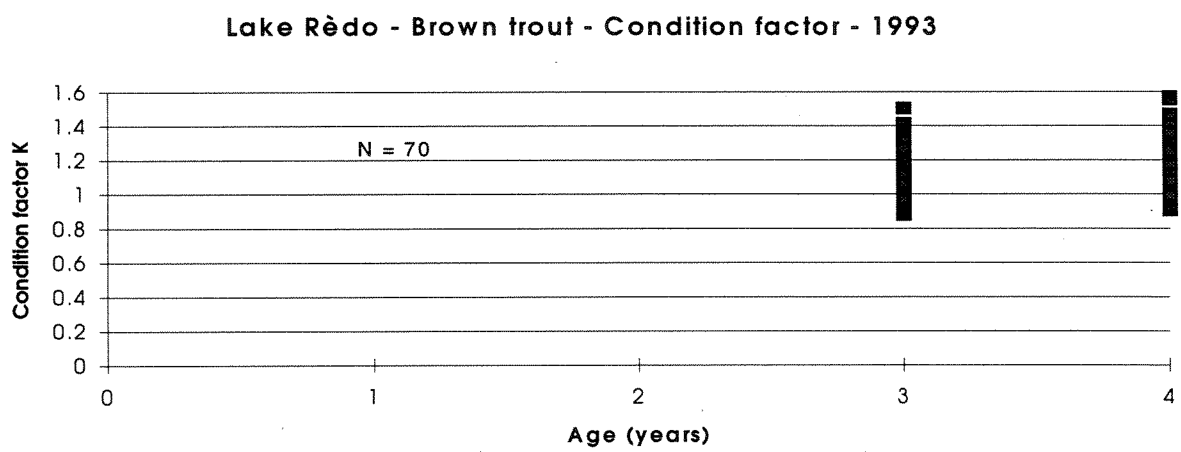


Figure 4.9 Estany Redo: Age of brown trout caught by testfishing in October 1993 (upper), empirical length according to age (middle), and the condition factor (below)

Region summary - Pyrenees

The two lakes, Étang d'Aubé, France and Estany Redo, Spain, have both brown trout populations which apparently are only selfreproducing in Estany Redo. In Ètang d'Aubè, five different species have been identified, the most abundant being the Arctic charr. Both the charr and the brown trout are dependant on stocking. However, there are clearly spawning places for charr in Étang d'Aubé. In 1994, the population of Arctic charr was 3 years old. With a natural maturation to spawners at age 5, reproduction capability will be studied in 1996. The Hg and Pb had generally low levels in both lakes. In contrast to Ètang d'Aubè, Estany Redo had higher concentrations of Cd, exceeding the acceptable limits for human food.

As for the organic micropollutants, this region is only represented by Estany Redo. The highest concentrations of total hexachlorocyclohexanes and hexachlorobenzene are found in this lake. The concentration of the former is more than one order of magnitude higher than any other concentration observed in the AL:PE series. The concentration of hexachlorobenzene is also very high when compared with most AL:PE lakes. The other chlorinated products, total DDTs and PCBs, also exhibit important concentrations but they are found even in higher levels in the fishes from other European Lakes.

4.3.7 ALPS

Lago Paione Inferiore (5.2)

Lago Paione Inferiore was testfished in August 1991 as a part of the AL:PE 1 project (Wathne et al. 1995). The lake contained a population of rainbow trout, which was kept by repeated stocking every five years. In 1991, the catches consisted of three yearclasses (1-3 years) showing good growth and a high condition factor.

In September 1994, a minor testfishing took place. Ten fish were sent for analyses; five for heavy metals and five for organic compounds. In the 3 to 5 year old rainbow trout, weighting from 185 - 313 g, the cadmium and lead in liver ranged from 0.22 - 2.37 and 0.16 - 0.42 µg/g wet weight, respectively. Mercury in fillet ranged from 0.018 to 0.045 µg/g wet weight, se Table A7.1.

The concentrations of HCB, HCH, DDT and PCBs was analysed from five other fish, weight between 147 to 262 g, by CID-CSIC. The fish size and concentration of the different components are shown in Table A7.12.1-3. The fish had a concentration of total PCBs between 1.67 to 6.45, mean 4.67 $\pm$ 2.50 µg/kg wet weight, and between 201 to 1057, mean 585 $\pm$ 376 µg/kg lipid weight, Table A7.12.1-3.

The levels of organochlorinated compounds in this Lago Paione Inferiore are low in comparison with the mean of the AL:PE series. PCBs are the major compounds.

Lago Lungo (6.1)

Lago Lungo was testfished in October 1991 as a part of the AL:PE 1 project (Wathne *et al.* 1995). The lake contained a mixed population of Arctic charr (N = 76), brown trout (N = 7) and grayling (*Thymallus thymallus*) (N = 1). In 1991, the catches of Arctic charr, yearclasses from 6 up to 27, indicated a stunted population with no growth after 10 years and having a very low condition factor. The smaller population of brown trout had good condition and good growth.

In September 1993, a minor testfishing took place. Eleven arctic charr were sent for analyses; five for heavy metals and six for organic compounds. In the 11 to 15 year old charr, weighting from 95 to 175 g, the cadmium and lead in liver ranged from 0.97 - 4.38 and 0.38 - 1.84 µg/g wet weight, respectively. Mercury in fillet ranged from 0.01 to 0.06 µg/g wet weight, se Table A7.1.

The concentration of HCB, HCH, DDT and PCBs was analysed from six other fish, weighting from 69 to 123 g, by CID-CSIC. The fish size and concentration of the different components are shown in Table A7.13.1-3. The fish had a concentration of total PCBs between 15.1 to 37.8, mean 24.7 ± 12.2 µ g/kg wet weight, and between 972 to 3183, mean 2204 ± 1096 µg/kg lipid weight, Table A7.13.1-3.

The fishes from Lago Lungo can also be grouped among those showing highest pollution for organochlorinated compounds. Total DDTs and PCBs are the most abundant compounds.

Lago di Latte (6.2)

Lago di Latte was testfished in September 1992 as apart of the AL:PE 1 project (Wathne et al. 1995). The population of Arctic charr contained yearclasses between 6 and 18 years of age, having a slow growth and a very low condition factor. In spite of good spawning conditions, occasional stockings have been practised over many years, last in 1986.

In September 1993, a minor testfishing took place. Eleven Arctic charr were sent to analyses; five for heavy metals and six for organic compounds. In the 11 to 15 year old charr, weighting from 32 to 50 g, the cadmium and lead in liver ranged from 0.91 - 5.66 and 0.44 - 2.26 µg/g wet weight, respectively. Mercury in fillet ranged from 0.03 to 0.07 µg/g wet weight, se Table A7.1.

The concentrations of HCB, HCH, DDT and PCBs was analysed from six fish, weight between 28 to 47 g, by CID-CSIC. The fish size and concentration of the different components are shown in Table A7.14.1-3. The fish had a concentration of total PCBs between 21.0 to 74.9, mean 45.7 ± 26.7 µg/kg wet weight, and between 442 to 2438, mean 1245 ± 846 µg/kg lipid weight, Table A7.14.1-3.

The fishes in Lago di Latte stand out for their high concentration of total DDTs, 200 µg/kg (Table A7.14.2-3). This levels are almost one order of magnitude higher than those observed in the lakes that are not from the Alpine sites. The PCBs also shows one of the highest concentrations, 46 µg/kg, in this lake. The concentration of hexachlorobenzene is also one of the highest in the AL:PE series.

Schwarzsee ob Sölden (11)

Schwarzsee ob Sölden is a new lake in the AL:PE 2 project. The only fish species in the lake is the Arctic charr, which have been introduced probably in the last century or even earlier. At least during the last 40 years no additional introduction and only scientific fishery activities have been performed. The exploitation rate has been recorded, showing catches like:

1968-1982: 460 specimens
1989-1994: 147 specimens

Until the beginning of the 1980's reproduction was normal but decreased around 1986. Since 1988, the reproduction has completely failed.

Due to the decreasing number of fish and their importance for a local project fishing, fishing activities performed by the University of Innsbruck could not follow the AL:PE standard. Fish where caught in July 1992, September 1992, July/August 1993 and September 1994 by gill nets and in April/May 1993 by angling. Gill nets with mesh sizes of 19 (3), 22 (3), and 25 mm (3) were exposed for 5-7 hours during daytime and checked each hour. For each sampling period 2-3 days were necessary to get at least 15 fish. In September 1992 and August 1993 also gill nets with 12, 16 and 30 mm were used and exposed over night. However, no size related fish could be caught with this trial of nets. The results from the three testfishings in 1992 are shown in Figure 4.10.

An Austrian research project on histology and physiology have been run as an additional project to AL:PE 2. Results from that special project shows that with increasing age the number of fish with severe, but sublethal pathological changes in liver and kidney, increased. This might be the main reason for the high variability of all parameters measured including growth rate.

A minor testfishing took place on September 29, 1994. Twelve fish from Schwarzsee ob Sölden were examined in Austria, five fish for Cd and Pb, and another seven fish for Hg. Another three charr were sent to CID-CSIC for analyses of organic compounds.

In five 8 to 12 year old charr, weighting from 96 - 147 g, the cadmium and lead in liver ranged from 6.27 - 21.02 and 1.02 - 3.55 µg/g wet weight, respectively (Table A7.1). Mercury in the fillet from the seven 11 to 18 year old charr, weight between 66 to 201 g, ranged from 0.0130 to 0.0477 µg/g wet weight.

The concentrations of HCB, HCH, DDT and PCBs was analysed from three fish, weighting from 79 - 123 g, by CID-CSIC. The fish size and concentration of the different components are shown in Table A7.15.1-3. The fish had a concentration of total PCBs between 14.7 to 95.6, mean 46.5 $\pm$ 43.1 µg/kg wet weight, and between 485 to 2212, mean 1061 $\pm$ 998 µg/kg lipid weight, Table A7.15.1-3.

Schwarzsee ob Sölden and Lago di Latte are those showing highest pollution within the AL:PE series. The highest concentrations of PCBs, 46.5 µg/kg, are observed here.

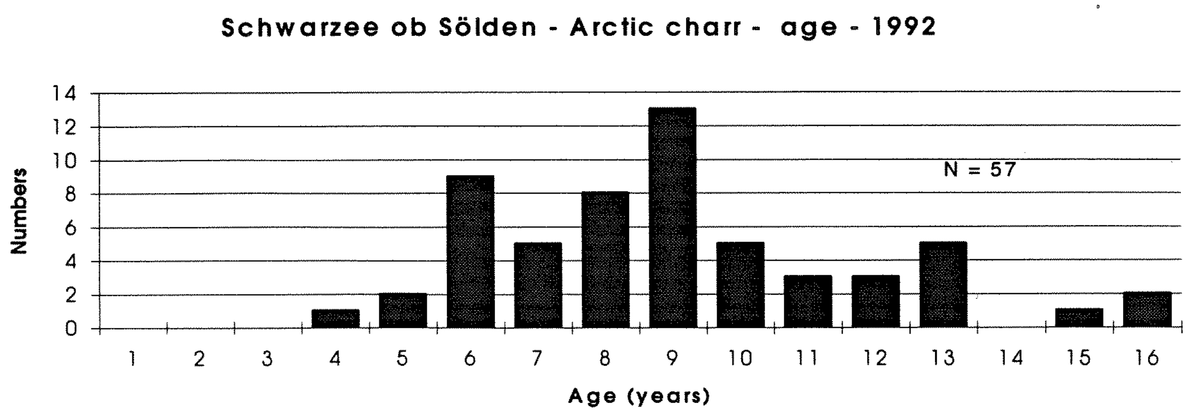
Furthermore, the lake also stands out by the high concentrations in total DDTs, 125 µg/kg, and hexachlorobenzene, 1.6 µg/kg.

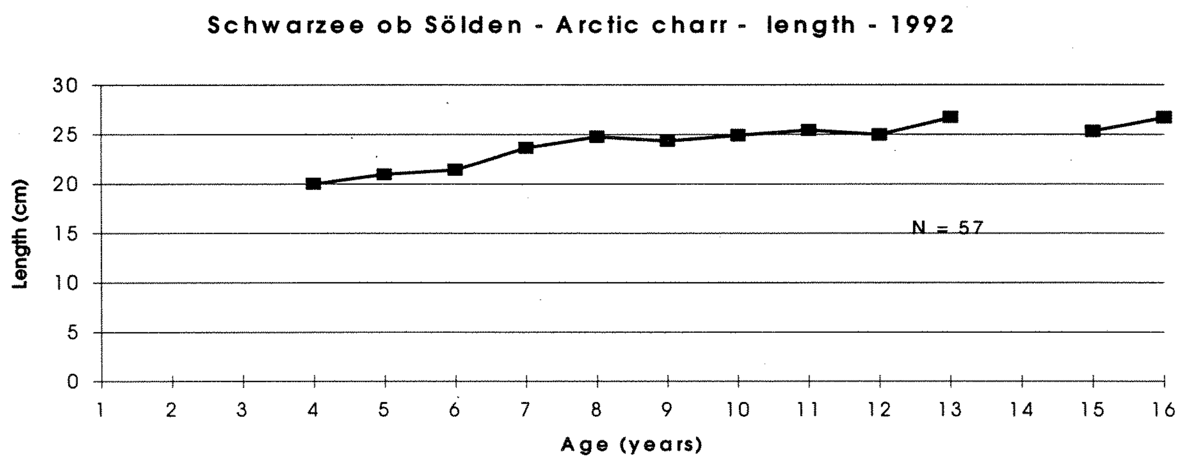
Region summary - Alps

The Alp region is represented by four lakes: Lago Paione Inferiore, Lago Lungo and Lago di Latte, Italy and Schwarzsee ob Sölden, Austria. In Lago Paione Inferiore, annual stocking of rainbow trout supply the existing fish population. In the three other lakes, Arctic charr is the main species, where Lago Lungo, as the only lake with more than one species, has a mixed population of brown trout and grayling. The fish populations in Italy are maintained by stocking, whereas the population in Schwarzsee ob Sölden is slowly depleted due to reproduction failure.

Of the heavy metals, Hg was found in low concentrations in all lakes, Lago di Latte having the highest values. Cd and Pb, on the other hand, was found in very high concentrations in all lakes, for Cd exceeding the acceptable limits for food consumption in all lakes. Schwarzsee ob Sölden had very high levels, and as the only AL:PE lake, even exceeding the acceptable limits for food consumption for Pb.

The four lakes in this region can be grouped in two parts: the western Alps (Lago Paione Inferiore) and the Tyrol (Lago di Latte, Lago Lungo, and Schwarzsee ob Sölden). A strong contrast is observed





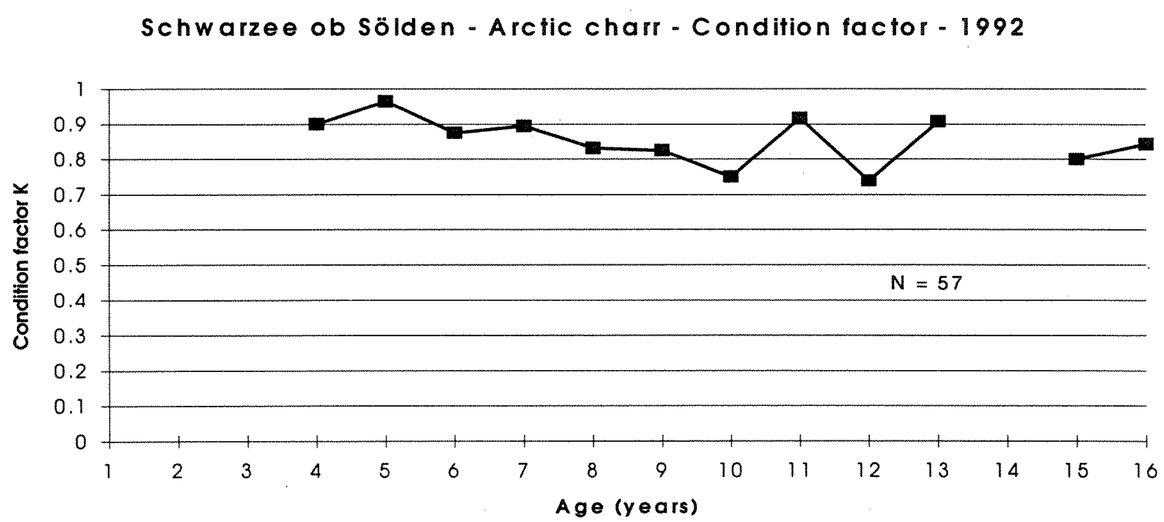


Figure 4.10 Schwarzsee ob Sölden: Age of Arctic charr caught by testfishing in July and September 1992 (upper), empirical length according to age (middle), and the condition factor (below)

between the two parts. Whereas the West Alps generally show low concentrations of organochlorinated compounds, the highest levels of PCB congeners and DDT derivatives are found in the Tyrol region. This difference is particularly important for the Tyrol area since the three lakesstudied consistently show a high pollution for these two groups of compounds. In addition, high levels of hexachlorobenzene are also found in some lakes of Tyrol (Lago di Latte and Schwarzsee ob Sölden).

4.3.8 TATRA MOUNTAINS

Dlugi Staw (15.3)

Dlugi Staw in the Polish Tatra National Park, was stocked with brook trout in 1960. No data on fish from earlier period exist. No fish management after the 1960-stocking, including test fishing, are known.

On the 9th of October, 1993, a testfishing was performed by the Karol Starmach Institute of Freshwater Biology. One standard SNSF-gillnet series was used. No fish was caught during testfishing.

Zielony Staw (15.4)

Zielony Staw in the Polish Tatra National Park has since 1948 been stocked with brook trout. After 1980, a stocking density of 600 fish/ha has been used (Dawidowicz and Gliwicz, 1983). As a management control, testfishing by the use of angling methods has been performed (Lysak and Ligaszewski, National Institute of Animal breeding, Cracow, Poland, unpublished). Whether reproduction has taken place in the lake is not known.

Zielony Staw was testfished by the Karol Starmach Institute of Freshwater Biology on October 9th, 1993 with one single net of the multimesh size SNSF-gillnet series. 23 brook trout was found, giving a CPUE of 150 fish. Of the 23 brook trout, only data from 12 fish exist. Age analyses by scales (not recommended age determination method for brook trout) demonstrated yearclasses between two and six years. The growth was good up to the age of 4, thereafter decreasing. In spite of a reduced growth for the older fish, a very good condition factor was found ($K > 1.2$), Figure 4.11.

To sample fish for heavy metals and organic micropollutants, another testfishing with the same fishing effort as in 1993 took place in October 1994. Three species of fish were found; twelve brook trout, eleven brown trout and two hybrids between brown and brook trout, giving, a total CPUE of 181. The previous stocking of brown trout was not known to the Park Management.

The brook trout consisted of the same age classes as the previous year (2-6 years), Figure 4.11. A better growth of the two and three year old charr was found, and a reduced condition factor was found in the oldest yearclasses, Figure 4.11.

The age determination of the brook trout have been performed in Poland by the use of scales. This method, however, is not recommended for age determination of charr in general, see sampling protocol for AL:PE 1, Wathne *et al.* (1995). The five brook trout which were sent to NIVA for heavy metal analyses, had an age, based on otoliths, between 6 and 12 years (Table A7.1). Data from Poland, however, are used in the following, including Figure 4.11 and 4.12, but the representativity of this data are thus questioned.

The population of brown trout consisted of three yearclasses (1-3 years). The growth and condition factor was very similar to the brook trout population caught in 1994 (Figure 4.12).

The two hybrids of brown and brook trout, were one and two years old, respectively. The length, weight and condition factor was 10.5 and 18.8 cm, 9 and 16.5 g and K = 1.04 and 0.98, respectively.

Five brook trout was analysed both for heavy metals and organic micropollutants. In the 6 to 12 year old charr, weighting from 119 - 201 g, the cadmium and lead in liver ranged from 0.63 - 2.14 and 0.11 - 0.31 µg/g wet weight, respectively, Table A7.1. Mercury in the fillet from the same charr ranged from 0.016 to 0.037 µg/g wet weight.

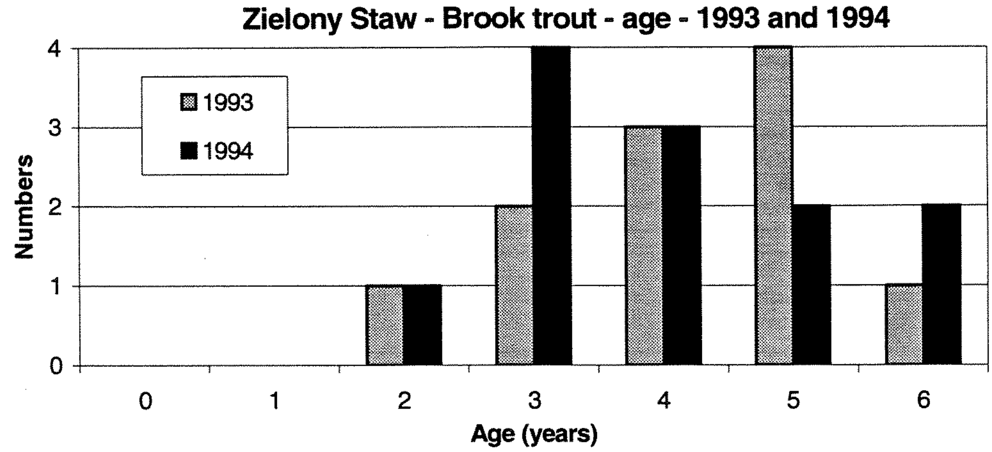
The concentrations of HCB, HCH, DDT and PCBs were analysed by CID-CSIC from the same five brook trout that were used for heavy metals, fish weight between 119 to 202 g. The fish size and concentration of the different components are shown in Table A7.16.1-3. The fish had a concentration of total PCBs between 5.86 to 12.26, mean 7.49 ± 3.58 µg/kg wet weight, and between 311 to 1077, mean 540 ± 342 µg/kg lipid weight, Table A7.16.1-3.

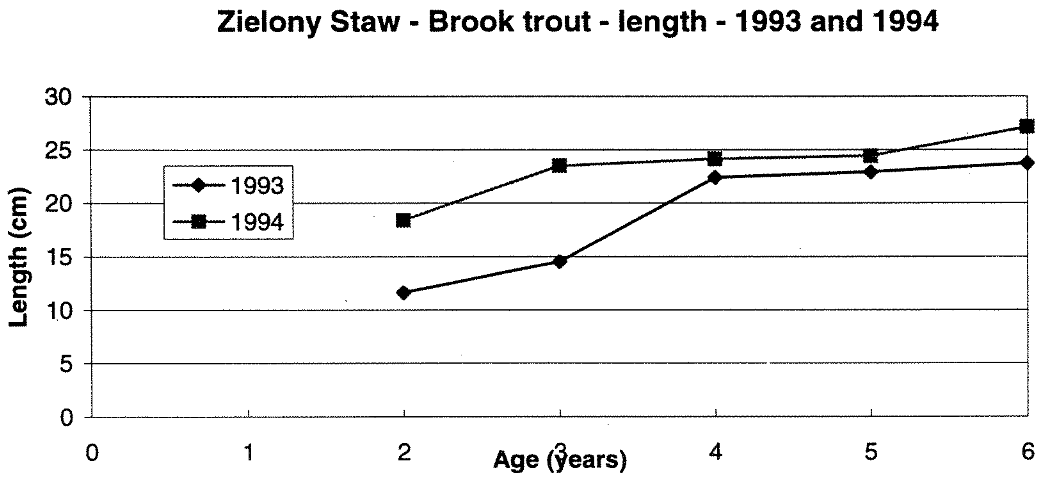
The concentrations of organochlorinated products in Zielowny Staw are relatively low. Total DDTs, 9.1 µg/kg, are the major products. The levels of PCBs are also significant, 7.5 µg/kg. This lake, however, has the lowest concentrations of hexachlorobenzene.

Regional summary - Tatra Mountains

Only one of the two studied lakes was found to contain fish, Zielony Staw. By a repeated testfishing (1993 and 1994), the lake was found to contain two species of salmonids, brook trout and brown trout. The latter was found for the first time in 1994. The brook trout population is old, having yearclasses up to 6 (determined in Poland) or 12 (determined in Norway) years.

Of the heavy metals, only Cd was found in high concentrations, exceeding the limits for human food consumption. The concentrations of organochlorinated products are relatively low. DDT derivatives are the major products. The levels of PCBs are also significant. This lake is, however, showing the lowest concentrations of hexachlorobenzene.





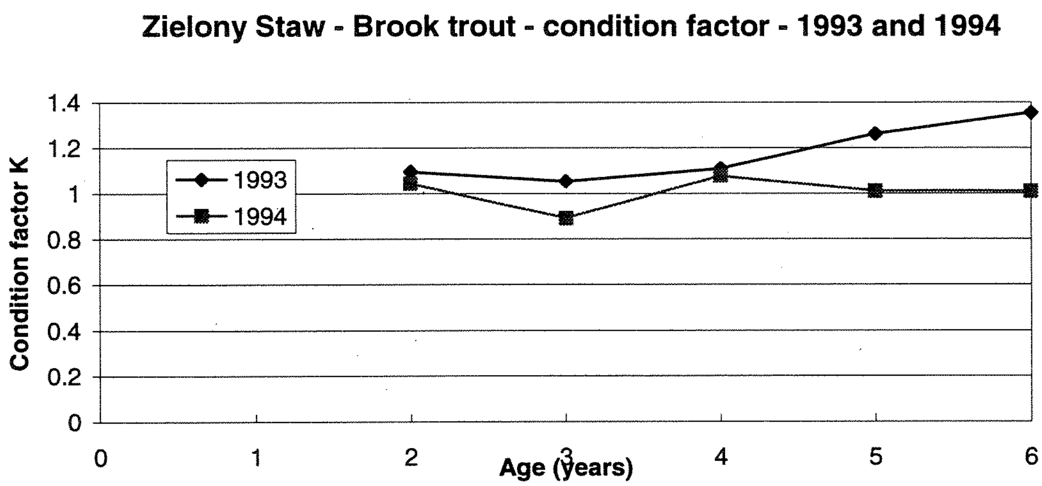


Figure 4.11. Zielony Staw: Results of testfishing in 1994 and 1993, showing the age of the population of brook trout (upper), empirical length according to age (middle), and the condition factor (below).

Figure 4.12. Zielony Staw: Results of testfishing in 1994, showing the age of the population of brown trout (upper), empirical length according to age (middle), and the condition factor (below).

4.4 REGIONAL HEAVY METAL CONCENTRATIONS IN FISH

4.4.1 Concentration levels

The 68 fish which were sent frozen to NIVA, and examined for Cd and Pb from liver and Hg from fillet, were caught in 15 AL:PE lakes. Five fish were analysed from each locality except Lagoa Escura (3). Fish from Schwarzsee ob Sölden were examined in Austria (five fish for Cd and Pb, and another seven fish for Hg). Four different species of fish were identified in the 15 lakes:

Brown trout:	Øvre Neådalsvatn, Stavsvatn, Lochnagar, Lough Maam, Estany Redo
Arctic charr:	Arresjøen, Lago Lungo, Lago di Latte, Ètang d'Aubè, Schwarzsee ob Sölden, Chibiny
Rainbow trout:	Lago Paione Inferiore, Lagoa Escura
Brook trout:	Zielony Staw, Laguna Cimera

The concentrations of Cd, Pb, and Hg in the fish from the different AL:PE sites are shown in Figure 4.13 - 4.16. The Figs. 4.13, 4.14 and 4.15 for Cd, Pb, and Hg respectively are given with no adjustments for differences in fish parameters. Fig 4.16 shows the concentrations of Hg adjusted for differences in fish length, and normalised to a fish length of 27 cm for all sites.

Significant differences were seen for Cd, Pb, and Hg between several lakes: low concentrations of Cd were observed in Lake Chibini, Øvre Neådalsvatn, and Lagoa Escura, and low concentrations were also observed of Pb in Øvre Neådalsvatn, Lake Chibini and Arresjøen.

The highest concentration of Cd were seen in Schwarzsee ob Sölden followed by Lago di Latte, Lago Lungo, and Lochnagar. The highest concentrations of Pb were also seen in the same sites and in the same sequence.

The lowest concentrations of Hg were registered in Øvre Neådalsvatn, Zielony Staw, Lago Paione Inferiore, Laguna Cimera and Étang d'Aubé, while the highest concentrations of Hg were found in Arresjøen, and Lagoa Escura. Regarding Hg concentrations, minor changes within classification of fish contamination was introduced by the use of fish length adjustment (compare Fig. 4.15 and 4.16).

Acceptable limits for Hg in fillet, and Cd and Pb in liver for human food consumption are set to 0.3, 0.5 and 2.0 µg/g wet weight respectively (JMG 1990 a, b, 1995). The concentrations of Hg and Pb were below these acceptable limits for human consumption in all of the AL:PE sites except for Schwarzsee Ob Sölden (Pb = 2.3 µg/g). Cd was too high for most of the sites, except in lakes Øvre Neådalsvatn, Lough Maam, Lagoa Escura, Étang d'Aubé and Lake Chibini.

The concentration of the metals Hg, Pb, and Cd are arranged according to geographical positions of the AL:PE sites and according to accumulations of the metals in the fish (Fig 4.17.). The geographical distributions are quite pronounced, and Hg seems to have the highest concentrations in the western localities close to the Atlantic ocean. The highest contamination's appeared in Arresjøen (Svalbard) and Lagoa Escura (Portugal). Values are also quite high in the Irish Lough Maam.

Pb showed low concentrations in the northern sites, higher values in the western localities, and the highest figures in the central, south-east Europe (Fig. 4.17). Cd shows more or less the same pattern as

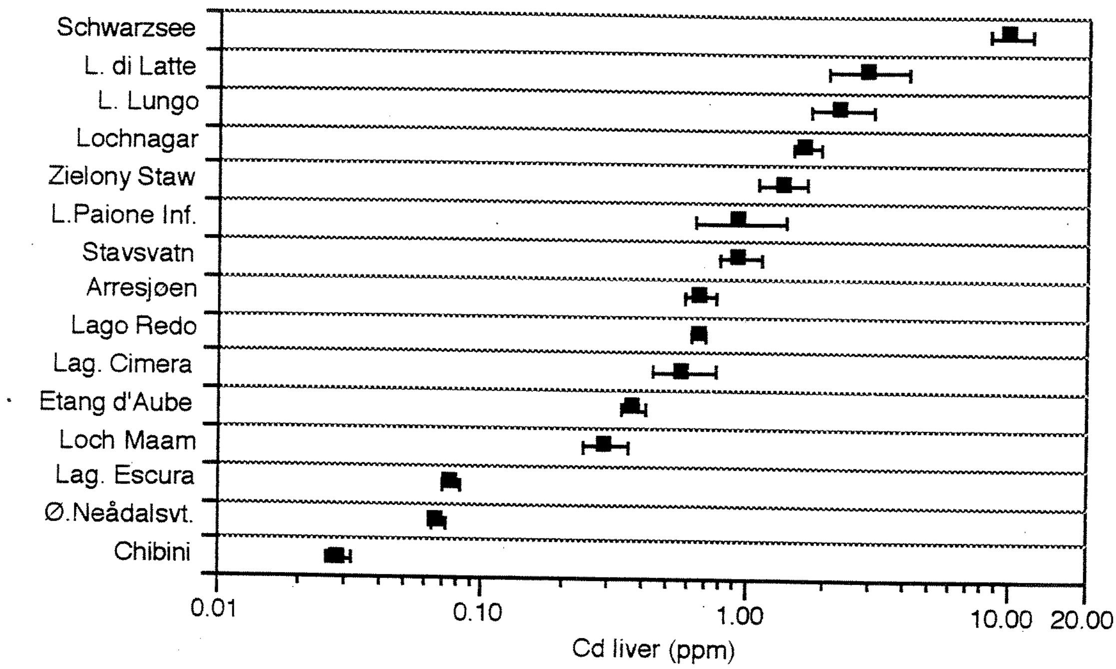


Figure 4.13. Concentrations, +/- std.error, of Cd in fish liver from the various AL:PE sites with no adjustment for differences in fish parameters.

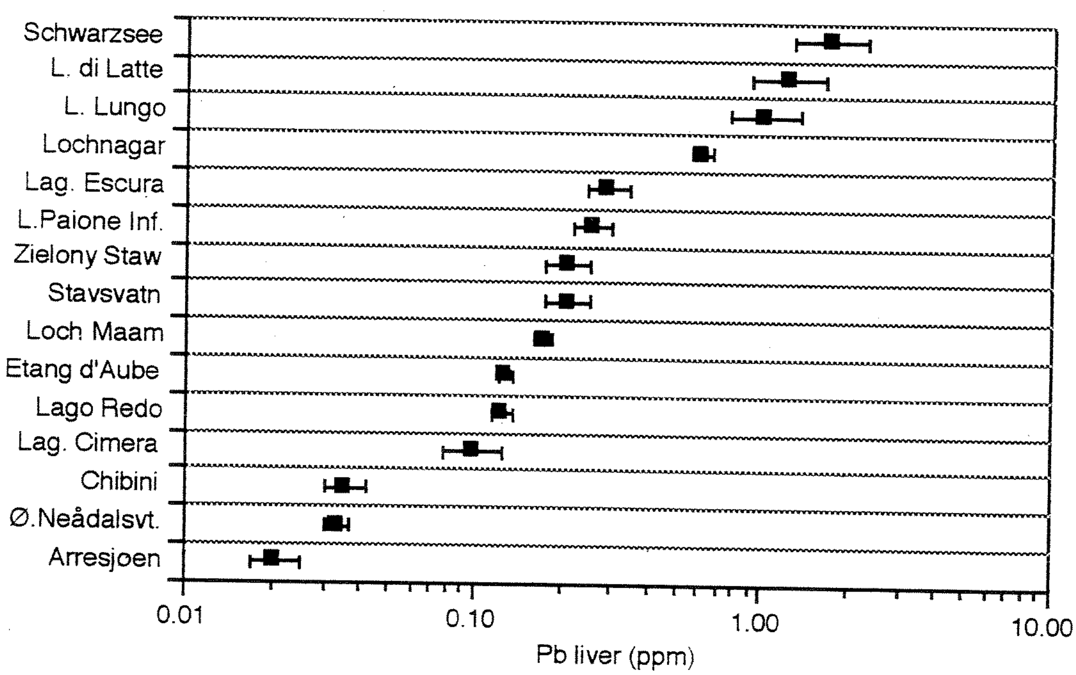


Figure 4.14. Concentrations, +/- std. error, of Pb in fish liver from the various AL:PE sites with no adjustment for differences in fish parameters.

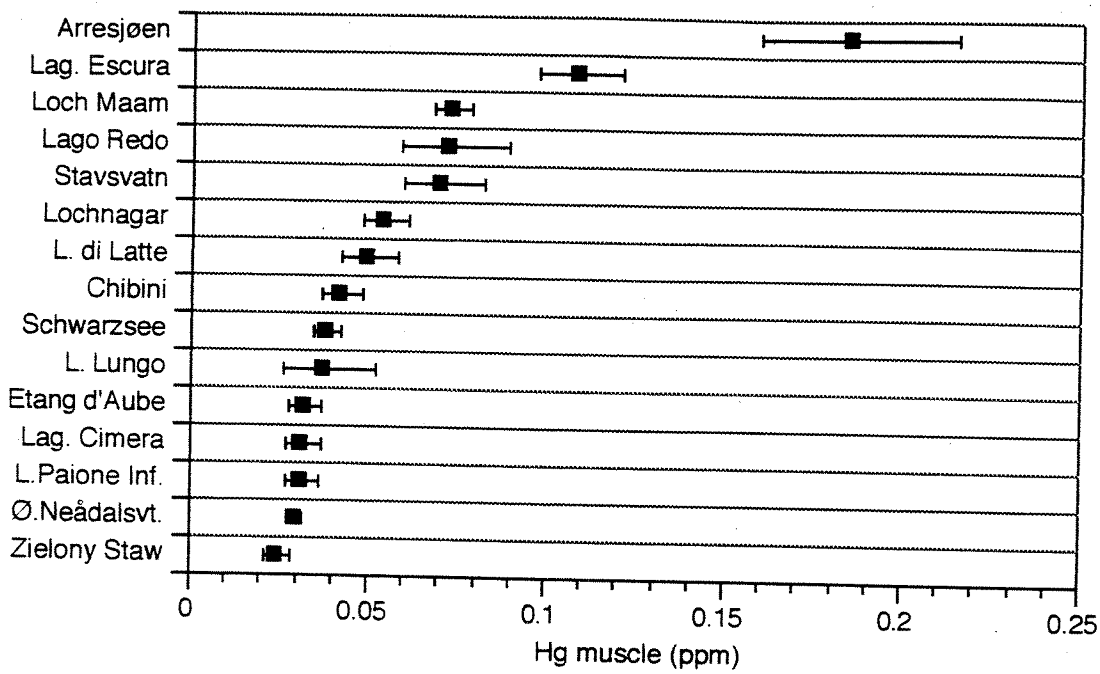


Figure 4.15. Concentrations, +/- std. error, of Hg in fish fillet from the various AL:PE sites with no adjustment for differences in fish parameters.

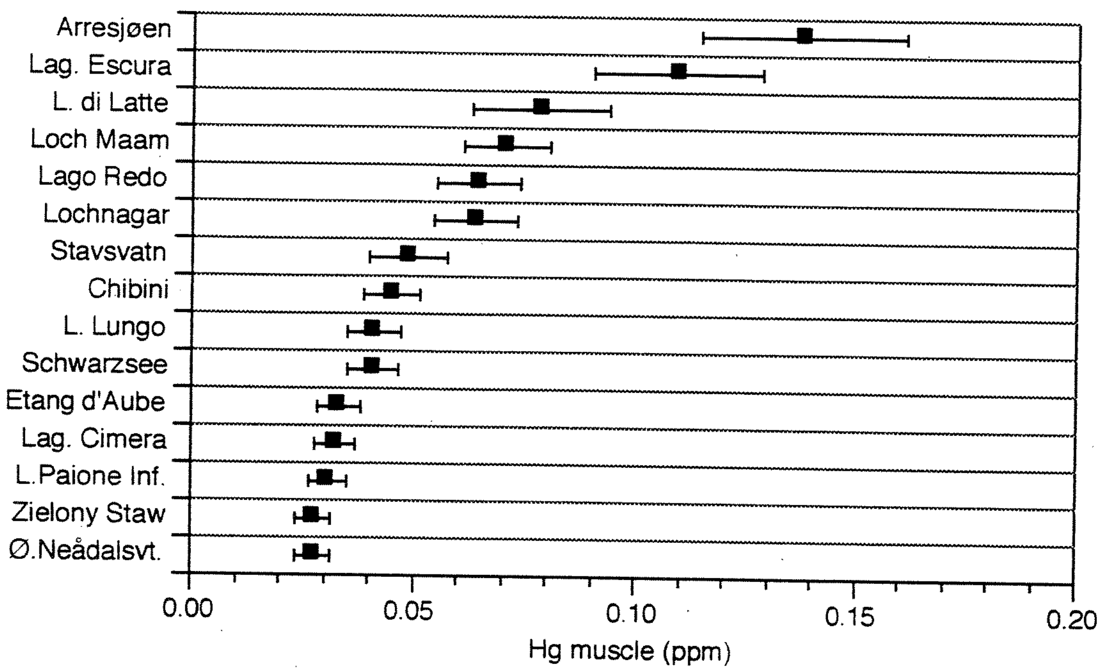
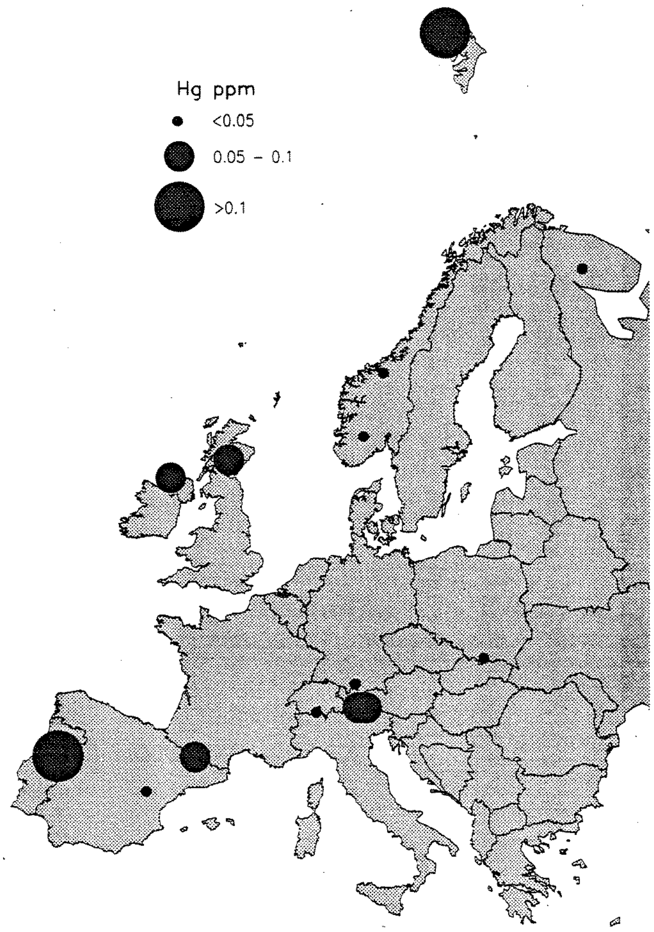
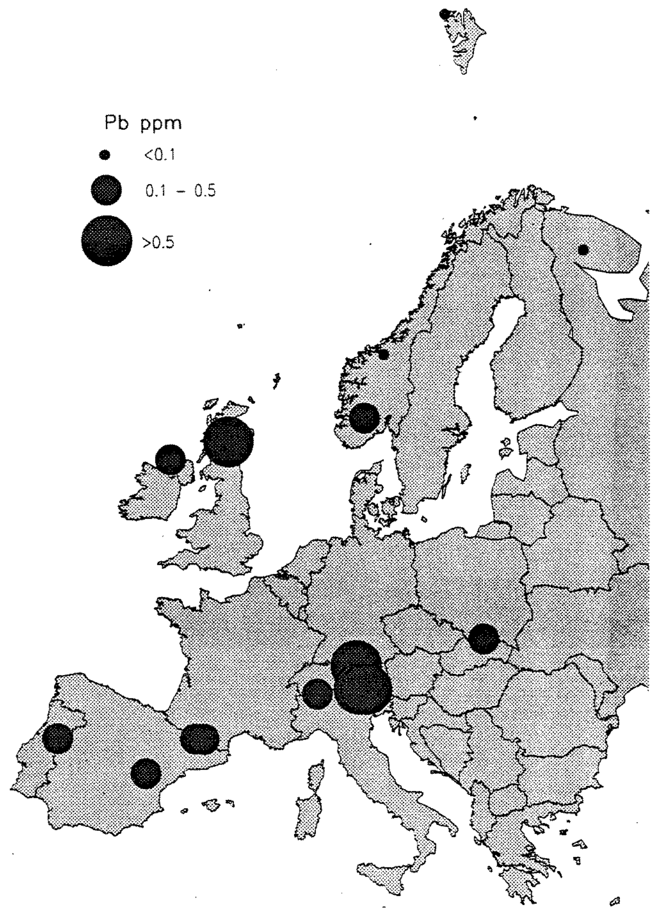


Figure 4.16. Concentrations, +/- std. error, of Hg in fish fillet from the various AL:PE sites with adjustment for differences in fish length (standard length 27 cm).





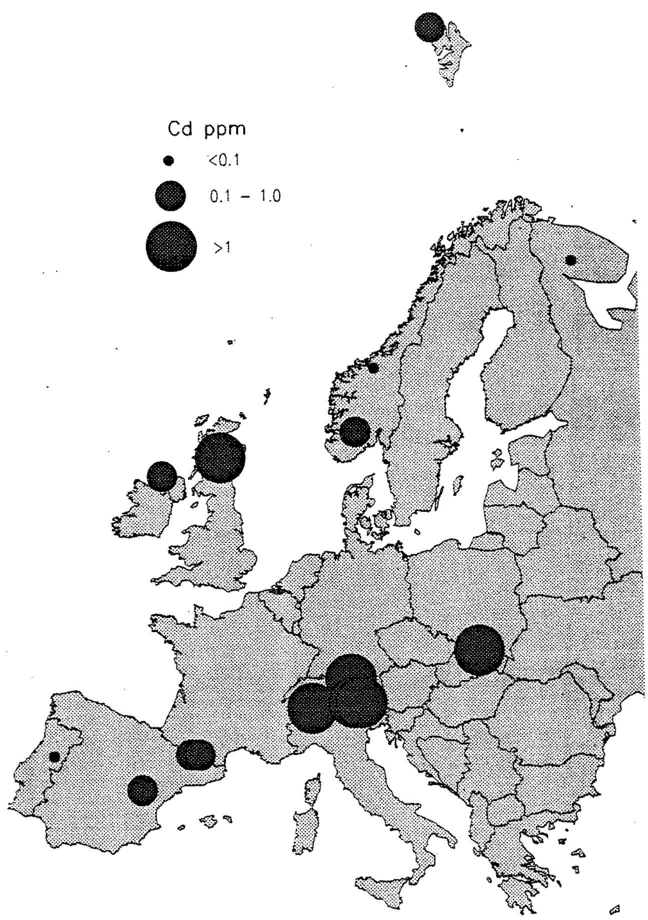


Fig. 4.17. AL:PE 2 sites examined for Hg, Pb and Cd in fish. The concentrations of metals are arranged according to geographical positions and according to accumulations of the metals. For Hg and Cd, the two largest circles represents values higher than expected background levels. For Pb, only half of the largest circles represents values exceeding background levels.

for Pb, but with generally higher concentrations, especially compared to acceptable limits for human consumption. Both for Pb and Cd, the concentrations in Lochnagar (Scotland) were higher than expected from its geographical position. Øvre Neådalsvatn showed the lowest or second lowest values for all three metals. This site is therefore also well suited as a reference locality concerning accumulation of heavy metals in fish.

4.4.2 Statistics

Statistical analyses demonstrated that for some of the lakes, correlation existed between fish size (length, age, weight) and concentrations of Cd and Pb. For the whole material, no significant correlation was identified between the measured fish parameters and concentration of Cd and Pb. For Hg, a correlation was seen between the size (length, age) of the fish and the Hg concentrations for the whole material. However, site identity demonstrated the strongest controlling variable for the examined heavy metals in fish.

Principal components analysis showed high covariance for Cd and Pb (e.g. high concentrations of Cd and Pb in the same lake), but no covariance with Hg.

The first principal component explains 64.9% of the total variance in the heavy-metal concentrations and the second component a further 32%. A total of 96.9% variance is captured by the two PCA axes. In Figure 33 the position of the individual fish samples are shown in relation to the three heavy-metal variables (biplot arrows) and the lakes from which the fish samples were collected. Figure 4.18 shows a clear contrast between PCA axis 1 with high correlations with Pb (0.97) and Cd (0.97) and PCA axis 2 with a high correlation (0.96) with Hg. These patterns are shown in Figures 4.19 - 4.21 where the concentrations of Pb, Cd, and Hg are plotted for the individual fish samples,with the size of the symbol being proportional to the concentration and the different type of symbol reflecting the different lakes as in Figure 4.18.

It is clear that above-average Pb and Cd values occur consistently in fish from Schwarzsee ob Sölden, Lago di Latte, and Lago Lungo, whereas above-average Hg concentrations are found in fish from Arresjøen, Estany Redo, Lagoa Escura, Stavsvatn, Lough Maam, and Lochnagar. All the lakes with above average Hg concentrations are along the western part of the AL:PE project (Portugal, Spain, Ireland, Scotland, southern Norway, Spitsbergen).

The results of the (partial) RDA are shown in Table A.7.17 in terms of the different predictor and covariables used in each analysis, the total variance in the heavy metals explained by the predictor variables, and the statistical significance of the overall model. All the predictor variables explain 83.8% of the total variance in the heavy-metal concentrations whereas locality by itself explains 78.2%. When the effects of the different fish species sampled are partialled out, the percentage variance explained by locality falls to 66.2%. This drops to 48.3% when the effects of fish species, sex, growth stage, and age are partialled out. The addition of fish length and weight as covariables reduces the percentage variance explained by locality very slightly to 44.6%. All the RDA and partial RDA are statistically significant with $p = 0.0004$.

These results indicate that although variables such as fish species, sex, age, length, weight, and growth stage explain, in a statistical sense, some of the observed variation in the heavy-metal concentrations, there is still a highly significant relationship between lake locality and heavy-metal concentrations, even when the effects of other variables are allowed for statistically.

Results of a partial PCA where the effects of fish species, sex, growth stage, age, length, and weight are removed statistically and a PCA done of the residual variation in the heavy-metal concentrations not explained by these biological variables show that 95.9% of this residual variation (0.61) is represented by two partial PCA axes (axis 1 = 69.7%, axis 2 = 26.2% of the total residual variance). The partial PCA results (Figures 4.18 - 4.21) with a major contrast between Pb and Cd and Hg on axes 1 and 2. The relationship between above-average Pb and Cd concentrations in fish from lakes in Austria and Italy and between above-average Hg concentrations in fish from lakes in western and northern areas persists. Interestingly one can now identify which lakes have fish with above-average Pb, Cd, and Hg concentrations after the effects of fish age, species, etc. have been partialled out (Figures 4.23 - 4.25). These are the lakes in the upper-right quadrant of Figure 4.22 and are Arresjøen, Lagoa Escura, Stavsvatn, Lochnagar, Lago di Latte, Zieloni Staw, and Schwarzsee ob Sölden.

4.4.3 Conclusions

The numerical analyses of heavy-metal concentrations in fish from 15 AL:PE lakes show the strong contrast in the type of heavy metals between lakes in Italy and Austria with high Pb and Cd values and lakes in northern and western Europe with high Hg concentrations.

There are several explanations to the observed accumulation of heavy metals in this fish. Some metals are partly taken up by the fish directly from the water, other elements enter the fish mainly by food uptake. The metals could be transported at long distance by air from industrial areas to these remote AL:PE localities. Some metals might also originally be present in the bedrock of these AL:PE catchments. The acid precipitation of the last century increase the solubility and the washing out of metals from the catchments into the lakes and their sediments. Analyses of metals through sediment cores would also confirm higher metal concentrations in the upper (recent) layers compared to lower (older) layers, stating the increasing contributions over the last decades. Elevated metal concentrations in lower (older) sediment layers may indicate local supply of metals. However, the direct airborne transport of metals into the catchment, or the washing out of metals from the catchments due to acid rain, are expected to be the main source for accumulation in fish in remote areas.

Without any air transport of Hg, Cd, or Pb, nor any marked leakage of these elements from the catchments of the AL:PE sites, the accumulations of these elements in the fish were expected to be: Hg (fillet) 0.01 - 0.05 ppm, Cd (liver) 0.03 - 0.3 ppm, and Pb (liver) 0.02 - 0.2 ppm (Grande 1979, Rognerud & Fjeld 1991). Six AL:PE lakes showed higher concentrations for Hg than expected (see Fig. 4.17 for Hg, filled and half filled circles). For Pb, one half of the lakes had higher accumulation than the expected background values, and only three of the lakes showed values below expected concentrations for Cd (see Fig. 4.17 for Cd, open circles). It is not likely that all of these contaminated sites release all these elements from their catchments, and certainly not without any acid precipitation. It is therefore reasonable to believe that many of these sites also receive air transported Hg, Cd, and Pb.

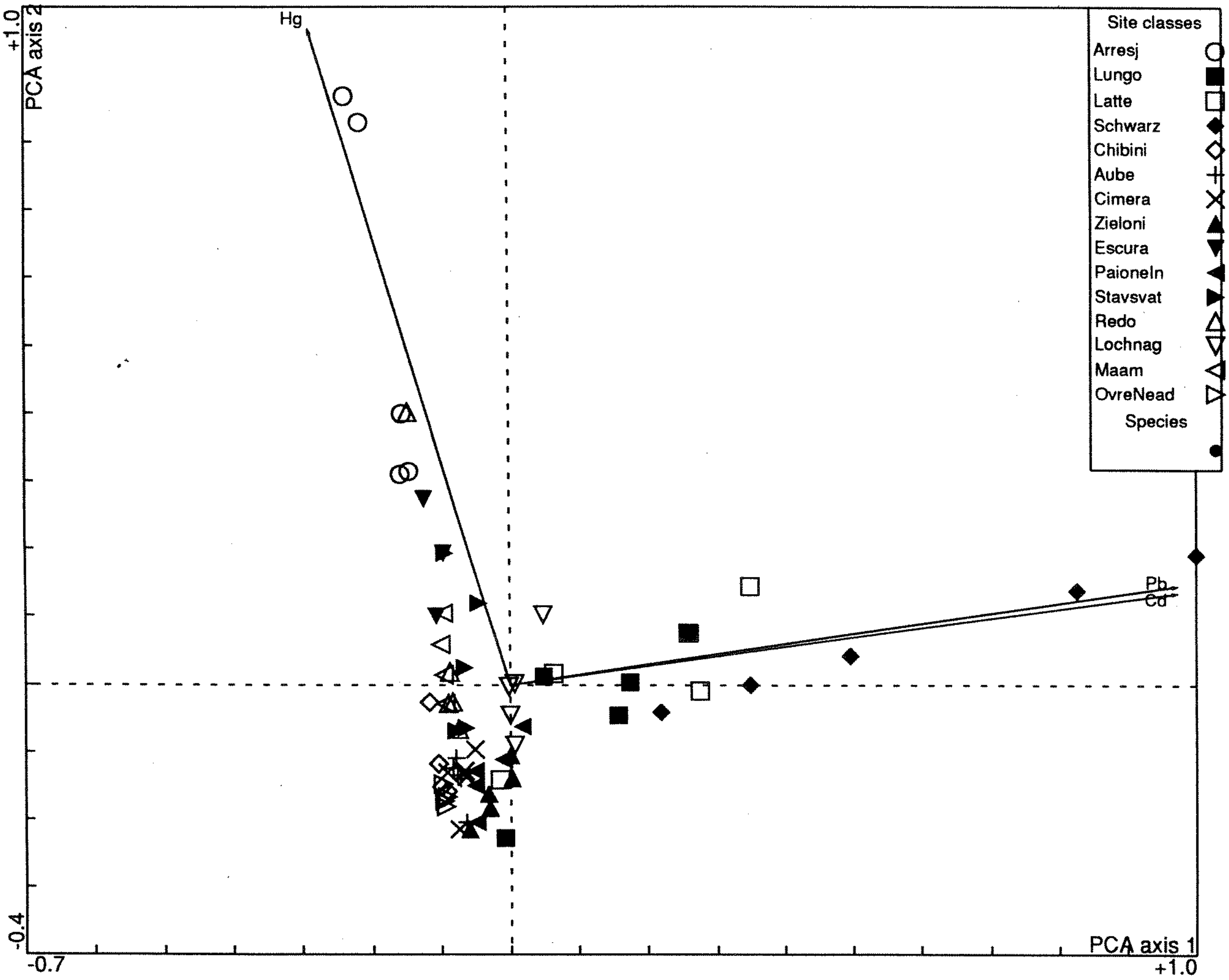


Figure 4.18. Position of individual fish samples on PCA axes 1 and 2 in relation to the correlation biplot arrows for Pb, Cd, and Hg. The 73 samples are coded by lake. The variable scores are variance adjusted.

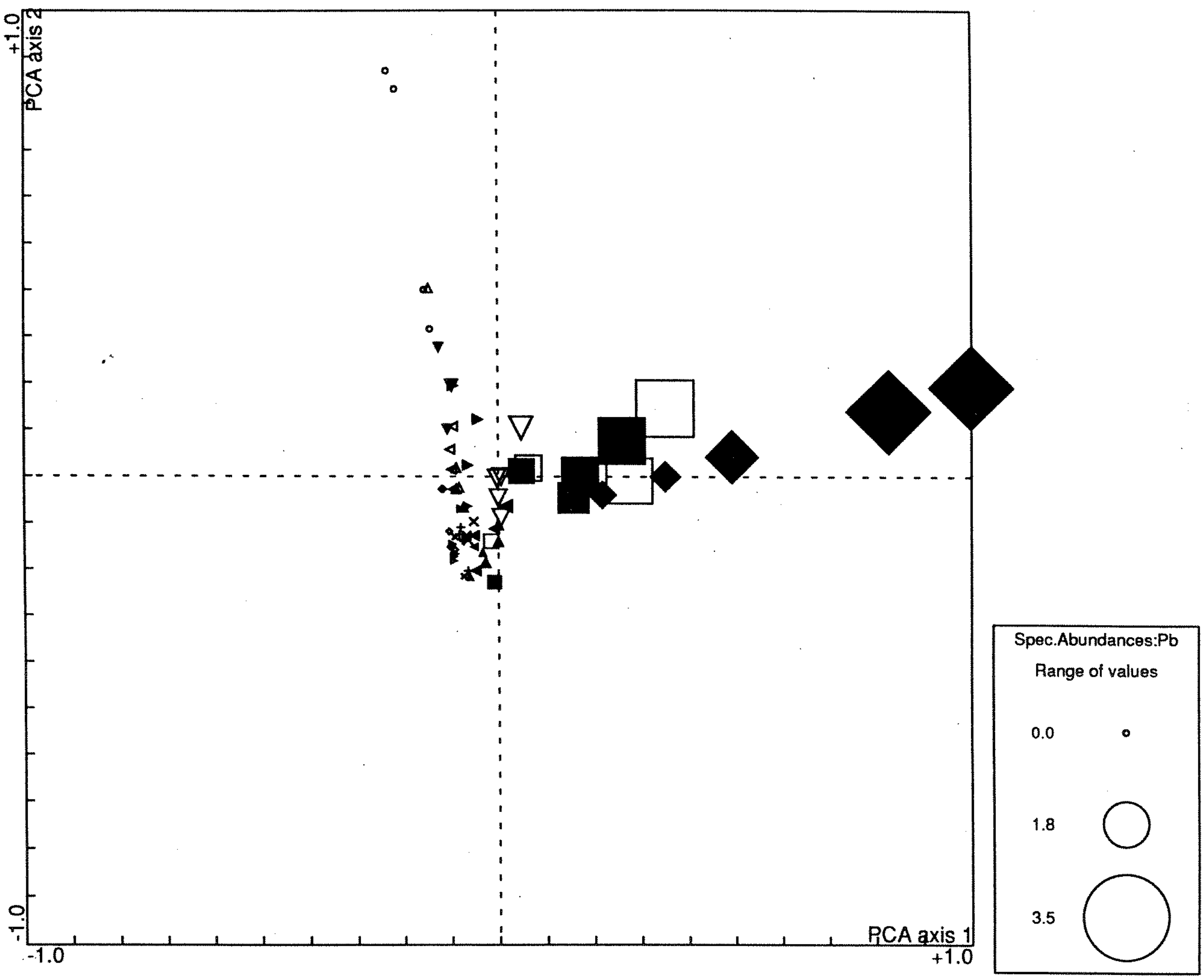


Figure 4.19. Pb concentrations in individual fish samples on PCA axes 1 and 2. The 73 samples are coded by lake (Figure 4.18).

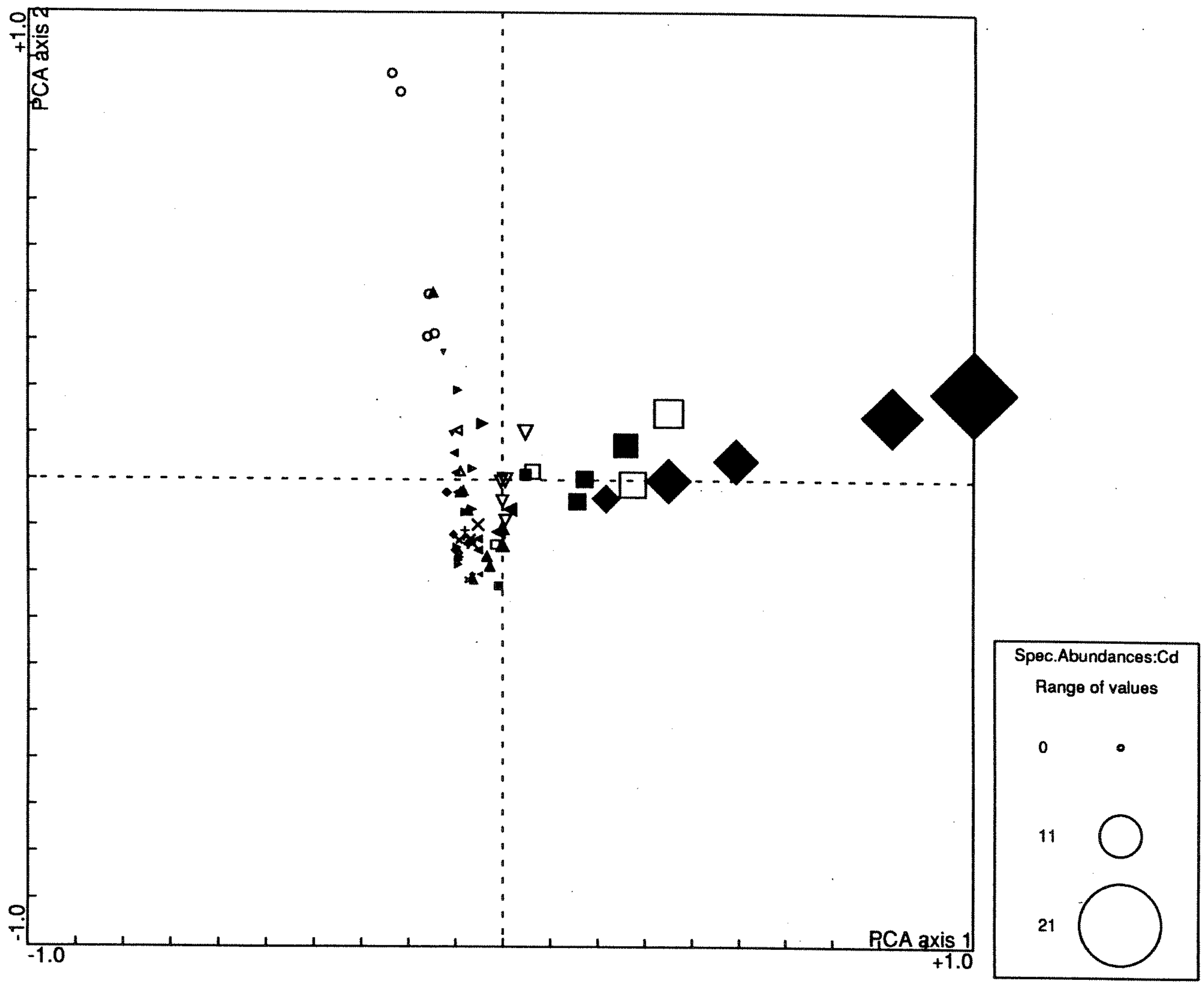


Figure 4.20. Cd concentrations in individual fish samples on PCA axes 1 and 2. The 73 samples are coded by lake (Figure 4.18)

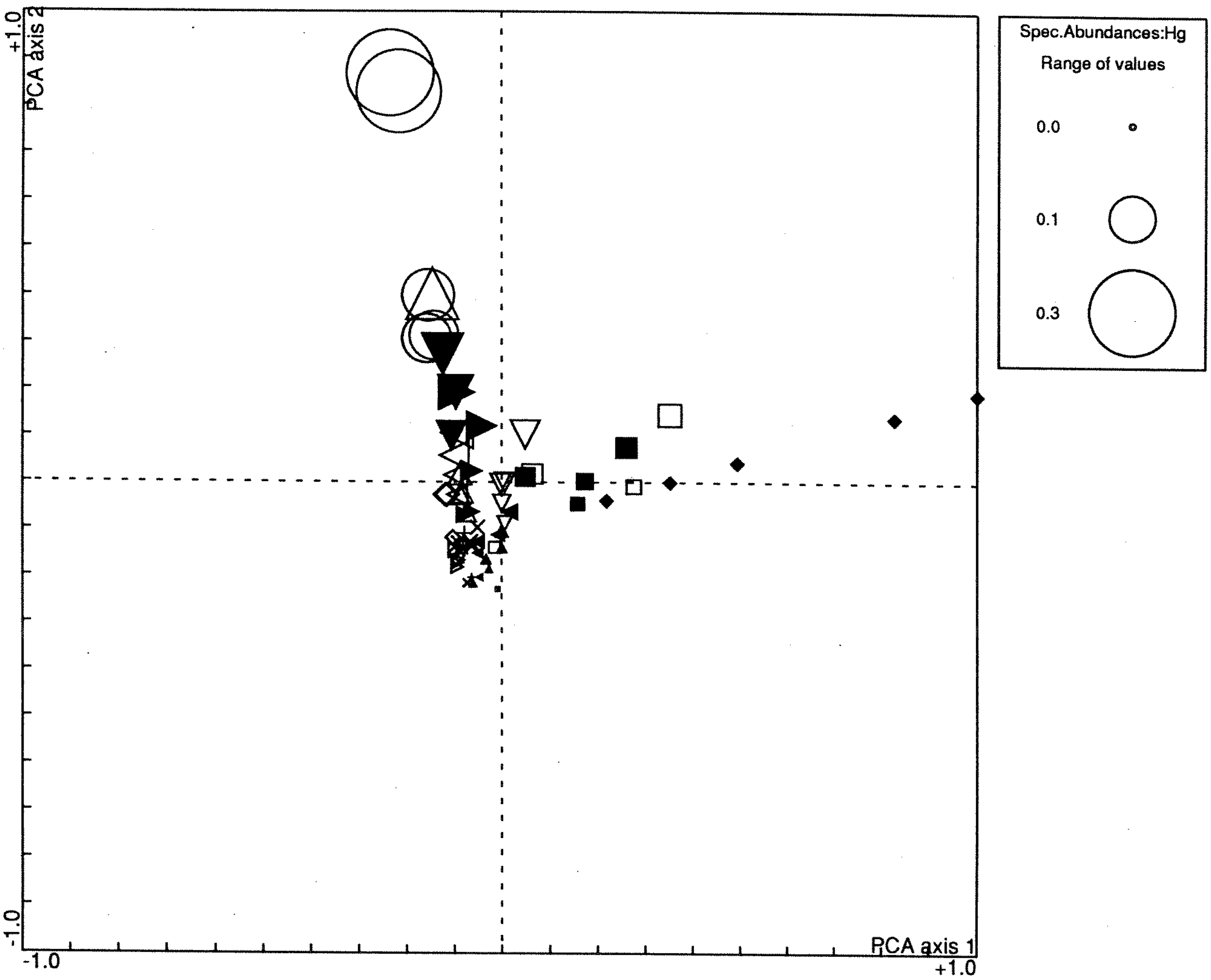


Figure 4.21. Hg concentrations in individual fish samples on PCA axes 1 and 2. The 73 samples are coded by lake (Figure 4.18).

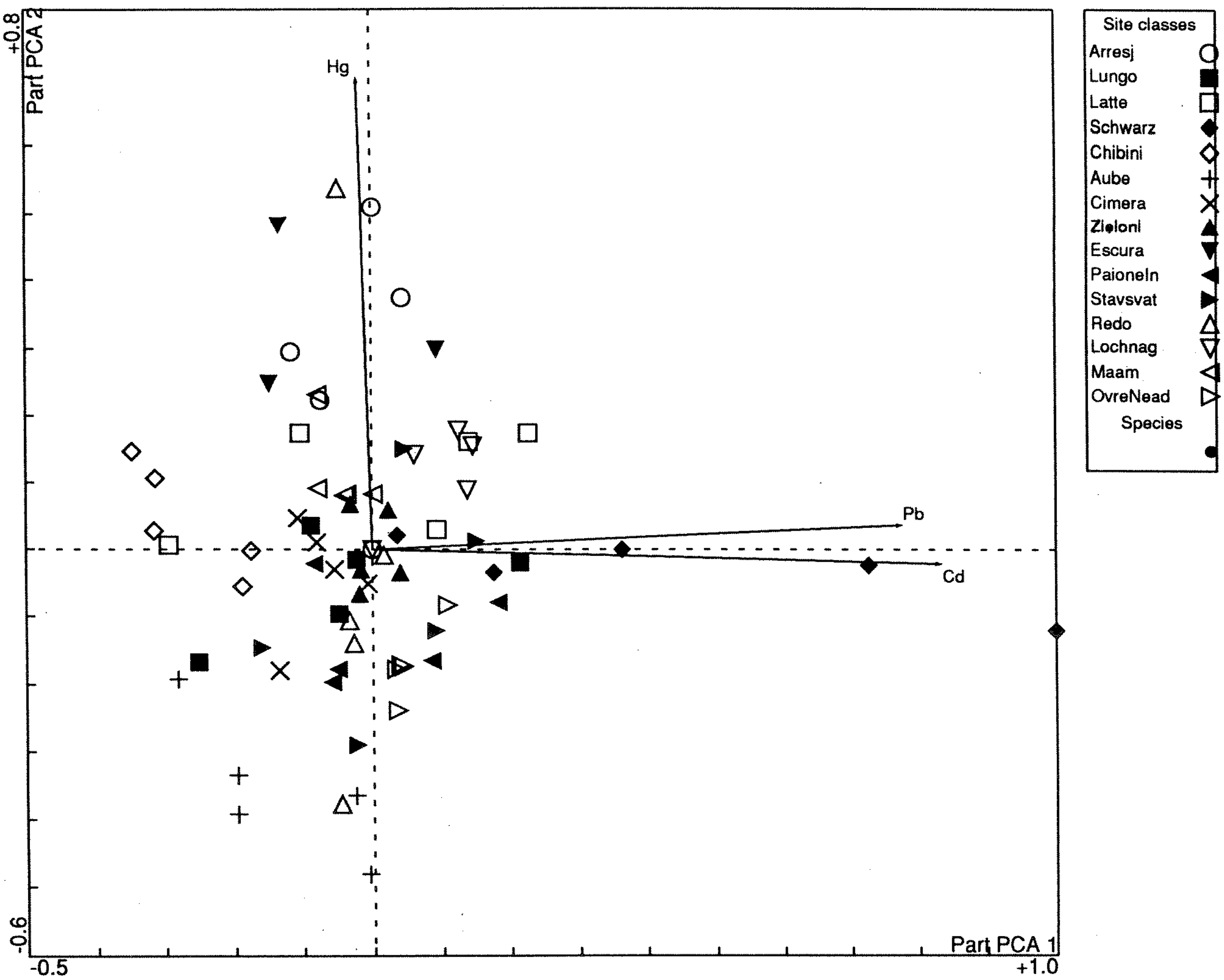


Figure 4.22. Position of individual fish samples on partial PCA axes 1 and 2 in relation to the biplot arrows for Pb, Cd, and Hg. The 73 samples are coded by lake. In the partial PCA the effects of fish sex, species, age, length, weight, and growth stage have been partialled out.

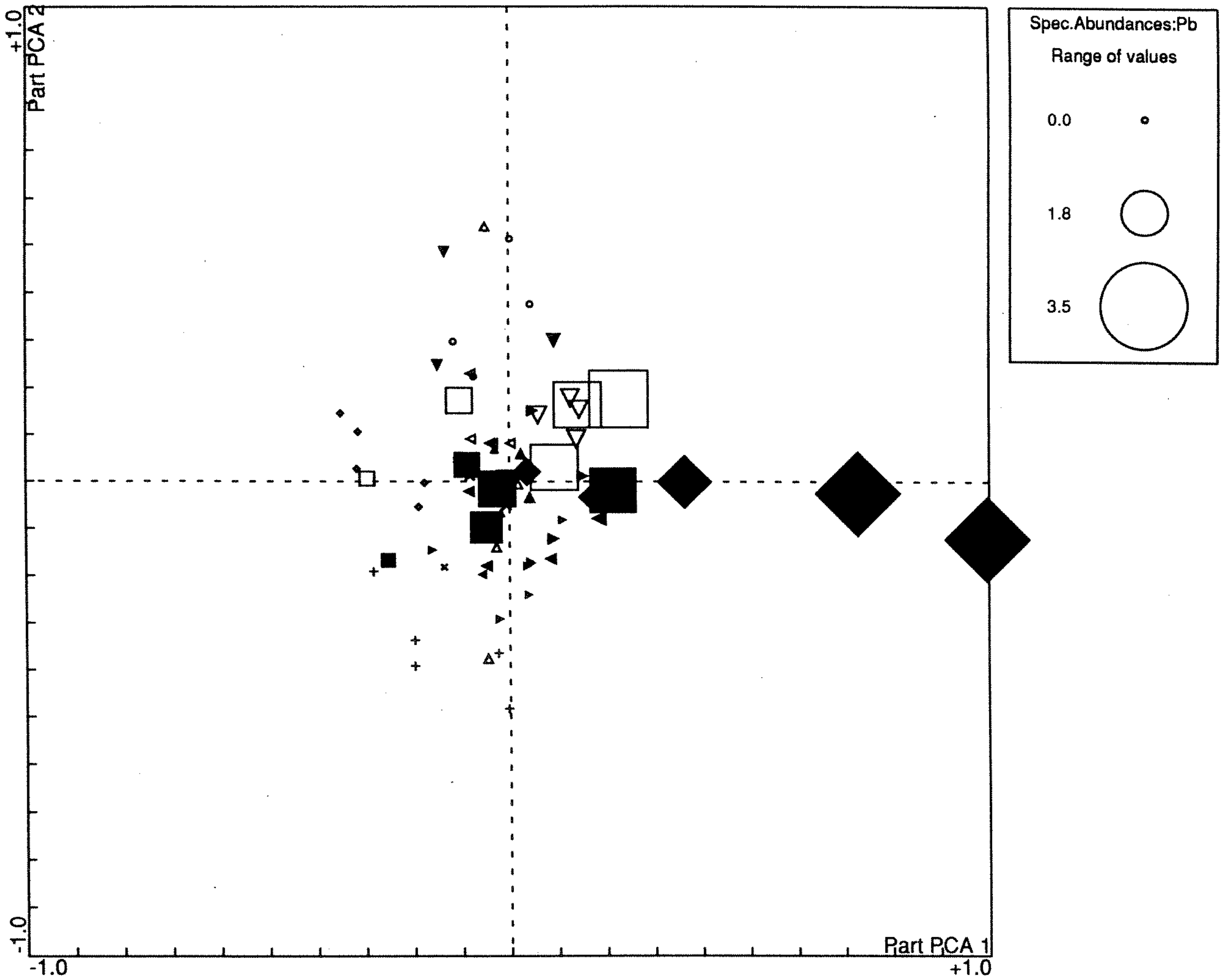


Figure 4.23. Pb concentrations in individual fish samples on partial PCA axes 1 and 2. The 73 samples are coded by lake (Figure 4.22).

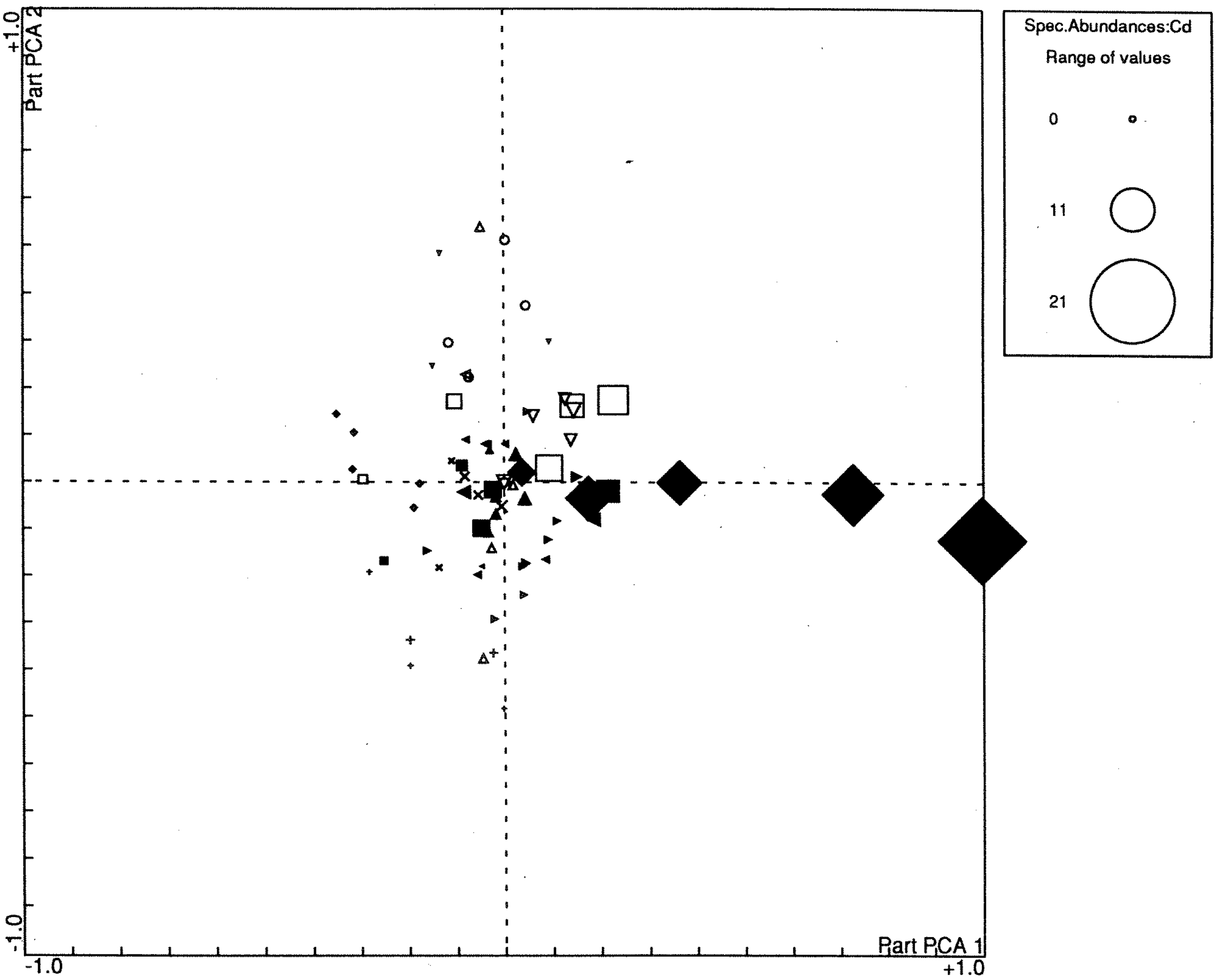


Figure 4.24. Cd concentrations in individual fish samples on partial PCA axes 1 and 2. The 73 samples are coded by lake (Figure 4.22).

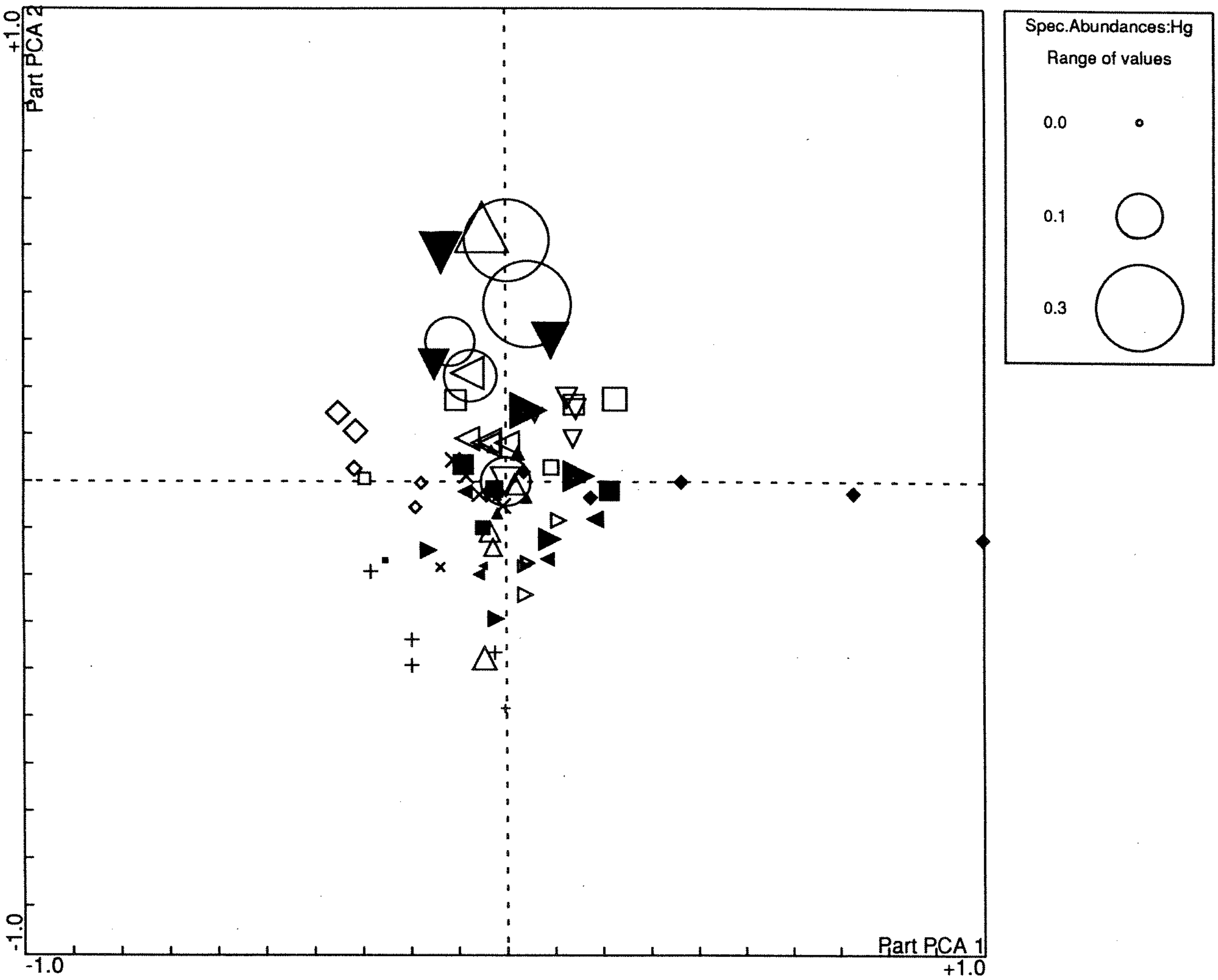


Figure 4.25. Hg concentrations in individual fish samples on partial PCA axes 1 and 2. The 73 samples are coded by lake (Figure 4.22).

4.5 ORGANIC MICROPOLLUTANTS IN FISH

4.5.1 INTRODUCTION

The organochlorinated compounds in the muscle tissue of fishes from 14 lakes of the AL:PE 2, Lagoa Escura, Laguna Cimera, Lago Redo, Lago Paione Inferiore, Lago di Latte, Lago Lungo, Schwarzsee ob Sölden, Zielony Staw, Loch Maam, Lochnagar, Øvre Neådalsvatn, Stavsvatn, Chibini and Arresjøen, have been analysed. Two main objectives were addressed:

a) To use the concentrations of these compounds in the fishes as an indication of the load of these compounds in the waters of each lake. This objective is supported by the fact that a substantial amount of these compounds is bioconcentrated (not degraded) and the concentration in the fish tissues are related to the concentration in the waters.

b) To ascertain whether the organochlorinated compounds are related with the health problems of the fishes in high altitude lakes, particularly those concerned with reproduction.

The analyses were concentrated in the muscle because this tissue is related with long term effects of pollutant accumulation. 3-6 individual fish per lake were analysed which resulted in a data set of 72 samples after analysis of the 15 lakes included in the study.

The results of PCB and DDE/DDT in the fish analyses are in good agreement with the concentrations observed in the sediments. Thus, they exhibit approximately the same geographical distribution in terms of higher and lower polluted sites. The fish analyses also show a general good correspondence between PCB and DDE/DDT concentrations. Usually the two compounds are observed to increase or decrease alike in the lakes.

The PCB distribution found in the fish tissues is similar to that present in the sediments although it shows a clear enrichment in the heavier congeners. This effect probably reflects the different bioaccumulation factor of each of these compounds.

HCB and HCH seem to be distributed following the influence of local sources. However, generally speaking there is a group of lakes with very low levels (almost blanks): Lagoa Escura, Loch Maan, Lochnagar and Laguna Cimera. Some lakes have a moderate pollution level: Stavsvatn, Zielony Staw and Estany Redo. Another with relative high pollution, Arresjøen and Lago Lungo, and the lake with the highest pollution level, Schwarzsee ob Sölden.

This classification among low, moderate, high pollution corresponds to the concentrations of the major chlorinated compounds, the PCBs and DDTs. The concentrations of these compounds change alike.

4.5.2 REGIONAL DESCRIPTIONS

The concentrations of hexachlorobenzene, summed polychlorobiphenyl congeners, DDT derivatives and hexachlorocyclohexanes are summarised in Figures 4.26 - 29.

a) Svalbard. This region is represented by Arresjøen. As indicated above, this region is characterised by low amounts of PCB congeners and DDT derivatives. The concentrations in the lake studied are low but they are not the lowest in the AL:PE series. This is in part in contrast with the very low amounts of organochlorinated pollutants found in the sediments of this lake.

b) Kola. This region is represented by Chibiny. The concentrations are very low for all organochlorinated compounds. The PCB congeners are those present in higher abundance although their concentrations range among the lowest of the whole AL:PE series.

c) Norway. This region is represented by Øvre Neådalsvatn and Stavsvatn. The concentrations of organochlorinated compounds in these lakes are low. The two lakes examined exhibit significant differences which probably reflect local influences or inhomogeneous deposition trends in this area.

d) British Isles. This region is represented by Lough Maam and Lochnagar. The concentrations of organochlorinated compounds are low and rather uniform between lakes. The most abundant products correspond to the PCB congeners. These lakes range among those showing lowest concentrations of total DDTs.

e) Iberia. This region is represented by Lagoa Escura and Laguna Cimera. The concentrations in these two lakes range among the lowest of the whole series of lakes studied. The only exception to this trend is the relatively high amount of DDT derivatives in Laguna Cimera.

f) Pyrenees. This region is represented by Lago Redo. The highest concentrations of total hexachlorocyclohexanes and hexachlorobenzene are found in this lake. The concentration of the former is more than one order of magnitude higher than any other concentration observed in the AL:PE series. The concentration of hexachlorobenzene is also very high when compared with most AL:PE lakes. The other chlorinated products, total DDTs and PCBs, also exhibit important concentrations but they are found even in higher levels in the fishes from other European Lakes.

g) Alps. This region is represented by Lago Paione Inferiore, Lago di Latte, Lago Lungo and Schwarzsee ob Sölden. These lakes can be grouped in two parts: the western Alps (Lago Paione Inferiore) and the Tyrol (Lago di Latte, Lago Lungo and Schwarzsee ob Sölden). A strong contrast is observed between the two. Whereas the West Alps generally show low concentrations of organochlorinated compounds, the highest levels of PCB congeners and DDT derivatives are found in the Tyrol region. This difference is particularly important for the Tyrol area since the three lakes studied consistently show a high pollution for these two groups of compounds. In addition, high levels of hexachlorobenzene are also found in some lakes of Tyrol (Lago di Latte and Schwarzsee ob Sölden).

h) Tatra Mountains. This area represented by Zielony Staw. The concentrations of organochlorinated products are relatively low. DDT derivatives are the major products. The levels of PCBs are also significant. However, Zielony Staw is the AL:PE 2 lake that shows the lowest concentrations of hexachlorobenzene.

Figure 4.26 Total polychlorobiphenils in the fish muscle from the AL:PE2 lakes considered in this study. Each value is the average of 3-6 individual determinations.

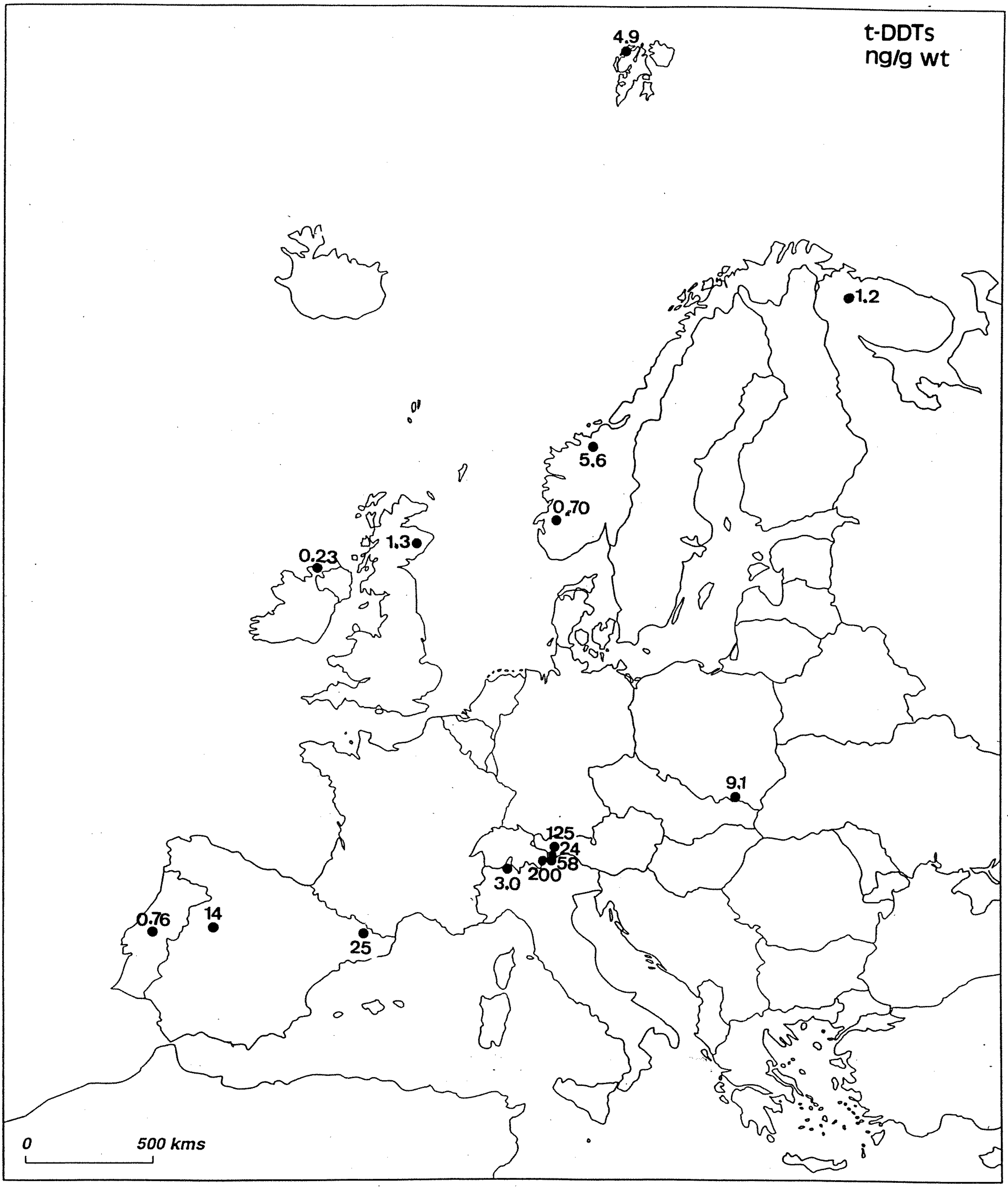


Figure 4.27 Total DDTs in the fish muscle from the AL:PE2 lakes considered in this study. Each value is the average of 3-6 individual determinations.

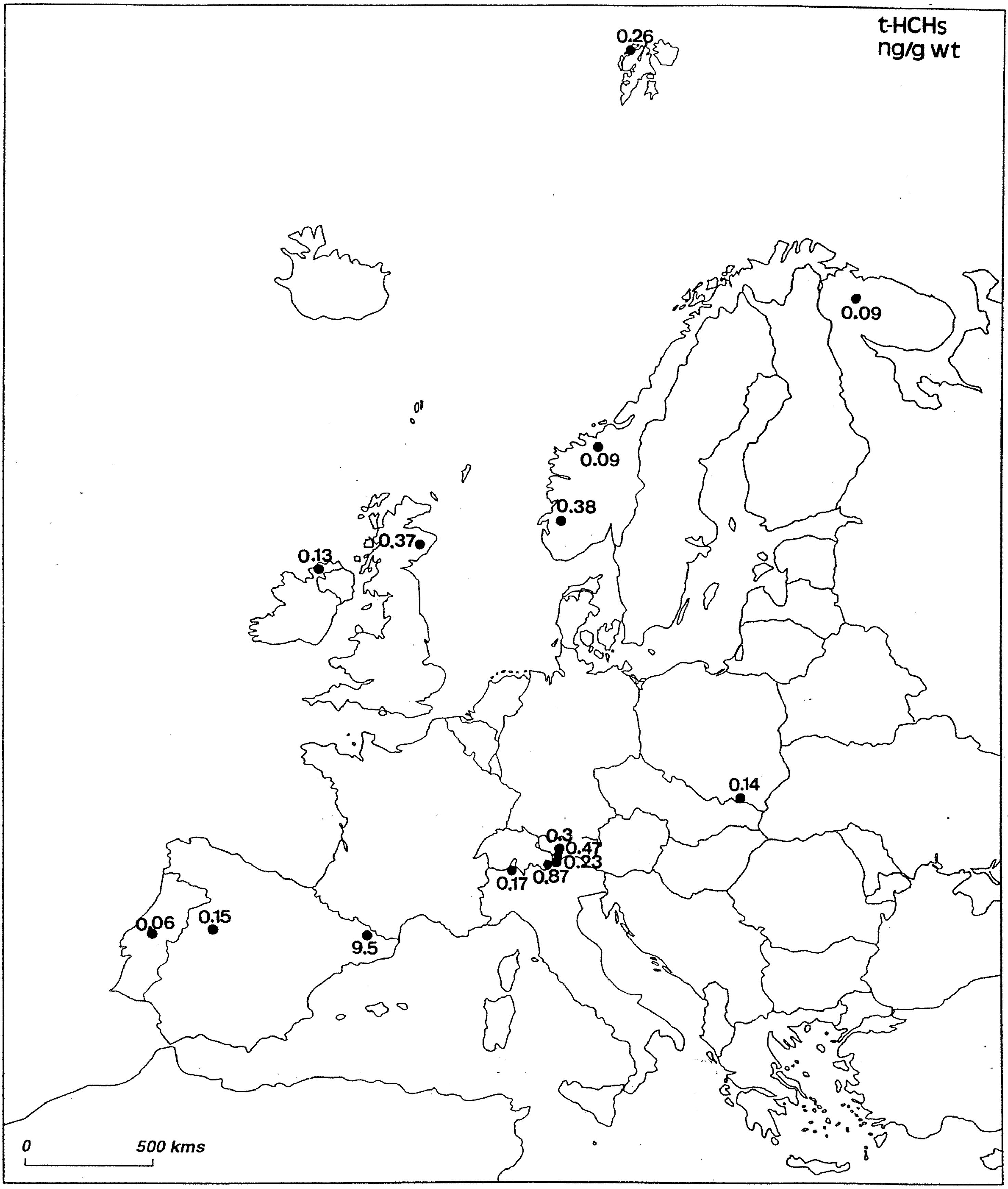


Figure 4.28 Total hexachlorocyclohexanes in the fish muscle from the AL:PE2 lakes considered in this study. Each value is the average of 3-6 individual determinations.

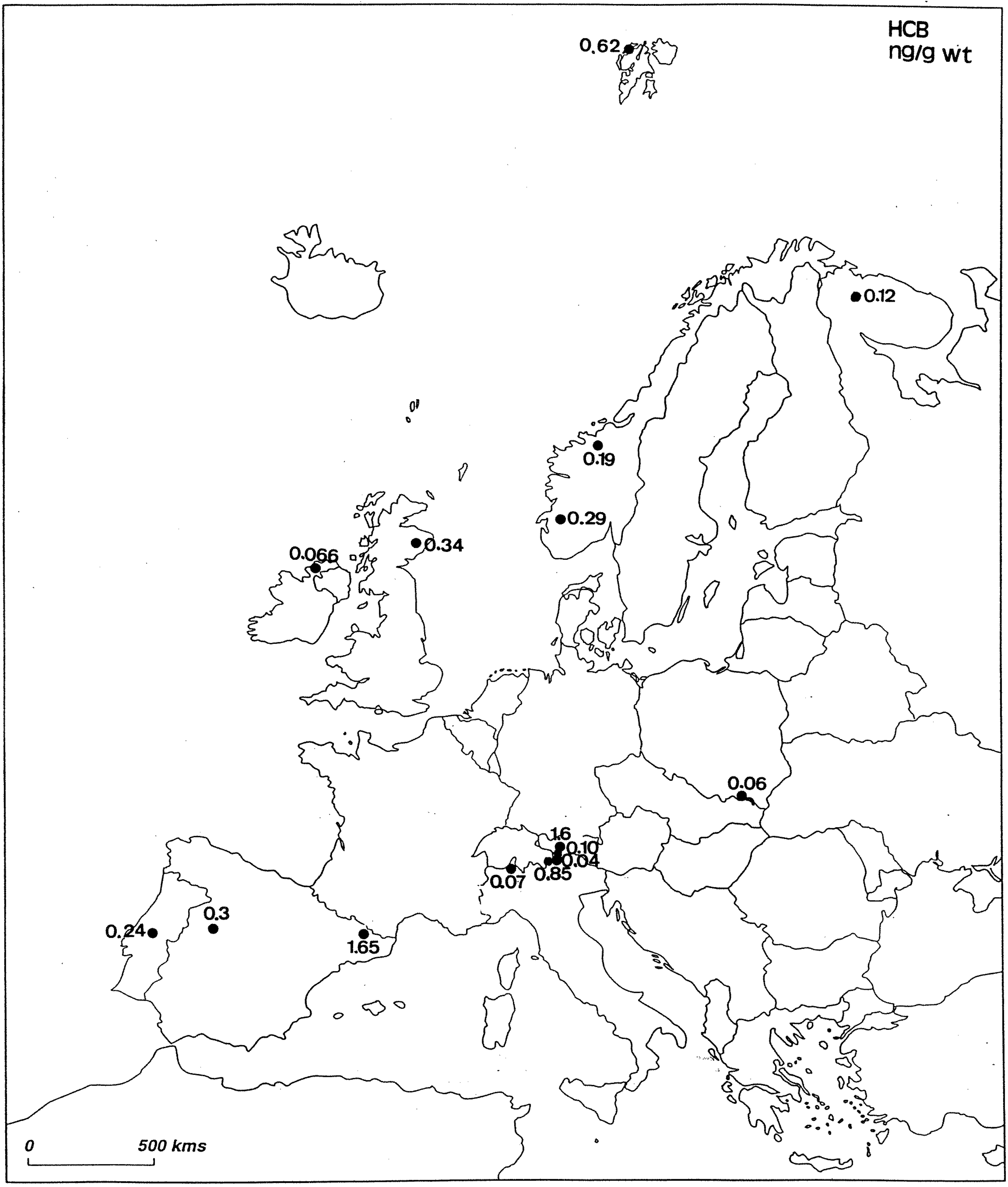


Figure 4.29 Hexachlorobenzene in the fish muscle from the AL:PE2 lakes considered in this study. Each value is the average of 3-6 individual determinations.

4.5.3 OVERALL SUMMARY AND CONCLUSIONS.

Distribution patterns.

The overall evaluation of the concentrations of hexachlorobenzene, total PCB congeners, DDT derivatives and hexachlorocyclohexane isomers show a major difference between the organochlorinated compounds of industrial origin and those used as pesticides.

Thus, total PCB congeners (mean 13 ng/g, standard deviation 16 ng/g) range between 1.8 and 46 ng/g (1.4 orders of magnitude) and their standard deviation is 120% of the mean. Hexachlorobenzene (mean 0.44 ng/g, standard deviation 0.53 ng/g) ranges between 0.06 and 1.65 ng/g which corresponds to the same order of magnitude than the PCBs (1.4) and to a standard deviation which is 120% of the mean. The similitude in the range of variation of these two products is remarkable in view of the different physico-chemical properties of hexachlorobenzene with respect the dominant PCB congeners in the lake (Nos. 118, 153, 138 and 180).

Conversely, the total DDT derivatives (mean 32 ng/g, standard deviation 57 ng/g) range between 0.23 and 200 (2.9 orders of magnitude) and the standard deviation is 180% of the mean. The hexachlorocyclohexanes (mean 0.06 ng/g, standard deviation 0.5 ng/g) also show a high dispersion (2.2 orders of magnitude) and their standard deviation is 270% of the mean.

This different dispersion pattern suggest that the concentrations of the industrial organochlorinated products in the fish population of the lakes reflect a more or less uniform distribution that has a maximum concentration near the Tyrol area and extends over all Europe. Conversely, the organochlorinated pesticides, in addition to a uniform distribution, are more affected by the influence of local sources.

Geographic patterns.

The first result evidenced by this study is the definition of a *hot spot* in the Tyrol area due to the high levels or organochlorinated compounds. This zone is characterised by having the highest concentrations of hexachlorobenzene, PCBs and DDTs among all the AL:PE lakes studied. The second most polluted region corresponds to the Pyrenees, where Lake Redo has the highest concentrations of hexachlorobenzene and hexachlorocyclohexane isomers and significant amounts of PCBs and DDTs. The Tatra Mountains also show similar concentrations of PCBs and DDTs but very low amounts of hexachlorobenzene and hexachlorocyclohexane isomers. The other areas, Kola, Norway, British Isles, Iberia, exhibit rather low concentrations of these four groups of compounds. These concentrations can be considered to represent the background atmospheric-pollution by these compounds and correspond to 1.4-3.5 ng/g t-PCBs, 0.23-5.6 ng/g t-DDTs, 0.06-0.38 ng/g t-HCHs and 0.06-0.34 ng/g HCB. There are, however some exceptions, such as the moderate but significant concentration of t-DDTs in Laguna Cimera or t-PCBs in Øvre Neådalsvatn.

Concentration ranges.

It is difficult to compare the present results with those obtained in other studies because of biases produced by differences in analytical criteria. In any case, the comparison with the aquatic systems considered in other studies gives a rough estimate of the differences with other ecosystems. Thus, in clean coastal areas of the Mediterranean Sea we have found concentrations of PCBs in the order of 10-55 ng/g and t-DDTs of 10-110 ng/g. The concentrations in several European Rivers and Lakes from areas that are not receiving pollution discharges are in the same order as those found in these lakes. For instance t-DDTs of 10-130 ng/g or <5-13 of t-HCHs in some Italian Rivers (Galassi *et al.*, 1981; Amodio *et al.*, 1988). These examples and other evidence support that there is not a major contrast between the low composition of organochlorinated compounds from the AL:PE Lakes and these other environments. This, in turn, also evidences the high mobility of these compounds between different ecosystems, including atmospheric transport.

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APPENDIX

A 7

FISH

Table A.7.1. Fish from AL:PE 2 lakes analysed at NIVA for heavy metals and total PCB.

J.no	Length	Weight	Age	Cd-Liver	Pb-Liver	Hg-Fillet	PCB-Fil.	Sex	Stage	Flesh-col.	Cond.fact.
Arctic charr Arresjøen											
1	34.4	311	19	0.84	0.02	0.16	24.3	M	2	Yellow	0.76
2	34.4	298	18	0.45	0.00	0.14	13.4	F	7.3	Y	0.73
3	29.6	166	17	0.77	0.03	0.14	14.5	F	2	Y	0.64
4	35.7	403	31	0.91	0.03	0.26	59.2	M	5	White	0.89
5	46.5	1050	20	0.5	0.02	0.27	12	M	7.2	Read	1.04
Arctic charr Lago Lungo											
11	23.1	112	15	1.59	0.89	0.06		F	5	Light Reac	0.91
12	23.8	112	12	2.98	1.46	0.05		M	5	W	0.83
13	27.9	175	11	4.38	1.84	0.06		M	2	LR	0.81
14	24.6	120	12	3.36	1.21	0.04		M	5	W	0.81
15	23.1	95	11	0.97	0.38	0.01		F	5	R	0.77
Arctic charr Lago di Latte											
16	17.1	39	11	0.91	0.44	0.03		M	5	W	0.78
17	17.1	40	13	4.97	1.73	0.04		M	5	W	0.80
18	18.5	50	14	4.61	1.78	0.06		F	5	LR	0.79
19	17.3	35	14	1.91	0.93	0.06		F	5	W	0.68
20	16.6	32	15	5.66	2.26	0.07		M	5	W	0.70
Arctic charr Schwarzsee ob Sölden											
139	24.8	96.22	9	15.1	3.55						0.63
140	27.8	147	8	10.19	2.19						0.68
141	25.1	123.8	12	21.02	3.55						0.78
142	24.6	127.3	9	6.27	1.02						0.86
143	22.3	108.9	10	10.37	1.10						0.98
						0.36 (kidney,mean 7 fish)					
Arctic charr Lake Chibini											
49	23.5	103	7	0.028	0.03	0.041		M	2	R	0.79
50	18.8	55	7	0.024	0.07	0.031		M	1	R	0.83
51	25	133	5	0.025	0.03	0.033		M	1	R	0.85
52	30.4	285	8	0.026	0.03	0.062		F	5	R	1.01
53	30.9	268	6	0.042	0.03	0.052		F	5	R	0.91
Arctic charr Étang d'Aubé											
54	24.5	181	7	0.35	0.15	0.019		F	2	LR	1.23
55	24.4	163	6	0.26	0.12	0.038		M	5	LR	1.12
56	26	201	5	0.43	0.14	0.034		F	2	R	1.14
57	27.5	239	6	0.5	0.11	0.041		M	5	LR	1.15
58	28.5	246	21	0.38	0.13	0.035		M	5	LR	1.06
Brook trout Laguna Cimera											
44	24.4	152	2	0.26	0.05	0.037		F	5	W	1.05
45	26.5	175	2	0.36	0.07	0.017		M	5	W	0.94
46	26	178	3	0.88	0.11	0.034		F	5	W	1.01
47	25.8	155	2	0.69	0.14	0.036		F	5	LR	0.90
48	30.1	259	3	1.16	0.18	0.042		F	5	LR	0.95

J.no	Length	Weight	Age	Cd-Liver	Pb-Liver	Hg-Fillet	PCB-Fil.	Sex	Stage	Flesh-col.	Cond.fact.
Brook trout Zieloni Staw											
64	26.5	150	10	1.35	0.20	0.026		M	5	R	0.81
65	23.5	121	10	2.14	0.31	0.037		M	5	W	0.93
66	24.5	143	12	2.13	0.29	0.029		M	5	R	0.97
67	21.5	119	6	0.63	0.11	0.016		F	5	R	1.20
68	26.5	201	8	1.31	0.21	0.021		M	5	W	1.08
Rainbow trout Lagoa Escura											
21	25.1	185	3	0.07	0.22	0.09		M	2	R	1.17
22	25.6	203	3	0.07	0.28	0.13		M	2	R	1.21
23	29.5	277	3	0.09	0.39	0.11		F	1	LR	1.08
Rainbow trout Lago Paione Inferiore											
59	28.4	260	3	2.37	0.42	0.045		F	1	LR	1.14
60	26.4	185	5	0.46	0.29	0.035		F	1	LR	1.01
61	27.1	246	4	0.33	0.26	0.018		F	2	LR	1.24
62	28.6	301	4	1	0.16	0.03		M	2	R	1.29
63	27.6	313	3	2.22	0.22	0.036		F	5	LR	1.49
Brown trout Stavsvatn											
6	32.4	374	5	0.67	0.12	0.05		M	5	LR	1.10
7	41	734	7	0.84	0.27	0.07		F	5	LR	1.06
8	40.7	768	7	1.84	0.30	0.09		F	5	LR	1.14
9	38.7	598	7	1	0.16	0.05		M	5	LR	1.03
10	38.8	650	7	0.75	0.26	0.11		F	5	LR	1.11
							14.6 (mean all 5 fish)				
Brown trout Lago Redo											
24	28.7	240	6	0.72	0.11	0.16		M	5	LR	1.02
25	29.6	264	6	0.82	0.12	0.05		M	5	LR	1.02
26	31.3	351	6	0.57	0.16	0.07		F	7.2	LR	1.14
27	31	284	6	0.6	0.10	0.06		M	5	LR	0.95
28	29.5	277	6	0.65	0.14	0.06		F	5	LR	1.08
Brown trout Lochnagar											
29	16	41	2	1.36	0.54	0.04		M	2	W	1.00
30	22.2	97	3	1.57	0.52	0.06		F	2	LR	0.89
31	23.4	119	3	1.91	0.74	0.05		F	2	LR	0.93
32	23.9	138	3	1.33	0.55	0.05		F	2	LR	1.01
33	32.2	296	4	2.58	0.77	0.08		F	3	LR	0.89
Brown trout Loch Maam											
34	25.5	185	4	0.56	0.20	0.09		M	5	LR	1.12
35	27.6	241	4	0.19	0.16	0.06		F	5	LR	1.15
36	26.7	223	4	0.38	0.14	0.07		M	5	LR	1.17
37	29.7	299	5	0.24	0.17	0.07		F	5	R	1.14
38	29.4	284	5	0.23	0.20	0.08		M	5	R	1.12
Brown trout Øvre Neådalsvatn											
39	28.2	314	3	0.067	0.03	0.028		M	2	LR	1.40
40	27.8	298	3	0.063	0.03	0.026		M	2	LR	1.39
41	28.6	315	3	0.084	0.05	0.029		M	2	LR	1.35
42	29.5	377	3	0.065	0.03	0.034		F	2	R	1.47
43	33.7	524	5	0.065	0.03	0.034		M	5	R	1.37

Table A.7.2.1 Body weights and lengths, tissue water and lipid contents in fish from Arresjoen Lake.

	1	2	3	4	5	Mean	s.d.
Body:							
weight (g)	323.3	440.5	108.5	27.7	37.1	187.4	185.0
length (cm)	27.0	32.0	22.0	13.0	14.0	21.6	8.20
Tissue:							
water (%)	77.4	81.7	72.8	77.0	78.9	77.6	3.24
lipid (%)	(1)	0.83	0.58	1.22	0.83	0.87	0.26
Sex:	Female				Female		

(1) Not determined

Table A.7.2.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	Mean	s.d.
HCB	1.80	1.21	0.63	0.62	0.61	0.97	0.53
HCHs							
a-HCH	0.14	0.07	0.05	0.14	0.10	0.10	0.04
g-HCH	0.15	0.08	0.11	0.06	0.26	0.13	0.08
DDTs							
pp'-DDE	12.7	15.6	6.29	6.07	1.48	8.42	5.65
pp'-DDT	2.36	2.04	0.11	0.70	0.06	1.05	1.08
PCB no.							
28+31	0.45	0.23	0.20	n.d.	n.d.	0.18	0.19
52	1.53	1.20	0.37	n.d.	n.d.	0.62	0.71
101	2.17	1.36	0.56	n.d.	n.d.	0.82	0.94
118	3.39	2.64	0.58	0.36	0.84	1.56	1.36
153	11.8	13.8	3.56	2.82	0.05	6.40	6.01
138	10.6	8.76	2.47	2.12	0.97	4.99	4.38
180	5.90	4.17	1.26	0.77	n.d.	2.42	2.50
PCBs TOTAL	35.8	32.2	9.00	6.07	1.86	17.0	16.1

Table A.7.2.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	2	3	4	5	Mean	s.d.
HCB	146	107	51.1	72.9	94.0	41.2
HCHs						
a-HCH	8.74	9.50	12.2	11.8	10.6	1.71
g-HCH	10.6	19.1	5.79	32.7	17.0	11.8
DDTs						
pp'-DDE	1874	1078	498	567	1004	635
pp'-DDT	245	19.0	57.2	7.74	82.3	111
PCB no.						
28+31	27.7	34.5	n.d.	n.d.	15.6	18.2
52	144	62.9	n.d.	n.d.	46.9	68.5
101	163	96.4	n.d.	n.d.	64.9	79.8
118	318	99.6	29.4	101	137	125
153	1660	610	231	5.77	627	733
138	1054	423	174	116	442	429
180	502	216	63.3	n.d.	195	224
PCBs TOTAL	3869	1542	498	223	1528	1677

Table A. 7.3. Concentration of some metals (mg/kg dry weight) in organs and tissue of Arctic charr from Chibiny

Organ	Sample (n)	Cu	Ni	Co	Zn	Mn	Al	Sr
Muscle	5	2.4	1.2	0.7	22	0.8	8	9
Skelleton	4	2.8	3.7	2.8	54	7.2	26	1230
Gills	5	4.3	2.3	1.7	83	9	46	1010
Liver	5	51	0.6	0.6	100	4.4	11	4.3
Kidney	5	11	1.2	3.7	106	8	26	24

Table A.7.4.1 Body weights and lengths,tissue water and lipid contents in fish from Chibini Lake.

	1(53)*	2(52)	3(51)	4(49)	Mean	s.d.
Body:						
weight (g)**	207	233	100	79	155	77
length (cm)	26.0	24.0	21.0	20.0	22.8	2.75
Tissue:						
water (%)	72.6	72.9	69.7	72.0	71.8	1.44
lipid (%)	1.16	1.38	2.66	1.86	1.77	0.66
Sex:	Female	Female				

*Original fish code between brackets
** Approximative fish weight (fish have been received partly dissecated).

Table A.7.4.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	Mean	s.d.
HCB	0.16	0.04	0.12	0.16	0.12	0.06
HCHs						
a-HCH	n.d.	n.d.	0.02	0.02	0.01	0.01
g-HCH	0.10	0.03	0.22	0.13	0.12	0.08
DDTs						
op'-DDE	0.05	n.d.	0.11	0.13	0.07	0.06
pp'-DDE	0.53	0.21	0.32	0.35	0.35	0.13
pp'-DDD	0.24	0.07	0.47	0.40	0.30	0.18
op'-DDT	0.09	0.06	0.31	0.17	0.16	0.11
pp'-DDT	0.30	0.11	0.63	0.34	0.35	0.21
PCB no.						
28+31	n.d.	n.d.	n.d.	n.d.	n.d.	0.00
52	0.11	n.d.	0.52	0.62	0.31	0.30
101	0.16	0.19	0.25	0.31	0.23	0.07
118	0.47	0.28	0.56	0.57	0.47	0.13
153	0.43	0.14	0.72	0.57	0.47	0.25
138	0.49	0.11	0.47	0.46	0.38	0.18
180	0.26	0.04	0.30	0.30	0.23	0.12
PCBs TOTAL	1.92	0.76	2.82	2.83	2.08	1.06

Table A.7.4.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	Mean	s.d.
HCB	13.88	2.83	4.40	8.76	7.47	4.96
HCHs						
a-HCH	0.00	0.00	0.75	1.08	0.46	0.54
g-HCH	8.6	2.2	8.3	7.0	6.5	2.98
DDTs						
op'DDE	4.31	0.00	4.14	6.99	3.86	2.89
pp'-DDE	45.7	15.2	12.0	18.8	22.9	15.4
pp'-DDD	20.7	5.07	17.7	21.5	16.2	7.62
op'DDT	7.76	4.35	11.7	9.14	8.23	3.05
pp'-DDT	25.9	8.0	23.7	18.3	18.9	7.98
PCB no.						
28+31	0.00	0.00	0.00	0.00	0.0	0.0
52	9.48	0.00	19.5	33.3	15.6	14.3
101	13.8	13.8	9.40	16.7	13.4	3.00
118	40.5	20.3	21.1	30.6	28.1	9.51
153	37.1	10.1	27.1	30.6	26.2	11.5
138	42.2	7.97	17.7	24.7	23.2	14.5
180	22.4	2.90	11.3	16.1	13.2	8.2
PCBs TOTAL	166	55.1	106	152	120	61

Table A.7.5.1 Body weights and lengths,tissue water and lipid contents in fish from Ovre Neadalsvatn Lake

	1	2	3	4	5	6	Mean	s.d.
Body:								
weight (g)	237.0	236.0	74.7	90.4	101.0	237.0	162.7	81.5
length (cm)	22.5	22.0	15.0	17.0	18.0	22.0	19.4	3.17
Tissue:								
water (%)	71.9	74.8	72.1	71.6	74.3	74.3	73.2	1.44
lipid (%)	3.02	3.98	2.54	2.49	1.30	4.48	2.97	1.14
Sex:								

Table A.7.5.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	6	Mean	s.d.
HCB	0.54	0.60	0.34	0.17	0.02	0.08	0.29	0.24
HCHs								
a-HCH	0.39	0.090	n.d.	0.020	n.d.	0.01	0.09	0.15
g-HCH	0.36	0.30	0.34	0.46	0.09	0.18	0.29	0.13
DDTs								
op'-DDE	0.03	n.d.	0.03	0.08	0.03	n.d.	0.03	0.03
pp'-DDE	0.31	1.17	0.11	0.18	0.09	0.13	0.33	0.42
pp'-DDD	n.d.	0.62	n.d.	0.06	0.04	0.04	0.13	0.24
op'-DDT	0.05	0.08	n.d.	0.09	n.d.	n.d.	0.04	0.04
pp'-DDT	0.15	0.45	n.d.	0.13	0.08	0.18	0.17	0.15
PCB no.								
28+31	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.00
52	0.35	0.21	n.d.	0.26	n.d.	n.d.	0.14	0.16
101	0.02	0.41	0.19	0.16	0.03	0.06	0.15	0.15
118	0.15	0.27	0.11	0.18	0.09	0.13	0.16	0.06
153	0.17	0.99	0.25	0.43	0.33	0.39	0.43	0.29
138	0.22	0.92	0.32	0.34	0.17	0.36	0.39	0.27
180	0.20	0.49	0.36	0.15	0.07	0.20	0.25	0.15
PCBs TOTAL	1.11	3.29	1.23	1.52	0.69	1.14	1.50	1.08

Table A.7.5.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	6	Mean	s.d.
HCB	17.72	15.0	13.46	6.9	1.38	1.85	9.4	7.0
HCHs								
a-HCH	12.91	2.26	n.d.	0.80	n.d.	0.22	2.70	5.08
g-HCH	11.92	7.54	13.39	18.47	6.92	4.02	10.4	5.24
DDTs								
op'-DDE	0.93	0.00	1.02	3.37	n.d.	n.d.	0.89	1.31
pp'-DDE	10.3	29.4	4.33	7.23	6.92	2.90	10.2	9.76
pp'-DDD	0.00	15.7	n.d.	2.29	2.85	0.89	3.61	6.01
op'-DDT	1.79	1.88	n.d.	3.49	0.00	0.00	1.19	1.44
pp'-DDT	4.97	11.3	n.d.	5.22	6.15	4.02	5.28	3.65
PCB no.								
28+31	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0
52	11.6	5.28	n.d.	10.4	n.d.	n.d.	4.55	5.42
101	0.66	10.3	7.48	6.43	2.31	1.34	4.75	3.88
118	4.97	6.78	4.33	7.23	6.92	2.90	5.52	1.74
153	5.63	24.9	9.84	17.3	25.4	8.71	15.3	8.53
138	7.28	23.1	12.6	13.7	13.1	8.04	13.0	5.66
180	6.62	12.3	14.2	6.02	5.38	4.46	8.16	4.04
PCBs TOTAL	36.8	82.7	48.4	61.0	53.1	25.4	51.2	29.3

Table A.7.6.1 Body weights and lengths, tissue water and lipid contents in fish from Stavsvatn Lake.

	1	2	3	4	5	Mean	s.d.
Body:							
weight (g)	675.3	594.5	341.2	258.3	296.6	433.2	188.6
length (cm)	35.5	35.0	33.0	25.0	26.5	31.0	4.91
Tissue:							
water (%)							
lipid (%)	1.60	1.24	1.69	1.04	1.81	1.48	0.32
Sex:	Female	Female					

Table A.7.6.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	Mean	s.d.
HCB	0.10	0.06	0.09	0.10	0.58	0.19	0.22
HCHs							
a-HCH	0.04	0.02	0.03	0.04	n.d.	0.03	0.02
g-HCH	0.06	0.03	0.08	0.12	n.d.	0.06	0.05
DDTs							
pp'-DDE	6.15	2.07	4.15	3.04	9.86	5.05	3.09
pp'-DDT	0.17	0.06	0.12	0.60	1.93	0.58	0.79
PCB no.							
28+31		0.10	0.22	0.22	0.06	0.15	0.08
52	0.12	0.09	0.08	0.46	0.92	0.33	0.36
101	0.25	0.10	0.16	0.19	0.54	0.25	0.17
118	0.69	0.28	0.49	0.62	2.08	0.83	0.71
153	1.58	0.61	0.94	1.06	4.18	1.67	1.44
138	1.52	0.51	0.91	1.12	4.23	1.66	1.48
180	1.53	0.50	0.86	1.24	4.22	1.67	1.48
PCBs TOTAL	5.69	2.19	3.66	4.91	16.23	6.57	5.74

Table A.7.6.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	Mean	s.d.
HCB	6.41	5.05	5.09	9.30	32.21	11.6	11.6
HCHs							
a-HCH	2.30	1.50	1.73	3.41	n.d.	1.79	1.24
g-HCH	3.95	2.29	4.64	11.53	n.d.	4.48	4.33
DDTs							
pp'-DDE	385	166	246	292	544	327	145
pp'-DDT	10.6	4.69	7.32	57.3	106.7	37.3	44.4
PCB no.							
28+31		8.18	13.0	21.4	3.53	11.5	7.62
52	7.76	6.89	5.01	44.6	50.6	23.0	22.6
101	15.5	8.14	9.48	18.2	29.6	16.2	8.57
118	43.3	22.7	28.91	59.8	115.1	54.0	37.0
153	99.0	48.7	55.83	102.0	230.6	107.2	73.11
138	94.9	40.9	54.28	107.1	233.6	106.2	76.36
180	95.5	40.30	50.9	119.16	232.9	107.7	77.01
PCBs TOTAL	356	176	217.4	472	896	426	302

Table A.7.7.1 Body weights and lengths, tissue water and lipid contents in fish from Nagar Lake.

	1	2	3	4	5	Mean	s.d.
Body:							
weight (g)	110.3	108.4	139.4	175.3	211.3	148.9	44.2
length (cm)	21.0	19.5	21.0	23.0	25.0	21.9	2.13
Tissue:							
water (%)							
lipid (%)	1.22	2.62	2.46	1.45	1.11	1.77	0.71
Sex:					Female		

Table A.7.7.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	Mean	s.d.
HCB	1.12	0.11	0.14	0.25	0.07	0.34	0.44
HCHs							
a-HCH	0.01	0.05	0.04	0.05	0.02	0.03	0.02
g-HCH	0.09	0.61	0.29	0.54	0.11	0.33	0.24
d-HCH	0.004	0.017	0.009	n.d.	0.016	0.009	0.007
DDTs							
pp'-DDE	0.49	0.96	1.49	1.84	0.58	1.07	0.58
pp'-DDT	0.06	0.35	0.24	0.54	0.10	0.26	0.20
PCB no.							
28+31	0.29	0.36	0.43	0.61	0.84	0.51	0.22
52	0.27	0.40	0.28	0.45	0.17	0.31	0.11
101	0.16	0.23	0.19	1.84	0.58	0.60	0.71
118	0.24	0.44	0.45	0.56	0.30	0.40	0.13
153	0.38	0.86	0.73	0.80	0.35	0.62	0.24
138	0.36	0.63	0.63	0.80	0.27	0.54	0.22
180	0.31	0.62	0.61	0.71	0.25	0.50	0.21
PCBs TOTAL	2.01	3.54	3.32	5.77	2.76	3.48	1.84

Table A.7.7.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	Mean	s.d.
HCB	92.0	4.34	5.76	17.2	6.51	25.2	37.7
HCHs							
a-HCH	1.14	1.81	1.59	3.22	1.93	1.94	0.78
g-HCH	7.44	23.1	11.75	37.2	10.2	17.9	12.3
d-HCH	0.35	0.64	0.37	n.d.	1.46	0.56	0.55
DDTs							
pp'-DDE	40.4	36.5	60.5	127.0	52.0	63.3	36.9
pp'-DDT	5.15	13.5	9.66	37.2	9.1	14.9	12.8
PCB no.							
28+31	24.2	13.7	17.6	41.8	75.8	34.6	25.4
52	22.6	15.4	11.3	30.9	15.0	19.1	7.79
101	13.0	8.71	7.55	18.9	15.1	12.7	4.7
118	19.3	16.7	18.2	38.5	27.2	24.0	9.08
153	31.0	32.9	29.6	55.1	31.6	36.1	10.73
138	29.3	23.9	25.6	54.9	24.2	31.6	13.23
180	25.2	23.5	25.0	49.1	22.5	29.0	11.24
PCBs TOTAL	165	135	134.8	289	211	187	82

Table A.7.8.1 Body weights and lengths,tissue water and lipid contents in fish from Maan Lake.

	1	2	3	4	5	Mean	s.d.
Body:							
weight (g)	199.1	270.1	210.5	194.7	187.5	212.4	33.3
length (cm)	23.0	26.0	25.0	24.0	23.5	24.3	1.20
Tissue:							
water (%)							
lipid (%)	1.33	2.07	2.47	1.89	0.88	1.73	0.63
Sex:	Female			Female			

Table A.7.8.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	Mean	s.d.
HCB	0.078	0.067	0.065	0.061	0.058	0.066	0.008
HCHs							
a-HCH	0.04	0.02	0.03	0.03	0.02	0.03	0.01
g-HCH	0.11	0.10	0.07	0.11	0.07	0.09	0.02
d-HCH	0.04	n.d.	n.d.	n.d.	0.02	0.01	0.02
DDTs							
pp'-DDE	0.14	0.21	0.12	0.32	0.11	0.18	0.09
pp'-DDT	0.09	0.04	0.04	0.08	n.d.	0.05	0.04
PCB no.							
28+31	1.92	0.43	0.28	1.65	0.28	0.91	0.80
52	0.76	0.36	0.31	2.37	0.34	0.83	0.88
101	0.48	0.08	0.04	0.90	n.d.	0.30	0.39
118	0.59	0.31	0.18	1.03	0.16	0.45	0.36
153	0.27	0.36	0.21	0.43	0.21	0.30	0.10
138	0.33	0.32	0.18	0.35	0.17	0.27	0.09
180	n.d.	0.21	n.d.	0.15	0.12	0.10	0.09
PCBs TOTAL	4.35	2.07	1.20	6.88	1.28	3.16	2.72

Table A.7.8.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	Mean	s.d.
HCB	5.87	3.27	2.63	3.23	6.60	4.3	1.8
HCHs							
a-HCH	3.16	1.08	1.12	1.34	2.11	1.76	0.88
g-HCH	8.31	4.93	2.84	5.70	7.71	5.9	2.20
d-HCH	2.88	n.d.	n.d.	n.d.	2.11	1.0	1.39
DDTs							
pp'-DDE	10.6	5.16	2.53	8.79	6.34	6.69	3.15
pp'-DDT	6.43	3.91	1.70	4.11	n.d.	3.23	2.46
PCB no.							
28+31	145	20.8	11.4	87.6	32.1	59.3	56.2
52	57.5	17.2	12.5	125.8	38.9	50.4	45.8
101	35.9	4.06	1.80	47.9	n.d.	17.9	22.3
118	44.5	14.9	7.42	54.7	18.7	28.0	20.4
153	20.4	17.7	8.34	22.9	24.2	18.7	6.31
138	24.7	15.6	7.17	18.5	19.2	17.0	6.40
180	n.d.	9.94	n.d.	8.07	14.2	6.4	6.29
PCBs TOTAL	328	100	48.7	365	147	198	164

Table 7.9.1 Body weights and lengths, tissue water and lipid contents in fish from Escura Lake.

	1(25)*	2(30)	3(38)	Mean	s.d.
Body:					
weight (g)	202.4	174.6	264.2	213.7	45.9
length (cm)	23.7	21.3	25.4	23.5	2.06
Tissue:					
water (%)	73.7	77.1	76.4	75.7	1.78
lipid (%)	1.99	1.53	1.30	1.61	0.35
Sex:					

* Original fish code between brackets

Table 7.9.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	Mean	s.d.
HCB	0.032	0.017	0.023	0.024	0.008
HCHs					
a-HCH	0.022	0.014	0.011	0.016	0.006
g-HCH	0.048	0.051	0.042	0.047	0.005
DDTs					
pp'-DDE	0.51	0.48	0.63	0.54	0.08
pp'-DDT	0.15	0.41	0.10	0.22	0.17
PCB no.					
28+31	0.09	0.25	0.07	0.14	0.10
52	n.d.	n.d.	n.d.	n.d.	
101	n.d.	0.07	n.d.	0.02	
118	0.39	0.43	0.29	0.37	0.07
153	0.40	0.47	0.28	0.39	0.09
138	0.78	0.82	0.31	0.64	0.28
180	0.26	0.13	0.23	0.21	0.07
PCBs TOTAL	1.92	2.17	1.19	1.76	0.61

Table 7.9.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	Mean	s.d.
HCB	1.65	1.15	1.78	1.53	0.33
HCHs					
a-HCH	1.08	0.89	0.87	0.95	0.12
g-HCH	2.44	3.36	3.20	3.00	0.49
DDTs					
pp'-DDE	25.4	31.6	48.2	35.1	11.8
pp'-DDT	7.44	27.0	7.38	13.9	11.3
PCB no.					
28+31	4.59	16.4	5.71	8.89	6.51
52	n.d.	n.d.	n.d.	n.d.	
101	n.d	4.35	n.d.	1.45	
118	19.6	27.8	22.3	23.3	4.1
153	20.3	30.7	21.8	24.3	5.6
138	39.1	53.8	24.0	39.0	14.9
180	13.2	8.76	17.7	13.2	4.5
PCBs TOTAL	96.8	142	91.6	110	35.6

Table A.7.10.1 Body weights and lengths,tissue water and lipid contents in fish from Cimera Lake.

	1	2	3	4	5	Mean	s.d.
Body:							
weight (g)	181.3	230.7	157.9	197.5	140.6	181.6	35.0
length (cm)	23.0	25.0	22.0	24.0	20.5	22.9	1.75
Tissue:							
water (%)	79.4	81.0	79.8	80.9	80.4	80.3	0.68
lipid (%)	1.00	0.90	1.10	1.10	1.10	1.04	0.09
Sex:		Female	Female	Female	Female		

Table A.7.10.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	Mean	s.d.
HCB	0.46	0.31	0.19	0.35	0.17	0.30	0.12
HCHs							
a-HCH	0.03	0.02	0.03	0.02	0.03	0.03	0.01
g-HCH	0.14	0.09	0.14	0.12	0.11	0.12	0.02
DDTs							
pp'-DDE	8.18	22.9	7.03	16.6	6.39	12.2	7.26
pp'-DDT	1.53	1.94	0.83	1.49	0.74	1.31	0.51
PCB no.							
28+31	0.37	0.11	0.03	0.16	0.05	0.14	0.14
52	0.68	0.37	0.59	0.42	0.41	0.49	0.13
101	0.88	0.50	0.24	0.48	0.39	0.50	0.24
118	0.61	0.39	0.21	0.35	0.23	0.36	0.16
153	0.81	1.13	0.33	0.87	0.38	0.70	0.34
138	0.89	1.69	0.89	1.25	0.79	1.10	0.37
180	0.62	0.71	0.16	0.53	0.12	0.43	0.27
PCBs TOTAL	4.86	4.90	2.45	4.06	2.37	3.73	1.65

Table A.7.10.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	Mean	s.d.
HCB	46.1	32.6	17.7	31.2	15.4	28.6	12.5
HCHs							
a-HCH	2.89	2.36	2.46	2.14	2.43	2.46	0.27
g-HCH	14.5	10.9	13.0	10.0	10.6	11.8	1.90
DDTs							
pp'-DDE	817	2430	639	1463	788	1228	743
pp'-DDT	152	206	75.3	131.3	68.8	126.7	56.9
PCB no.							
28+31	37.2	0.047	0.013	0.069	0.017	7.47	16.6
52	67.7	38.7	53.7	36.7	37.7	46.9	13.6
101	88.1	52.5	21.9	42.1	36.6	48.2	24.9
118	61.4	41.3	19.3	30.9	21.8	34.9	17.1
153	81.0	120	29.8	76.3	35.5	68.4	36.8
138	88.6	180	80.5	110	73.2	106	43.2
180	61.9	75.0	14.8	46.9	10.9	41.9	28.4
PCBs TOTAL	486	507	220	343	216	354	181

Table A.7.11.1 Body weights and lengths, tissue water and lipid contents in fish from Redo Lake.

	1	2	3	4	5	Mean	s.d.
Body:							
weight (g)	204.0	200.7	295.0	236.5	219.5	231.1	38.4
length (cm)	25.0	25.0	26.5	23.5	25.0	25.0	1.06
Tissue:							
water (%)	75.2	75.0	74.4	71.7	75.0	74.3	1.46
lipid (%)	4.20	3.08	7.66	7.39	3.86	5.24	2.13
Sex:			Female	Female			

Table A.7.11.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	Mean	s.d.
HCB	1.26	1.08	2.41	1.87	1.62	1.65	0.52
HCHs							
a-HCH	1.80	1.57	4.16	3.67	2.05	2.65	1.18
g-HCH	4.79	3.43	9.67	10.23	6.12	6.85	2.99
DDTs							
pp'-DDE	19.6	25.0	21.3	12.1	30.4	21.7	6.79
pp'-DDT	3.48	2.32	3.51	3.57	4.16	3.41	0.67
PCB no.							
28+31	0.07	0.11	0.19	0.13	0.40	0.18	0.13
52	0.29	0.50	0.44	0.56	0.24	0.41	0.14
101	0.88	1.17	1.24	0.89	1.57	1.15	0.29
118	0.51	0.54	0.63	0.33	0.64	0.53	0.13
153	3.56	2.57	4.16	2.61	3.81	3.34	0.72
138	2.49	3.03	2.52	2.38	3.25	2.73	0.38
180	1.60	1.79	1.24	0.92	2.30	1.57	0.53
PCBs TOTAL	9.40	9.71	10.42	7.82	12.21	9.91	2.31

Table A.7.11.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	Mean	s.d.
HCB	29.6	35.0	31.5	25.4	42.0	32.7	6.2
HCHs							
a-HCH	42.3	51.3	54.4	49.8	53.2	50.2	4.7
g-HCH	113	111	126	138	159	129	19.7
DDTs							
pp'-DDE	462	812	278	163	788	501	294
pp'-DDT	81.8	75.4	45.9	48.3	108	71.8	25.6
PCB no.							
28+31	0.002	0.001	0.001	0.004	0.038	0.009	0.016
52	6.72	16.3	5.69	7.62	6.15	8.49	4.42
101	20.7	37.9	16.2	12.0	40.8	25.5	13.0
118	12.0	17.6	8.22	4.42	16.6	11.8	5.57
153	83.8	83.7	54.3	35.3	98.7	71.2	25.7
138	58.7	98.5	32.9	32.2	84.3	61.3	29.9
180	37.7	58.2	16.2	12.5	59.7	36.8	22.4
PCBs TOTAL	220	312	134	104	306	215	101

Table A.7.12.1 Body weights and lengths,tissue water and lipid contents in fish from Paione Inferiore Lake.

	1(59)*	2(60)	3(61)	4(62)	5(63)	Mean	s.d.
Body:							
weight (g)	212.6	146.9	167.8	261.9	216.6	201.2	45.0
length (cm)	22.0	24.5	23.0	24.0	24.0	23.5	1.00
Tissue:							
water (%)	75.0	76.3	82.7	74.5	75.5	76.8	3.37
lipid (%)	0.94	0.61	0.83	0.94	1.16	0.90	0.20
Sex:					Female		

*Original fish code between brackets

Table A.7.12.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	Mean	s.d.
HCB	0.13	n.d.	n.d.	0.10	0.14	0.07	0.07
HCHs							
a-HCH	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.00
g-HCH	0.17	0.19	0.10	0.16	0.24	0.17	0.05
DDTs							
pp'-DDE	2.88	3.45	0.90	1.89	2.61	2.35	0.98
pp'DDD	0.87	n.d.	0.06	0.13	0.50	0.31	0.37
op'-DDT	n.d.	0.12	0.04	0.07	0.24	0.09	0.09
pp'-DDT	0.34	0.33	0.12	0.38	0.17	0.27	0.12
PCB no.							
28+31	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.00
52	n.d.	n.d.	n.d.	n.d.	0.82	0.16	0.37
101	0.35	0.39	0.12	0.10	0.32	0.26	0.14
118	1.03	0.47	0.17	0.40	0.71	0.56	0.33
153	1.56	1.90	0.47	0.85	1.56	1.27	0.59
138	1.64	2.03	0.40	1.01	1.22	1.26	0.62
180	1.43	1.66	0.51	0.91	1.33	1.17	0.46
PCBs TOTAL	6.01	6.45	1.67	3.27	5.96	4.67	2.50

Table A.7.12.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	Mean	s.d.
HCB	13.6	n.d.	n.d.	10.5	11.6	7.16	6.63
HCHs							
a-HCH	0.00	0.00	0.00	0.00	0.00	0.0	0.0
g-HCH	18.1	31.1	12.0	17.0	20.7	19.8	7.08
DDTs							
pp'-DDE	306	566	108	201	225	281	174
pp'-DDD	92.8	0.00	6.87	14.3	42.7	31.3	38.0
op'-DDT	0.00	19.2	5.18	6.91	20.8	10.4	9.11
pp'-DDT	36.2	54.1	14.5	40.4	14.7	32.0	17.2
PCB no.							
28+31	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.0
52	n.d.	n.d.	n.d.	n.d.	70.7	46.9	31.6
101	37.2	63.9	14.5	10.6	27.6	30.8	21.3
118	110	77.0	20.5	42.6	61.2	62.2	33.9
153	166	311	56.6	90.4	134	152	98.5
138	174	333	48.2	107	105	154	110
180	152	272	61.4	97	115	139	81.1
PCBs TOTAL	639	1057	201	348	514	585	376

Table A.7.13.1 Body weights and lengths, tissue water and lipid contents in fish from Lungo Lake.

	1	2	3	4	5	6	Mean	s.d.
Body:								
weight (g)	69.6	78.6	69.5	123.5	120.6	124.1	97.7	27.7
length (cm)	16.5	17.5	17.0	22.0	20.4	21.5	19.2	2.43
Tissue:								
water (%)	78.3	69.9	78.1	75.3	79.1	78.2	76.5	3.47
lipid (%)	0.80	1.56	1.72	1.54	0.74	0.87	1.21	0.45
Sex:					Female	Female		

Table A.7.13.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	6	Mean	s.d.
HCB	0.033	0.051	0.036	0.036	0.041	0.033	0.038	0.007
HCHs								
a-HCH	0.010	0.030	0.020	0.040	0.020	0.040	0.027	0.012
g-HCH	0.10	0.15	0.15	0.44	0.21	0.17	0.20	0.12
DDTs								
pp'-DDE	43.2	27.1	86.1	67.7	53.3	41.5	53.1	21.0
pp'-DDT	1.86	2.63	2.22	5.24	11.75	4.32	4.67	3.70
PCB no.								
28+31	0.43	0.65	0.87	4.13	1.82	2.79	1.78	1.45
52	2.61	1.80	2.24	5.56	2.52	5.21	3.32	1.63
101	0.43	0.66	0.74	4.02	1.03	1.49	1.40	1.34
118	1.59	5.44	9.08	6.30	7.77	4.59	5.80	2.62
153	4.85	2.69	7.97	7.51	4.37	4.32	5.29	2.04
138	3.88	2.51	5.97	5.86	3.45	3.43	4.18	1.41
180	3.39	1.38	5.19	4.43	2.47	0.81	2.95	1.71
PCBs TOTAL	17.2	15.1	32.1	37.8	23.4	22.6	24.7	12.2

Table A.7.13.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	6	Mean	s.d.
HCB	4.08	3.25	2.10	2.33	5.52	3.80	3.51	1.26
HCHs								
a-HCH	1.81	2.07	1.20	2.39	3.02	4.14	2.44	1.03
g-HCH	12.4	10.2	9.4	29.3	26.8	17.1	17.5	8.60
d-HCH	2.90	2.38	0.86	2.83	3.84	5.57	3.06	1.57
DDTs								
pp'-DDE	5390	1739	5011	4401	7237	4746	4754	1780
pp'-DDT	233	169	129	341	1596	494	494	556
PCB no.								
28+31	54.0	42.1	50.6	269	247	320	164	128
52	326	115	130	361	342	596	312	177
101	54.0	42.2	43.0	261	140	170	119	89
118	199	350	529	410	1056	526	512	294
153	606	173	464	489	594	495	470	157
138	485	161	348	381	468	393	373	116
180	424	88.5	302	288	336	92.4	255	136
PCBs TOTAL	2148	972	1867	2459	3183	2593	2204	1096

Table A.7.14.1 Body weights and lengths, tissue water and lipid contents in fish from Di Latte Lake.

	1	2	3	4	5	6	Mean	s.d.
Body:								
weight (g)	47.0	28.2	30.2	29.3	38.5	38.2	35.2	7.3
length (cm)	14.5	13.0	13.5	13.5	15.0	15.5	14.2	0.98
Tissue:								
water (%)	73.9	73.9	78.4	79.1	77.2	78.9	76.9	2.41
lipid (%)	2.78	5.75	3.07	4.75	4.11	3.83	4.05	1.10
Sex:	Female					Female		

Table A.7.14.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	4	5	6	Mean	s.d.
HCB	0.27	0.59	n.d .	3.82	0.06	0.35	0.849	1.469
HCHs								
a-HCH	0.09	0.11	n.d.	n.d.	0.10	0.24	0.09	0.09
g-HCH	0.57	0.38	0.15	0.93	0.30	2.36	0.78	0.82
DDTs								
op'-DDE	0.67	1.67	0.78	0.57	n.d.	n.d.	0.61	0.62
pp'-DDE	86.8	125	274	104	208	206	167	73.2
pp'-DDD	13.5	41.9	34.5	11.5	19.5	26.2	24.5	12.0
pp'-DDT	3.69	19.7	7.88	6.85	7.74	7.09	8.83	5.54
PCB no.								
28+31	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0.00
52	3.07	1.09	1.45	0.54	0.65	3.92	1.79	1.39
101	1.36	1.85	2.39	0.76	2.70	4.38	2.24	1.26
118	2.41	2.59	4.22	1.52	n.d.	n.d.	1.79	1.64
153	9.38	9.52	29.8	5.34	28.7	23.3	17.7	10.8
138	6.73	6.22	23.1	6.74	21.2	15.2	13.2	7.72
180	5.61	5.27	13.9	6.10	12.5	10.8	9.03	3.82
PCBs TOTAL	28.6	26.5	74.9	21.0	65.7	57.6	45.7	26.7

Table A.7.14.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	6	Mean	s.d.
HCB	9.86	10.3	0.00	80.3	1.48	9.22	18.5	30.6
HCHs								
a-HCH	3.24	1.91	0.00	0.00	2.43	6.27	2.31	2.34
g-HCH	20.50	6.61	4.89	19.58	7.30	61.62	20.1	21.45
DDTs								
op'-DDE	24.0	29.1	25.3	11.9	n.d.	n.d.	15.1	13.0
pp'-DDE	3123	2180	8932	2194	5061	5366	4476	2581
pp'-DDD	487	728	1124	242	474	684	623	300
pp'-DDT	133	343	257	144	188	185	208	79
PCB no.								
28+31	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	n.d.	0
52	110	19.0	47.2	11.4	15.8	102	51.0	44.8
101	48.9	32.2	77.9	16.0	65.7	114	59.2	35.0
118	86.7	45.0	137	32.0	0.0	0.0	50.2	53.6
153	337	166	971	112	698	609	482	335
138	242	108	753	142	515	396	360	247
180	202	91.7	451	128	305	283	243	131
PCBs TOTAL	1027	462	2438	442	1599	1504	1245	846

Table A.7.15.1 Body weights and lengths, tissue water and lipid contents in fish from Schwarzee ob Sölden Lake.

	1	2	3	Mean	s.d.
Body:					
weight (g)	78.8	122.6	78.8	93.4	25.3
length (cm)	20.3	22.0	20.4	20.9	0.95
Tissue:					
water (%)	68.3	71.5	72.5	70.8	2.19
lipid (%)	6.00	3.00	4.30	4.43	1.50
Sex:	Female	Female	Female		

Table A.7.15.2 Concentration of organochlorinated compounds (ng/g wet weight)

	1	2	3	Mean	s.d.
HCB	2.10	0.97	1.63	1.57	0.57
HCHs					
a-HCH	0.13	0.05	0.11	0.10	0.04
g-HCH	0.26	0.09	0.26	0.20	0.10
DDTs					
pp'-DDE	58.3	184	111	118	63.1
pp'-DDT	4.37	1.62	14.2	6.73	6.61
PCB no.					
28+31	0.40	0.32	0.44	0.39	0.06
52	0.21	0.07	0.47	0.25	0.20
101	0.56	0.40	1.64	0.87	0.67
118	1.76	0.73	4.88	2.46	2.16
153	10.9	4.95	35.7	17.2	16.3
138	9.68	4.93	33.7	16.1	15.4
180	5.69	3.34	18.8	9.26	8.31
PCBs TOTAL	29.2	14.7	95.6	46.5	43.1

Table A.7.15.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	Mean	s.d.
HCB	34.9	32.0	37.7	34.9	2.86
HCHs					
a-HCH	2.24	1.67	2.60	2.17	0.47
g-HCH	4.31	3.09	6.11	4.50	1.52
DDTs					
pp'-DDE	971	1039	2576	1529	908
pp'-DDT	72.8	53.4	329	152	154
PCB no.					
28+31	6.70	10.4	10.2	9.08	2.07
52	3.51	2.14	10.9	5.52	4.71
101	9.36	13.3	38.1	20.2	15.5
118	29.4	24.0	113	55.4	49.8
153	182	163	825	390	377
138	161	162	780	368	357
180	94.8	110	434	213	192
PCBs TOTAL	487	485	2212	1061	998

Table A.7.16.1 Body weights and lengths,tissue water and lipid contents in fish from Zielony Staw Lake.

	1(64)*	2(65)	3(66)	4(67)	5(68)	Mean	s.d.
Body:							
weight (g)**							
length (cm)	20.5	19.0	20.5	19.0	21.5	20.1	1.08
Tissue:							
water (%)							
lipid (%)	0.55	1.77	2.35	1.89	1.64	1.64	0.67
Sex:				Female			

* Original fish code between brackets

** Fish weight has not been measured since these fish have been received partly dissecated.

Table A.7.16.2 Concentration of organochlorinatedcompounds (ng/g wet weight)

	1	2	3	4	5	Mean	s.d.
HCB	0.04	0.05	0.05	0.10	0.06	0.06	0.02
HCHs							
a-HCH	0.01	0.01	0.01	0.02	0.02	0.01	0.01
g-HCH	0.10	0.05	0.16	0.16	0.15	0.12	0.05
d-HCH	0.012	0.005	0.015	0.017	n.d.	0.01	0.01
DDTs							
pp'-DDE	4.62	7.34	12.34	6.6	10.54	8.29	3.11
pp'-DDT	0.15	1.24	0.21	1.76	0.84	0.84	0.69
PCB no.							
28+31	1.31	0.50	1.05	1.25	0.58	0.94	0.38
52	1.55	1.21	2.07	0.74	0.56	1.23	0.61
101	0.14	0.24	0.36	0.31	0.38	0.29	0.10
118	0.45	0.22	1.37	0.73	1.10	0.77	0.47
153	0.77	1.24	2.64	1.09	1.76	1.50	0.73
138	0.55	0.99	2.16	0.87	1.53	1.22	0.63
180	1.12	1.46	2.61	0.90	1.64	1.55	0.66
PCBs TOTAL	5.89	5.86	12.26	5.89	7.55	7.49	3.58

Table A.7.16.3 Concentration of organochlorinated compounds (ng/g lipid weight)

	1	2	3	4	5	Mean	s.d.
HCB	6.96	2.76	1.96	5.15	3.42	4.1	2.0
HCHs							
a-HCH	2.59	0.55	0.51	1.31	1.00	1.19	0.85
g-HCH	18.3	2.83	6.86	8.51	9.45	9.20	5.70
d-HCH	2.14	0.28	0.64	0.91	n.d.	0.79	0.83
DDTs							
pp'-DDE	845	414	525	350	643	555	197
pp'-DDT	26.5	69.7	9.00	93.1	51.1	49.9	33.4
PCB no.							
28+31	240	28.2	44.9	66.1	35.7	83.0	88.9
52	283	68.0	88.1	39.1	33.9	102	103
101	25.9	13.8	15.5	16.3	23.4	19.0	5.3
118	82.9	12.1	58.3	38.5	67.1	51.8	27.3
153	140	69.9	112	57.5	108	97.5	33.5
138	100	55.6	91.9	46.3	93.4	77.5	24.7
180	205	82.3	111	47.7	100	109	58.7
PCBs TOTAL	1077	330	522	311	461	540	342

Table A.7.17. Statistics. Results of (partial) RDA of the fish-heavy metal concentrations in 73 fish from 15 lakes using different sets of predictor variables and covariables.

Predictors	**Covariables**	**% Variance Explained**	**p**
Length + weight + age + sex + stage +species + locality	-	83.8	0.0004
Locality	-	78.2	0.0004
Locality	Species	66.2	0.0004
Locality	Species + sex	66.4	0.0004
Locality	Species + sex + stage + age	48.3	0.0004
Locality	Species + sex + stage + length + weight + age	44.6	0.0004

p = probability, as estimated by an exact Monte Carlo probability based on 249 unrestricted permutations.

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