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1.0. WORKSHOP OVERVIEW

The Fifth Annual DFO LRTAP Workshop was held at the STEL Battery in St. John's, Newfoundland October 9-11, 1990. The thirty-six registered participants included representatives from DFO Headquarters, all DFO Regions excepting the Gulf Region (which does not have a LRTAP program), Environment Canada (including the Environmental Protection Service, Canadian Wildlife Service, Atmospheric Environment Service), Memorial University (Biology and Chemistry Departments), the Government of Newfoundland and Labrador (Departments of Environment and Lands, Mines and Energy) and the private sector. The meeting was also attended by the Newfoundland Acid Rain Technical group (NARTG), a committee with representation from Provincial and Federal governments and Memorial University, which serves to coordinate LRTAP activities within the Province of Newfoundland and Labrador.

The presentations and discussions of the workshop were taped and transcribed to facilitate the compilation and editing of the workshop proceedings. Selected excerpts from the taped proceedings have been included in this document and the full content of the workshop, both text and audio tape, is available upon request. Material presented in the Proceedings is a combination of edited versions of oral presentations at the workshop and, where available, written reports summarizing research activities of the Regions, by category.

On Day 1 of the workshop, Regional reports were presented on ongoing and proposed future research activities. The Research Report section which was organized into six categories and, within each category, presentations were grouped by Region. Research Report categories were as follows:

1. Cause and Effects Studies
2. Mitigation Studies
3. Organic Contaminant Studies
4. Metallic Contaminant Studies
5. Palaeoecology Studies
6. Biomonitoring Program

On Day 2, the Research Report section was completed with regional presentations on the DFO Biomonitoring Program. A report of LRTAP activities in the Pacific Region was also presented. Dr. Jerry Payne, DFO Newfoundland Region, provided the workshop keynote address entitled 'Organics in the acid rain drizzle: Are they really important?'. An overview of the National LRTAP Program was provided including a review of the highlights of the National LRTAP and Acid Deposition Assessment Report as well as a review of the National Program commitments and priorities over the next five years. A perspective on socioeconomic contributions to the National Program was presented. An overview of DFO modelling efforts, including both work completed to date and planned future developments and refinements, was provided. A presentation on management for the Biomonitoring Program and activities related to the development of a centralized data base was provided. At the completion of Day 2, Ms. Iola Price, DFO LRTAP Program Manager, addressed the workshop with a perspective on ongoing and future management of the Departmental LRTAP Program.

On Day 3, the workshop was divided into three discussion working groups to address key programming areas within the DFO LRTAP program. The three groups, including chairpersons, were as follows:

1. Biomonitoring (I. Davies, Central and Arctic Region)
2. Cause and Effects (G. LaCroix, Scotia-Fundy Region)
3. Palaeoecology (S. Ray, Newfoundland Region, presentation by J. Smith, Scotia-Fundy Region)

The workshop concluded with summary presentations from the three discussion working groups and an overall workshop summary was provided by the DFO LRTAP Program Manager, I. Price. Key issues raised in the working group discussions, major recommendations, objectives of the National LRTAP Program over the next five to six years, as well as potential problems facing the Departmental LRTAP Program are summarized below:

Cause and effect research:

-need for evaluation and understanding of the extent and mechanisms of chemical and biological recovery in lakes and rivers;

-more investigation of the role of nitrogen deposition in acidification and its relationship to critical loads is required;

-need for the development and refinement of a hierarchy of site and regional models for fishery/hydrological responses in both lakes and rivers in relation to acidification and recovery;

-need to evaluate fish movements in relation to acidification episodes to more fully define acidification impacts;

-need to develop and apply 'performance tests' on sub-lethal indicators;

-need to assess the importance of metallic and organic contaminants and effects on biota;

-need to define the future role of organic and metallic contaminants in the DFO LRTAP research agenda and recognition of problems arising from the lack of coordination and a well defined goal.

Palaeoecology research:

-need to establish a working group to coordinate and establish objectives for palaeoecological research for the DFO LRTAP program;

-need to focus on transfer functions to relate diatom assemblages to contemporary pH and the possibility of exploring new approaches to ensure confidence in these relationships;

-future work should focus pH reconstruction in lake sediment cores to look at a comparison of pre-acidification and contemporary pH, and not be concerned with developing a full recent pH history. This would eliminate problems related to integrity of the core (bioturbation and sediment mixing);

-should use comparison of acidification history (above) to evaluate efficacy of current emission reduction targets and critical loads;

-use dual (or more) tracers when dating core strata;

-consider a complete evaluation of pH history only in lakes with laminated, unmixed strata as determined from dating.

Biomonitoring:

-it is important to address resource shortfalls and effects of these shortfalls on the biomonitoring program, as originally developed. The program was designed to be a 'minimum effort' so there is little latitude for reduction in scope;

-there is a need to more fully integrate quality assurance and quality control (QA/QC) measures into the program. A separate QA/QC budget could be set up, outside of regional biomonitoring allocations and to be administered by the DFO Biomonitoring Working Group, to meet this need;

-the program urgently needs the establishment of a national data base (under development). The national data base, once developed, should be administered by a full time program manager, possibly funded out of the DFO LRTAP allocations.

National Program Summary:

-the focus of the National LRTAP Program over the next five (six) years will be related to (1) extension of the domestic acid rain control program and response of the environment to reduced sulphur dioxide emissions; (2) the provisions of the Canada/U.S. Air Quality Agreement; and (3) the U.N. Economic Commission for Europe LRTAP Convention and the Sulphur Dioxide and Nitrogen Oxide Protocols.

Research and monitoring thrusts will include the following:
- -monitoring the effectiveness of emission control measures on reducing ecosystem stress;
- -determining rate/extent of aquatic recovery;
- -determining causes of forest decline;
- -determining the health effects of LRTAP;
- -understanding the role of nitrogen in acidification and developing critical loads for nitrogen compounds;
- -research/monitoring/modelling in support of the NOX/VOC (Volatile Organic Compounds) Management Plan.

DFO Program Summary:

-the future DFO LRTAP Program (LRTAP V) will be funded under the Green Plan. The program will focus on acidifying pollutants and will not subscribe to the broader view of LRTAP that has, throughout LRTAP IV, included organics and toxic contaminants. Headquarters will strive to ensure that ongoing and approved projects with organic/toxics components are considered for funding under the DFO Science Green Plan Program on Toxic Chemicals;

-with the introduction of the Green Plan, the pending Canada/U.S. Air Quality Agreement, and the lessening of activities of acid rain lobby groups the public perception of the acid rain problem is changing. The public perceives that acid rain issues are well understood and that governments have taken the necessary steps to address the problem. The lack of public attention/concern for the issue could hurt future funding for LRTAP research, particularly under current economic conditions;

-there is a need for more accountability in the DFO LRTAP program as to how resources are utilized. Requirements for short, concise annual project reports will be implemented to provide Headquarters with feedback on regional LRTAP initiatives;

-with the uncertainty as to funding of the program in recent years, and the shift in focus a result of inclusion in the Green Plan, the DFO LRTAP Program lacks a clear direction, particularly with respect to research activities. The LRTAP Program Manager, supported by the LRTAP Subcommittee, will endeavour to develop a clear plan for the Departmental program, in order to direct and coordinate activities under the 5 year life of the Green Plan.

2.0. INTRODUCTION

Welcoming Address

Dr. Payne welcomed the participants on behalf of Mr. Larry Coady, Regional Director Science, who was unavailable. Dr. Payne emphasized to the participants the value of the Newfoundland fishery and stated that there was some perception that declines in the cod fishery may be due to pollutants and indicated that acid rain programs to determine contaminant levels are now included in the Northern Cod Program. Dr. Payne asked participants to consider such things as the biological significance of trace levels of organic contaminants in fish. He stated that he did not know of any information to suggest that levels of organic contaminants found would have any effect biologically but stated that he thought that heavy metals are more important than organics in the long term. Dr. Payne concluded his address by expressing his appreciation to the organizing committee and gave his good wishes to the participants for 'fruitful discussions' during the workshop.

Workshop Objectives

Ms. Iola Price, DFO LRTAP Program Manager, gave the Introduction for the workshop and asked participants to focus on what they thought the priorities for the Departmental LRTAP Program should be. She outlined the program for the workshop, including the intention to divide into discussion working groups, and asked that the working group chairpersons identify priorities and funding requirements for each of three key programming areas. She referred to her intentions, later in the workshop, to outline the future direction of the LRTAP program and to provide as much information as she could on how the program fit into the Government's intentions regarding the Green Plan.

3.0. KEYNOTE ADDRESS

ORGANICS IN ACID RAIN DRIZZLE: ARE THEY REALLY IMPORTANT?

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"There is no point in getting into a panic about a risk until you have compared the risk you care about with those that you haven't - but perhaps should."

Over the past decade, the public has often been subjected to a barrage of one-sided information on so-called toxic chemicals. As a result, a perception has formed that all chemical exposures, irrespective of dose, are of key importance in influencing rates of birth defects and cancer.

A number of chemicals have been screened in animal studies and shown to be carcinogenic, but the question of hazard or risk is a much more difficult to answer. Such screening includes very high dose levels, the argument being that the intrinsic carcinogenic character of the chemical substance may be independent of dose level, and high doses facilitate detection. However, many compounds are carcinogenic only at concentrations that seem to have little real relevance when viewed in terms of relative risk. Furthermore, many scientists would question the tenant that the intrinsic carcinogenic character of a chemical substance is independent of dose level. A more reasonable assumption is that many factors can influence chemical carcinogenicity, including dose, route of administration, duration of treatment, metabolite transformation, and status of important detoxification chemicals such as glutathione. Accordingly, potency of a chemical rather than its presence should be of key importance in carcinogenesis.

Only a very small number of chemicals or chemical complexes have been shown to be carcinogenic in humans, and these mostly under conditions of high-level exposures for prolonged periods. Important examples include tobacco smoke, chewing tobacco mixtures, aromatic amines, mineral dusts, drinking water contaminated with very high levels of arsenic, and food products contaminated with fungal aflatoxins.

Cancer rates in general have been declining in the western world in the past few decades. No evidence suggests that synthetic chemicals, some of which have been in use for several decades and are found as trace contaminants in food, have significantly influenced the rate of any type of cancer in the general population. Consumption of fish products, which may contain trace levels of contaminants, is often quite small, for instance, less than 2 kilograms per person per year in most Mediterranean countries.

The experimental and epidemiological evidence that implicates PCBs as potentially important human carcinogens is not convincing from a scientific perspective, especially in relation to the levels found in food.

Epidemiologic studies on DDT, HCB, or toxaphene cannot provide unequivocal evidence for distinct increases in cancer rates in those individuals exposed in production plants (or similar) to relatively high levels on a daily basis for prolonged periods. Therefore, in terms of relative risk, it is difficult to implicate an importance for trace levels of these substances in food.

Many persistent organohalogens are presently not in use or restricted in use to a major degree limiting their importance in the future.

Heavy metals have been observed to be important human carcinogens only under prolonged exposures to relatively high levels in the form of mining dusts or refinery associated fumes.

Sensitive screening methods are discovering many sources of natural and cooking-derived mutagens in plant and animal tissues. The scientific evidence gives no reason to assume that these are not much more important sources of ingested carcinogens than synthetic chemicals.

Given the recent experimental evidence on the importance of diet and nutrition in carcinogenesis, a new paradigm is needed to assess carcinogens in food. This paradigm should recognize not only the importance of natural mutagens and carcinogens but also, for hundreds of millions of people, the importance of malnutrition and poverty, which seem to be vastly more important in influencing carcinogenicity than synthetic chemicals.

Analysis (with all its associated costs to government agencies) carried out to determine if a chemical has a risk of one, two, or ten in a million of causing cancer seems an elitist exercise when viewed from the perspective of the very high risk of cancer and other diseases found in economically disenfranchised people. This group is thought to be 10 to 20% of the population even in such "privileged" countries as Canada.

Many people, including scientists, health and environmental officials, and toxic tort lawyers, have a vested interest in being virtuosos of the negative in discussion of toxic chemicals. However, a focusing of attention on phantom or insignificant risks can result in a betrayal of the risks that are important in causing cancer and other types of poverty-associated disease. For instance, in industrialized countries alone, poverty-related diseases could be responsible for hundreds of thousands of premature deaths.

SPECIFIC COMMENTS AND CONCLUSIONS ABOUT LEVELS OF CARCINOGENS IN AQUATIC ORGANISMS AND IMPLICATIONS FOR HUMAN HEALTH

Organohalogens

Studies such as those carried out by the coordinated monitoring project of the International Council for the Exploration of the Sea (ICES) have demonstrated that the concentrations of major organochlorine pesticides and PCB residues in fish from the Northwest Atlantic, the Northeast Atlantic, and the North Sea are generally well within the guidelines set for fish products by regulatory agencies in various countries. Likewise, extensive surveys in the Gulf of Mexico and along the northeast and northwest coasts of the United States have demonstrated (with exception) the presence of relatively low levels of PCBs in finfish and shellfish.

However, finfish and shellfish collected near point sources of gross pollution in harbours, estuaries, rivers, or in the immediate vicinity of sewage dumping grounds and outfall sites can often be expected to contain unacceptable or near unacceptable levels of major persistent organochlorines such as PCBs and DDT. Such grossly polluted areas are - or should be - generally recognized as being "off limit" to fishing.

In addition, fish taken from some regions of the Great Lakes contain elevated levels of PCBs and other priority chemicals and health advisories have been in place in the affected Canadian provinces and American states for some time. Elevated levels of PCBs have also been detected in some species of finfish from the Mediterranean Sea, but concentrations that exceed guidelines for human consumption appear to be exceptional.

On the basis of scientific evidence, both experimental and occupational, on DDT, PCBs, mirex and toxaphene, it is difficult to make a credible case that the consumption of fish from the Great Lakes could significantly affect cancer rates in humans. However, monitoring and surveillance of any heavy consumers of fish products from the Great Lakes (or any similarly exposed populations consuming large quantities of fish from grossly polluted harbours, estuarines or rivers) should be continued. Also the dietary habits of any populations consuming meat and oils from marine mammals heavily contaminated with persistent organohalogens should be assessed.

Hydrocarbons

Hydrocarbons are not biomagnified to any extent in the tissues of finfish. This is consistent with the presence of a highly inducible enzyme system in fish which has been shown to respond to the presence of hydrocarbons under field as well as laboratory conditions. Shellfish species such as bivalves can accumulate high body burdens of hydrocarbons at point sources of high-level contamination such as oil-spill sites, but rapidly depurate in clean water.

Consumption of the trace levels of hydrocarbons found in tissues of fish should be quite trivial compared with, for instance, the levels generally regarded as safe in the occupational environment from such sources as asphalt fumes or coal and oil volatiles. The intake of hydrocarbons from other sources of food could also be quite low in comparison with the levels consumed in fish products.

Even the consumption of fish contaminated with high levels of a variety of mutagenic hydrocarbons from combustion/pyrolytic sources such as creosote (a highly unlikely occurrence) could have a very small carcinogenic potential in comparison with consumption of the potently mutagenic and carcinogenic heterocyclic amines formed upon cooking food.

Heavy Metals

The extensive documentation on the concentrations of carcinogenic heavy metals (cadmium, mercury, nickel and chromium) in finfish and shellfish in areas covered by the ICES coordinated monitoring programme, coastal Europe, the Mediterranean, Asia and the Pacific Ocean has been reviewed elsewhere [1-3]. Heavy metal carcinogenicity in humans has been associated with gross exposures for prolonged periods to mineral dusts or fumes under mining and refining conditions. Little concern appears to be generally expressed about the levels and particular chemical species of "heavy metal carcinogens" found in fish. Concentrations ingested through the consumption of fish products should normally be quite trivial compared with, for instance, the levels regarded as safe in the occupational environment (respiratory intake is considered to be 5000 cubic meters per year). Any focus of concern should be directed towards those populations consuming large quantities of fish from hot-spot sources of metal pollution connected with mining or metal refining.

Few data are available on the levels of arsenic found in fish. Although the levels ingested via fish products would be expected to be quite small in comparison with levels regarded as safe in the occupational environment, the consumption of water contaminated with very high levels of arsenic is known to cause cancer in humans. Thus, an evaluation of the carcinogenic potential of the particular arsenic compound(s) found in fish products would be of interest.

<u>Vvolatile Organohalogens</u>

Compounds such as methylene chloride, chloroform, perchloroethylene, and ethylene dichloride have recently been shown to be carcinogenic when administered to experimental animals for prolonged periods in large doses. Concern has recently been expressed about these compounds since they are often found in groundwater originating from industrial wastewaters and waters that have been chlorinated. However, due to their volatility and metabolic lability, these compounds are not considered to be of concern as major fish contaminants. Studies conducted on fish collected near the Los Angeles sewage outfall, which contains relatively high levels of volatile organohalogens, supports this hypothesis.

SPECIFIC COMMENTS AND CONCLUSIONS ON CARCINOGENESIS IN AQUATIC ORGANISMS

Superficial neoplasms, tumours or papillomas in fish were often reported during the early 1900's, long before synthetic chemicals came in use to any extent. A viral etiology has often been suggested for papilloma diseases in flatfish. In addition to any presumed effects of synthetic chemicals, a reasonable suggestion would be that disease incidence could be modified by fish behaviour or general stress resulting from such factors as anorexia, malnutrition, sub-optimal temperatures and salinity. In addition to suggestions of a viral etiology, studies have demonstrated that inflammatory responses from bacterial or parasitic infections could account for some of the lesions reported as superficial neoplasms or tumours in fish.

Evidence from studies in the Northwest Pacific, in Puget Sound and Vancouver Harbour indicates that point sources of gross pollution from urban/industrial sources could lead to increased rates of papilloma-type diseases in flatfish. Whether the diseases are caused directly or indirectly by synthetic chemicals or due to general debilitation resulting from bacterial or viral infections precipitated by such factors as high organic loading or fluctuating salinities has not been established.

Critical studies in the North Sea have often failed to find a strong association between superficial papillomas, nodules or tumours in fish in relation to the relatively high levels of pollution in coastal areas. In addition, it has been demonstrated that hydrographic conditions, fish behaviour and seasonality can markedly alter the incidence of disease.

The incidence of superficial tumors and neoplasms in fish appear not to have been affected in the general area of dumping grounds in the North Sea and the Northeast Atlantic. The papillomas or skin nodules found in fish taken from relatively clean waters in coastal Newfoundland were firmly established to have a viral association. Evidence is very good that the high incidence of pseudobranchial tumours often found in such species as cod and whiting have no specific association with pollution.

Because of problems in identifying and interpreting the nature of various superficial tumours which may be linked to a viral, bacterial, or parasitic etiology, more emphasis is being placed on histopathological studies of various tissues.

Liver and other tumours have been shown to be prevalent in fish taken from the grossly polluted Hudson and Fox Rivers which flow, respectively, near the conurbations of New York and Chicago in the USA. Boston Harbour on the northeast coast of the USA is considered to be grossly polluted throughout. The high prevalence of neoplasms found in fish in the Harbour was confined to a sewage outfall area, demonstrating the importance of "dose-response" relationships even in relatively small areas of gross pollution.

Considering both field studies on skin tumours or papillomas and various other types of tissue neoplasms, only a few studies have provided strong evidence for cause-effect relationships. These include the neoplasms observed in fish taken from (a) the Buffalo River, which is contaminated with aromatic amines and very high levels of creosote hydrocarbons; (b) the Black River, which is contaminated with very high levels of creosote hydrocarbons (and similar hydrocarbons from combustion/pyrolytic sources; and (c) a region of Puget Sound which is also highly contaminated with aromatics (suggested to be due to creosote and similar hydrocarbons from combustion/pyrolytic sources).

Aromatic amines used in the production of dyes are well-known potent mutagens and carcinogens (including in humans) and the diseased fish in the Buffalo River were taken from an area receiving seepage from old disposal sites for dye-products. A role for creosote or similar hydrocarbon complexes is also supported by the known mutagenic potency of fractions enriched in aromatics from combustion/pyrolytic sources of petroleum hydrocarbons.

Studies on neoplasia in fish in Puget Sound failed to find a correlation with levels of persistent organochlorines such as PCBs. This failure is consistent with the nonmutagenic and weak carcinogenic nature of these compounds and supports the hypothesis that organohalogens are only important as carcinogens in high doses when they may act in some epigenetic manner modulating enzyme or hormonal systems or altering cell to cell interactions.

Fish from the Rhine River, which is generally considered to be heavily or grossly polluted with a large variety of contaminants from urban and industrial sources, has a very low frequency of neoplasms. This seems to illustrate the importance of "dose" even in waters and sediments highly contaminated with many, if not "all", synthetic chemicals of general concern.

The only field study to demonstrate a relationship between fish neoplasia and heavy metal pollution, Torch Lake in Michigan - which is contaminated to an extreme degree with tailings from a copper mine - has recently been questioned. Special chemicals used in the extraction process for copper, and not the metal itself, could be the cause of the very high tumour frequency found in fish in the lake.

Tumorous lesions were not observed in fish (in laboratory studies) or in oysters (from an oil spill in France) exposed to high concentrations of petroleum hydrocarbons for several months. Hæmatopoietic neoplasms often found in some species of bivalves appear to be an infection which can increase under conditions of general stress. No good evidence points to the disease being directly caused by chemical carcinogens.

Natural compounds in decomposing sewage or the environmental conditions associated with any such high organic loading, and not synthetic chemicals, may be of key importance in influencing carcinogenesis/"tumorigenesis" in the marine environment.

Overall, the claim that an "epidemic" of cancer in the marine environment is occurring does not seem justified. On the contrary, given the long list of industrial and natural chemicals that can be classified as having carcinogenic potential, cancer is being found in association with point sources of what most observers would classify as gross pollution conditions. The "sewer and dirty harbour syndrome" should not be generalized to give the false impression that our seas and waterways are full of cancerous fish.

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JERRY PAYNE: My recommendation as I said is somewhat of a conundrum in the ..[sentence was not completed]. We need more information on what we call dose responses. It's premature. Like if you look at the, say, PAH business in terms of ocean dumping or guidelines. It's very difficult to use a basis in science to suggest regulations at the moment. For example if we use the MFO as a response, as a toxic response, you see, we're way beyond levels which are possibly background. So, does that mean then that we have to landfill. What do we do with that kind of ... [sentence was not completed]. So we need better data on dose responses relationships.

KEN MINNS: I'm not sure that I agree with you. It seems to me that a lot of what you're talking about really lies in the realm of science. It's more a question of human choice. It seems to me that when I eat food I should have some choice as to whether there are additives in it. If I want to have a salt shaker with DDT in it then that's my choice.

JERRY PAYNE: I agree with you. I agree with you but when you come as a regulator if you're looking for a force say this group is advocating we ban this or ban that, whatever. What I'm saying is you have to try to present possibly to that group that makes those decisions both sides of the coin. You have to try, as a scientist, to put both sides of the issue on the table. You know, like for argument's sake, to me as a toxicologist, if I didn't know the difference I could be upset say about chlordane or what have you. If you have traces of chlordane in your food you have a right to know there's chlordane there. But if I know the relative risks of chlordane, you know eating fish with chlordane is approximately equivalent to eating 4 spoonfuls of peanut butter every month. We can't obviously have a labelling system where we put all those things out but at the moment the information has been somewhat one sided. We can be detracting resources from things which are really important in causing mortality and morbidity in terms of the unit population and putting all our resources on things which are not so important, okay.

KEN MINNS: Yeah, that was the other thing I wanted to ask you about. You, at one point had a slide which include the phrase 'public interest' and I was wondering who was going to define that?

JERRY PAYNE: Well I think it's the public. I don't think it's the Avalon Wilderness Society or Greenpeace. I think when you use the word 'public', people use the word 'public' very loosely. They are just not advocacy groups but I think that we are basically, you get the advocacy groups saying we're acting on the basis of public interest are often they are not acting on the basis of the interest any more than any other group. The best example, is like the DNA issue in the U.S. and Harvard back a decade ago in which you picked at random, okay, what you call public and give those people, what you call a jury, and that's totally different. That's totally different from picking, okay, a, you know, not to malign any of the environmental groups, but saying that they are the spokesmen for the public is also equally false.

BOB WILSON: Jerry, you did ask me whether I thought the level of PAHs for ocean dumping should be one part per million and I guess the answer to that question is no. I don't think it should be as low as that. I don't know how high it should be but I don't think it should be as low as one part per million. I wouldn't have raised that subject since this is a meeting about acid rain except that gives me a chance to talk about one of our favourite topics which is bioassays. Your sediment from the Candlestick Pond area, I think your incorrect in saying you couldn't ocean dispose it if it had 4.05

ppm of PAH in it. In fact, what would happen is that you would be asked to do some toxicity tests before you could ocean dispose of it. If the sediment passed the bioassays then you would be allowed to take it off the dump site of your choice and throw it over the side. The two bioassays that we're using on the West Coast are the amphipod bioassay and the second one is the one that you referred to as one of the tests selected by ICES. It's the oyster bioassay and we're having real problems with the oyster bioassay. In several of the cases that we've looked at, well in fact of the 10 most recent applications that have been processed using the oyster larvae test, there have been no passes and, in a couple of tests at least, there has been a negative correlation between toxicity in the test and the level of PAH and sediment. More oyster larvae survive and grow normally with higher concentrations of PAH in sediments. I think that illustrates one of the dilemmas that people have in applying these scientific principles to try to produce less absurd nonsense out of the previously more nonsensical information that we have.

JERRY PAYNE: Yeah, I agree with you. You agree with me, I think. That's one of the points I'm making. But even if you back up a bit though, I mean I don't think acute toxicity tests in embryo bio-assays is a relevant test for long term chronic toxicity with PAH. I mean you get into the tumour trials usually in Black Rock Harbour you may need about 2 to 3 ppm for 3 years exposure to get a tumour in a fish. So it's kind of a little bit of chancier to suggest that once you go down to Portugal Cove and find 2.5 PPM you can do a battery of tests to clear it. We know conceptional those battery of tests had to be something like a long term cancer trial or something like that in flatfish. This is why we need a little bit more dose response, you know, biological effect testing.

IOLA PRICE: We live in an imperfect world and toxicity tests and environmental tests are never precise and never give the right kinds of answers to the people who actually need those answers. But one point I would like to make about chlordane or any of the other compounds that you've mentioned is that biologically speaking organisms living today have not had sufficient time to develop the biological responses to properly detoxify those materials and that's why, in fact, some of them have been banned or their use severely restricted in North America because toxicologists, in fact, do realise that there are organisms other than fish and other than humans who are showing dose responses and their biological systems have not yet responded by producing the kinds of enzymes that would detoxify those materials before there is some other kinds of biological response.

JERRY PAYNE: Well it's yes and no. I disagree with you. The evolution that's been looked at. There's really no basis for the concept as you put, you know, adaption phenomenon but I do agree with you about the birds. The birds in the Great Lakes is one case, you know. The adaption thing has been somewhat looked at and there's basically no difference whether you're adapted or not adapted - to a certain extent. Except in a case where the DDT resistance in some of the insects. But I do agree, the bird situation in the Great Lakes is one case in which you certainly do have evidence of real effects on real life animals in a real world.

4.0. RESEARCH REPORTS

4.1. CAUSE AND EFFECT STUDIES

Central and Arctic Region R. Hecky

Overview of Cause and Effect Studies on Ecosystem Acidification at ELA

Four major cause-effect acidification studies are now underway at ELA: (1) Lake 223 recovery, (2) Lake 302S acidification, (3) the Lake 239 wetland acidification (with University of Alberta), and (4) the Lake 302 upland snowmelt acidification project (with OME). These four major initiatives are reported on in the attached reports and abstracts from the Glasgow International Symposium on Acidic Precipitation.

The Lake 223 recovery is presenting us with good news and bad. Without any active mitigation effort, i.e. liming, etc. the lake's pH has risen due to internal alkalinity generation and to a lesser extent dilution. Positive responses have been demonstrated, most importantly the successful reproduction of fish species which were not extirpated by acidification to pH 5.1. For the most part, the change in reproductive success has occurred at pH's similar to those at which reproductive failure occurred during acidification. The bad news is that community composition of phytoplankton, zooplankton and benthos has not responded in a similar way. Species changes are not occurring at the same pH's as during acidification. There is a hysteresis in the response, and it now seems that damaged communities may have limited ability to return to their pre-acidification state. This result was unexpected because the intensity and duration of acidification was much less in Lake 223 than in many lakes in eastern Canada. The short term and relatively mild acidification of L223 and the presence of upstream lakes was expected to constitute an optimal case for recovery. The prognosis for eastern Canadian lakes may be gloomier than hoped. It appears that long-term biological damage has been done, and the full consequences of that remain to be seen. Lake 223 will help answer that question as its recovery proceeds.

The Lake 302S experiment is demonstrating that not just biological changes but biogeochemical processes became altered as pH's descend below 5.0. There are clear signs in L302S that the sulfur and nitrogen cycles are being disrupted at pH 4.5 and the internal generation of alkalinity drastically reduced. This is linked in part to disruption of the littoral dynamics of the lake as the metaphytic filamentous green algae develop and eliminate or replace the natural epilithic and epiphytic phytobenthos. The interannual variability in the biological communities of L302S also significantly exceeds that of control lakes or L223 at its lowest pH. Lake 302S now seems much more sensitive to meteorological events and annual climate suggesting that important homeostatic mechanisms have been weakened by acidification to pH 4.5. This experiment, as well as elucidating some important consequences of acute acidification in lakes, has demonstrated the crucial role of littoral communities in the metabolism of the whole lake. The experiment also demonstrates that there may be important interactions between the acidification of lakes and climate change because warm, dry years favor metaphyton growth.

The wetland acidification experiment doubled the loading of sulfuric acid to the treated portion of the wetland in 1990-91. Previous additions had been at the rate of 20 kg S ha^{-1} which is comparable to Eastern Canada and 2x natural loadings at ELA. The doubled rate is more comparable to European situations where wetland degradation is well-documented. At 20 kg S ha^{-1} no significant adverse effects have been documented on wetland vegetation and sulfur retention has been shown to be more a function of hydrology than acid addition. Within the bog various nitrogen addition rates have been made and it is now clear that most of this nitrogen goes into new vegetative growth in the wetland with nearly total retention of N. Only at the highest rate of N addition, 35 kg N ha^{-1}, was there no growth response. Rates of addition which kill Sphagnum in Europe were found to be stimulatory at ELA suggesting that depositional history will be an important factor in defining critical loads for N.

The snowmelt acidification of the L302 upland minicatchment has successfully documented how the additions of H_2SO_4 and NH_4NO_3 (50 kg ha^{-1} y^{-1} as sulphate with an equimolar addition of nitrogen) can modify watershed processes. Acidification led to decline in export of DIC, alkalinity, and organic acidity while increasing the export of most cations and aluminum. Most disturbing was that the increase in release of total aluminum was accounted for by ionic aluminum for which export doubled in the acid treatment. Much of this Al is being mobilized from bare. bedrock surfaces as the normally stable weathering rind is leached by acid. The nitrogen additions have led to nearly complete retention of ammonium while exporting almost all the nitrate added. Analysis of a huge chemical data set is continuing, and will eventually elucidate at a fine, spatio-temporal scale the significant biogeochemical processes operating in upland watershed areas. These watershed processes are the source of much uncertainty as to the fate of LRTAP acid ions in watersheds and their significance to risk assessment models.

Future Research

Our sulfur research is now reduced to recovery of L223 and the low pH condition in L302S. Future research on sulfur issues will be directed to recovery aspects. A major outstanding issue is the role of nitrogen. Current national and international accords do not address NO_x, and its lack of control may undermine all the effort directed towards sulfur control. We have established its acidification potential. Canadian Shield lakes have very limited ability to withstand NO_3^- additions before they begin to acidify at rates comparable to sulfur additions. The outstanding issue is the ability of terrestrial systems to absorb nitrogen loadings before they saturate and release N. Our wetland experiment has given the short term answer to this question, i.e. nearly total retention. But the uplands do not show this capacity at least during snowmelt. We propose to continue the upland experiments by moving to nitrogen loadings throughout the ice-free season in addition to our snowmelt program. Gradations of N loading will be applied to isolated minicatchments to define their critical loads. This research must be done and we have a unique experimental set-up in place with which to conduct the research.

A major modifying factor in defining a lake's critical nitrogen load is its phosphorus loading. The L302N experiment will investigate the ability of phosphorus to offset lake acidifcation by nitrogen and the potential of phosphorus to mitigate nitrification.

Lake 223 Synopsis up to Fall 1990

Prepared by K.H. Mills

Lake 223, a small headwater lake in northwestern Ontario, was experimentally acidified with sulfuric acid from 1976 (pH 6.5) to 1981 (pH 5.1), and maintained at pH 5.1 in 1982 and 1983. Starting in 1984, we reduced acid additions and the lake pH gradually increased. We monitored changes in primary production, phytoplankton, littoral algal communities, zooplankton, benthos, and fishes during both the acidification and recovery phases of the experiment (see Mills et al., 1990, Abstract, Glasgow International Symposium on Acidic Precipitation, attached).

Primary production generally followed the trends in reference lakes, although there might have been a slight increase during the early years of acidification (1977-1981). The important point here is that we neither saw a decrease in primary production during acidification, or an increase during recovery. There were no real signs of phosphorus being preferentially lost to sediments during acidification, or released during recovery.

The phytoplankton community changed drastically with increased dominance of dinoflagellates during acidification from 1975 prior to acidification (pH 6.7) to 1982 (pH 5.1) in the middle of the three greatest years of pH depression. During recovery to pH 5.8 there has not been a return to the former community. The most abundant species during the height of acidification continue to be the most abundant species during recovery. Diversity decreased during acidification, and has proportionally increased during recovery, but we definitely do not have a similar community structure at pH 5.8 to that at a similar stage during acidification.

The zooplankton community structure (in terms of proportional representation of major groups in the community) has returned to preacidification structure, but a similar story to the phytoplankton species structure is present here, also. The primary cladoceran that appeared in the lake during acidification, <u>Daphnia catawba</u>, has almost disappeared from the lake during recovery and <u>Daphnia galeata</u> <u>mendotae</u> formerly the most abundant cladoceran, has reappeared, but not in the numbers present either prior to acidification or during the early years of acidification.

Dipteran emergence shows a very strange pattern, almost independent of the chemical change to Lake 223. It is probably more a function of white sucker abundance (their primary predator) than pH. Abundance declined during recovery, probably due to white sucker predation (when white sucker recruitment returned during recovery, the number of white suckers was about 10x that during the initial phases of the experiment). This increased predation is probably responsible for the decrease in chironomid emergence. Species diversity decreased during acidification and increased during recovery, but here again, the community structure during recovery is more similar to that at the height of acidification than during the analogous stage during acidification.

Littoral algal mats increased when we depressed the pH in Lake 223 to less than 5.1 and there was a pronounced decrease the first year (1988) when we allowed the pH to rise to 5.8. This decrease has continued to the present time.

All the fish species that remained in Lake 223 at the height of acidification resumed reproduction during recovery (see Mills and Chalanchuk, 1990, Abstract, Glasgow International Symposium on Acidic Precipitation). The white sucker condition and growth declined during recovery, a combination of effects from the early stages of acidification and slow build-up of the major predator, lake trout.

Reinvasions: Mayfly Hexagenia, fathead minnow (they are successfully reproducing now in Lake 223), crayfish (no sign of successful reproduction yet, but pH may not yet be a sufficiently high to allow this). Some reappearances of zooplankton species.

Summary: Biological recovery is occurring, but it is slow. We have not seen a mirror image of the acidification phase of the experiment. There may be quite long-term alterations of biological community structure from even relatively mild and relatively short pH depressions such as the experimental acidification of Lake 223. The lake has now been at pH 5.8 for three years. For the next two years it will be held at 6.1 to determine if the hysteresis in the relation of community structure to pH continues. In 1993, all acid additions will cease but further interventions may be undertaken to determine what actions are required to restore acidified lakes to their natural condition.

Experimental Recovery of Lake 223, the Experimental Lakes Area, Ontario: Initial Results

K.H. Mills[1], S.M. Chalanchuk[1], P.S.S. Chang[1], I.J. Davies[1], E.R. DeBruyn[1], D.L. Findlay[1], M.B. Jackson[3], G. Linsey[1], D.F. Malley[1], D.W. Schindler[1,2], J.A. Shearer[1], and M.A. Turner[1].

Lake 223, a small headwater lake in northwestern Ontario, was experimentally acidified with sulfuric acid from 1976 (pH 6.5) to 1981 (pH 5.1), and maintained at pH 5.1 in 1982 and 1983. Starting in 1984, we reduced acid additions and the lake pH gradually increased. We monitored changes in primary production, phytoplankton, littoral algal communities, zooplankton, benthos, and fishes during both the acidification and recovery phases of the experiment.

During acidification, alterations occurred in almost all trophic levels of Lake 223 biota. During pH recovery from 1984 to 1989, some of the biotic changes that occurred during acidification reversed. Littoral algal biomass increased during acidification, but receded when lake pH increased to 5.8. Species diversity of phytoplankton and dipterans decreased during acidification, but increased during recovery. Some species of zooplankton, benthos, and fishes that became extinct during acidification became reestablished during recovery. During acidification, all fish species ceased reproduction. During recovery, all remaining fish species resumed reproduction. Lake trout (_Salvelinus namaycush_) condition decreased during acidification, but increased during recovery due to increased abundance of lake trout prey.

Some of the biotic changes that occurred during acidification have not reversed during recovery. The phytoplankton, zooplankton, dipteran, and fish communities have not returned to their former species structures. Annual dipteran emergence decreased during the latter years of acidification and has remained at low levels during recovery. Low dipteran emergence may be due to trophic cascading effects, caused by high white sucker (_Catostomus commersoni_) abundance due to continued low abundance of lake trout.

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Fish Population Responses to the Experimental Acidification and Partial Recovery of Lake 223, a small Ontario Lake

K.H. Mills and S.M. Chalanchuk[1]

Lake 223 , a small headwater lake in northwestern Ontario, was acidified using sulfuric acid from 1976 (pH 6.5) to 1981 (pH 5.1). After two additional years at pH 5.1, the lake pH was allowed to gradually increase from 1984 (pH 5.4) to 1990 (pH 5.8).

During acidification, recruitment failures occurred for all five of the primary fish species in Lake 223: fathead minnow (*Pimephales promelas*), slimy sculpin (*Cottus cognatus*), pearl dace (*Semotilus margarita*), white sucker (*Catostomus commersoni*), and lake trout (*Salvelinus namaycush*). Fathead minnow and slimy sculpin became extinct from Lake 223 during acidification. Lake trout, white sucker, and pearl dace abundances increased during the early years of acidification, but decreased in later years. Losses of suitable prey resulted in progressive decline of lake trout growth and condition. Most lake trout were emaciated by fall 1982.

During recovery, recruitment resumed for pearl dace, white sucker, and lake trout at approximately the same pH levels where recruitment ceased during acidification. After white sucker and pearl dace resumed recruitment in 1984 (pH 5.4), lake trout condition immediately increased, but lake trout growth did not increase. Fathead minnow became reestablished in Lake 223 in 1988 and 1989, probably from emigrants from nearby Lake 224 (pH 6.8). Abundance of brook stickleback (*Culaea inconstans*), a species captured rarely prior to 1984, increased in Lake 223 during recovery. White sucker growth and condition gradually declined during recovery until 1987, when most fish were emaciated. This was probably due to increased abundance of white sucker during recovery and the persistent low abundance of their primary food source, dipterans.

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Synopsis of Lake 302S Results to 1 October 1990

Prepared by M.A. Turner

The Lake 302 acidification experiment has occurred in two phases. The first phase was to establish the relative acidification efficiency of nitric acid added to the north basin ~~of~~ Lake 302 with sulfuric acid added to the south (upstream) basin. The two basins were separated by a curtain installed in 1981 and were monitored for two years prior to the initiation of treatments. In the first phase, L302S was taken to pH 5.1 in a stepwise manner allowing comparison of biotic community responses with the earlier L223 experiment. In the second phase of the experiment, pH was taken to 4.5 to look at more extreme acidification effects.

General Experimental Hypotheses

General	The L302S acidification is a whole ecosystem experiment which examines both biological and chemical effects.
Past Ho	Sulfuric acid is a more efficient acidifier than is nitric acid. L302S was used as a "control ecosystem".
Past Ho	The chemical and biological changes associated with acidification of L302S to pH 5 will be similar to those observed in L223.
Present Ho	The continued acidification of L302S to pH 4.5 will alter biological and chemical properties of the ecosystem beyond those changes seen at pH 5.1 in L223.
Present Ho	Ecosystem properties will become increasingly unstable as compared to less stressed ecosystems.

Highlights of 1990

Most important results are that: (1) new disturbances are being detected at lower pH's, and (2) ecosystem composition and function appears to be highly unstable, continuing the first indications seen during 1988 and 1989. These findings support both of the "Present Ho's".

We appear to be detecting new dysfunctions in both the nitrogen and sulfur cycles. Ammonium values appear higher than would be expected based solely upon disruption of nitrification. Two possibilities are being investigated: H^+ exchange with sediment ammonia has increased; metaphyton decomposition is now a source of ammonium. Sulfate values are also unexpectedly high during late fall and early winter. The story emerging is that metaphyton shift the site of sulfur reduction to a zone above the normal sediment-water interface. During decomposition of the metaphyton, reduced sulfur compounds are exposed to oxygen to a greater extent than is typical of sediment-buried compounds. As a result, sulfate reduction is less effective on an annual time scale. This work appears to reconcile earlier discrepancies between observations made in Norway and North America by Rudd and Kelly. Internal alkalinity generation shows signs of being damaged. Less acid has been added than in any previous year (about 20 kg H^+ vs $\geq$40 kg) in spite of having to maintain the pH at 4.5. This observation is inconclusive until acid additions are ended for the year, and the chemical and hydrological budgets have been evaluated. The apparent disruption of the sulfur cycle by the metaphyton may be (partly) responsible.

There is an alternative and compatible hypothesis which is not yet being fully examined. Acidification may have caused the depletion of organic carbon reserves in the littoral sediments, possibly through either littoral carbon limitation and/or accelerated decomposition. This hypothesized depletion is consistent with the lowering of sediment-water interface seen in recent years, i.e. the appearance of Fe-Mn encrustations. As a result, microbial activities will be unable to maintain anoxia in the surface sediments, with the reoxidation of previously reduced sulfur compounds and reacidification the result. Another theoretical possibility which surfaced during the Glasgow Symposium was that internal weathering/exchange of Ca and Mg has been exhausted. This would be analogous to the situation for exhausted soils. We should be able to partly confirm this possibility if we see a large increase in Al in the water column in recent years. Previously, Al values have been relatively low in L223 and L302S, because the major source of Al in anthropogenically acidified systems has been due to watershed acidification. If water column Al values are increased, then we can anticipate toxicity effects occurring (in)directly throughout the foodweb.

Fluctuations in surviving biological populations continue to appear much greater than in unperturbed systems. Metaphyton development in 1990 appears to be intermediate in magnitude between 1988 and 1989, which were 10-fold different. As well, this algal development has been protracted, probably for climatic reasons. Both the magnitude and timing of photosynthesis and energy flow through acidified littoral foodwebs appears to be made more sensitive to climatic fluctuations by extreme acidification. Chironomid emergence in Lake 302S is about one-half of 1989 levels vs a 20% reduction in reference systems. Cladoceran ephippial eggs (a sign of population stress) have been found in much greater abundance than has ever been seen before in experimental or reference systems at ELA. Odonate populations, effectively the top predator in the lake, now are 10-fold less than in 1989 as determined from fall trapnet collections.

Major Results to Date

Internal alkalinity generation:

The roles of in situ sulfate reduction, denitrification, and cation exchange in buffering acid additions, first elucidated in L223, have been confirmed to be important in L302S. Acidification may be able to impair the operation of these processes as considered above. This is an active area of research.

Phosphorus:

There is no definitive pH-related trend, although one could argue that P has increased, consistent with the hypothesis that P increases in high sulfate waters. This feature needs further evaluation. The lack of any decline in P confirms the L223 conclusions, and is consistent with the absence of planktonic oligotrophication hypothesized to have occurred in Scandinavia.

Nitrogen:

There has been some increase in TDN due to the increase in NH_3 resulting from disruption of nitrification, confirming the phenomenon seen in L223. However, further disruption may be occurring as considered above.

Carbon:

There has been a substantial decline due to loss of both DIC (bicarbonate) and DOC. The reasons underlying the loss of DOC are uncertain. Two major hypotheses exist: (1) precipitation due to combination of complexation with increased H^+ and Al; and (2) heterotrophic utilization in presence of carbon limitation of benthic algae and substantially increased abundance of coccoidal blue-green algae.

Water column transparency:

Consistent with the L223 experiment, there have been major increases both in transparency and in its seasonal fluctuations. This has likely influenced both the lake's heat budgets and the metabolism of its algal communities.

Phytoplankton productivity:

There have been no consistent pH-related trends in phytoplankton productivity, consistent with the trends seen in L302S phosphorus, and in L223 phytoplankton. Again, the pattern corroborates the dissimilarity with the Scandinavian speculation concerning oligotrophication as a consequence of acidification.

Phytoplankton composition:

Through 1989, there has been a two-fold increase in algal biomass which correlates well with the decline in pH. The reasons for this increase are uncertain. The discrepancy with productivity needs to be reconciled, possibly reinterpreting the phosphorus changes which have occurred. Also, foodweb disruptions or altered nutrient ratios may explain the observation.

There has been substantially increased variation of phytoplankton biomass within a season as pH has declined. Chrysophytes remained relatively stable until pH 4.8, but have then crashed. Diatoms began to decline early during the acidification, unlike L223 where there was a bloom of Rhizoselenia. The L302S is more similar to that expected from anthropogenically acidified lakes. Dinoflagellates have now become the dominant planktonic alga. Cyanophytes were largely wiped out below pH 5, again consistent with expectations. Both chlorophytes and cryptophytes show no discernable pattern with pH.

Phytobenthos:

The responses of the phytobenthos have represented a dramatic new view of the effects of acidification.

In this community, net photosynthesis declines and respiration increases with acidification. These phenomena contradict entrenched dogma based largely on anecdotal evidence. Neither trend appears to have reversed with prolonged acidification in Lake 302S. Net photosynthesis is a function of DIC in the phytobenthos and it declines with DIC upon acidification. The reasons for the increase in respiration (and decomposition?) remain to be determined, but it may indicate a stress response in the microbial community as well. The consequence of these changes that the normal base of the littoral foodweb, epilithic and epiphytic periphyton are now unable to form the base of a foodweb, as P:R has declined with acidification. In contrast, the openwater average P:R of metaphyton has been 4.1 (1988) and 4.3 (1989), similar to neutral values. As a result, we have seen a shift in energy flow within the littoral zone, both long-term and seasonally. Metaphyton represents the only littoral potential for accrual of biomass, which is consistent with our qualitative observations. The potential ramifications for littoral dynamics are substantial and include biological, chemical, and physical effects. In 1988, near peak abundance, we crudely measured an average of 32 g dw/m^2 on littoral bottom. This equates to about 510 kg C of metaphyton in the 0-4 m stratum, versus about 200 kg C in plankton of the corresponding layer. At the 1988 peak, using the above mean coverage, I estimate metaphyton permitted only 11% of normal light levels to research the littoral lake bottom. The metaphyton now provide annual habitat (food or cover) for littoral microcrustacea, chironomids, etc. Densities of various cladocera (e.g. Simocephalus) are enormous.

Zoobenthos:

Green frog tadpoles: Fish trapnet collections confirm my qualitative observations of a dramatic decline in green frog tadpoles at pH 4.5. This suppression has continued in 1990. Leeches disappeared relatively early in the acidification process; although A. Bordeleau sighted several Macrobdella this spring. Crayfish are effectively extinct. While the population appeared marginally more resistant to acidification than in L223, this may have been due to invasions from L302N underneath the curtains. There have been tremendous increases in dragonflies, stoneflies and corixids. In 1990, the dragonfly abundance in fall of 1990 appears to be reduced markedly. I speculate that part of this decline may be due to predation by the loons residing in L302S without sufficient fish resources, given that their numbers seemed large during the spring. Chironomid emergence continues to fluctuate wildly, being one-half in 1990 of what was a record emergence in 1989.

Fish:

There are few if any lake whitefish and none were caught in 1990. However, the population was not reproducing at the start of the experiment which reduces the significance of this result. The same observations apply to white sucker. Among the cyprinids, only a very few large adult pearl dace and finescale dace remain. Extinction is imminent, although some adults may live to 10 years! Fathead minnows are effectively extinct.

Because of the continuing appearance of disruptions to significant biogeochemical cycles at pH 4.5, we plan to continue at that pH for two more years. The evidence for greater sensitivity (variance) in biological populations to meteorology suggests that the experiment should shift some emphasis towards exploring causes for this sensitivity and its consequences in a warmer, drier climate. This remains a LRTAP issue but intersects with climate issues. After two years and an evaluation of the above issues, a recovery phase would be run. There will be important differences from L223 in that biogeochemical disruptions will have been greater, possibly culminating in the elimination of some internal restorative processes and there will be no fish in the system. By trophic food web theory, quite different communities might emerge. At some future date the role of fish in restoration could be explored in L302S.

The Lake 302 North Experiment: Modification of Lake Acidification by Nitric Acid by Addition of Phosphorus

Prepared by J.W.M. Rudd

Background

Nitric and sulfuric acids are consumed in lakes by both algae and bacteria. Algae assimilate the acids and convert them to cellular proteins. There is a permanent gain of lake alkalinity when the S and N containing algal material sediments and is buried.

Bacterial acid consumption occurs in lake sediments where oxygen is absent. Sulfate reducing bacteria consume sulfuric acid converting it to reduced organic and inorganic S-endproducts. As long as these endproducts remain reduced, there is a permanent alkalinity gain. Nitric acid is consumed by denitrifying bacteria who convert the HNO_3 to nitrogen gas which is lost to the atmosphere resulting in a permanent alkalinity gain.

Consumption of sulfuric and nitric acids by algae or bacteria results in the production of 2 and 1 equivalents of alkalinity, respectively per mole of acid consumed. The bacterial processes have a greater potential for acid consumption than algal uptake because the nitrate and sulfate are used in energy generation, not just for biosynthesis as is the case for algae.

Algal uptake of acids is limited by the rate of supply of P. Thus, if P is added to a lake, the result is increased production of algal material and a stimulation of alkalinity production by algal uptake. Bacterial acid consumption is limited by the degree of anaerobiosis of the sediments. Sediment anaerobiosis can be increased by increasing the rate of supply of decomposable organic material to the sediments. The supply of organic carbon to the sediments can be increased by increasing algal sedimentation by addition of P. Thus addition of P to lakes results in the stimulation of nitric and sulfuric acid consumption by both algae and bacteria.

The understanding of in-lake alkalinity production that is summarized above originates largely from research done previously at ELA. Although we are certain that the addition of P to an acidified lake will result in stimulation of alkalinity production, this idea has never been tested in a quantitative manner using a whole-lake mass balance approach. Thus, there is no quantitative understanding of the efficiency of P addition in terms of stimulation of in-lake alkalinity production. There is also a lack of knowledge of how food chain recovery would be affected by P addition.

At the present time, nitrate concentrations in Canadian lakes are not high even in southern Ontario lakes where rates of input are high. This may change in the near future, however, if nitrate breakthrough from terrestrial watersheds occurs after many years of acid deposition. Recent indications are that this is beginning to occur in southern Ontario. Lake phosphorus concentration will be a critical factor defining the critical load of inorganic nitrogen which a lake can neutralize through internal alkalinity generation. In addition, mitigation of lake acidification by P addition would be most cost effective in lakes with high nitrate concentrations since both N and P are requirements of algal growth. However, this approach could also be used on lakes acidified by only sulfuric acid if appropriate amounts of nitrate were added with the P.

The Lake 302 N Whole-Lake Addition Experiment

A whole-lake experiment began at ELA in the spring of 1990 to examine the efficacy of P addition as a modifier in internal alkalinity generation and a mitigation of lake acidification. Sulfate and nitrate concentration have been increased to 75 and 25 μmoles/L by the addition of sodium sulfate and sodium nitrate. These concentrations simulate those of several lakes in the Adirondack Mountains of Upper New York State where deposition of nitric and sulfuric acids are similar to southern Ontario. The pH of Lake 302N is being controlled at 5.3 by the addition of hydrochloric acid. These conditions will be maintained for the first two years of the experiment (1990-1991). In the spring of 1992, P will be added to the lake in a 10:1 ratio of N:P. The other nitrate and sulfate addition rates will remain the same as for the first two years of the experiment. HCl will be added at the average rate of the first two years.

In the first year of the experiment, the phytoplankton community has exhibited strong P limitation as expected. The addition of nitrate in the absence of P has resulted in the dominance of green algae primarily Chlorella. This type of phytoplankton community structure is typical of nitrogen enriched ELA lakes.

It is expected that the addition of P at the 10:1 ratio will result in increased growth of the green algae which will stimulate consumption of nitric and sulfuric acids by both algal and bacterial processes. The level of P addition is expected to increase primary productivity by about a factor of 4 above oligotrophic ELA lakes. This level of productivity will be about 1/3 that of L227 at ELA which has been eutrophied by the addition of P and N fertilizers.

For the duration of the experiments (until 1994), addition of P, HCl, nitric and sulfuric acids will be the same as for 1992. During the three years of the P additions, it is expected that the nitrate and sulfate concentrations will decrease while alkalinity will increase (although the extent of the alkalinity increase is not known at this time).

UPLAND WATERSHED STATUS REPORT

Prepared by Craig Allan

This report summarizes the current status of the Upland Watersheds Research Project (UWP) currently being operated at the Department of Fisheries and Oceans (DFO), Experimental Lakes Area (ELA), near Kenora, Ont. with funding from the Ontario Ministry of Environment and DFO. A brief physical description of the study site, the instrumentation and data that has been collected is reported.

Physical Description

The physical layout of the 302 Upland study Area is presented in Fig. 1. The study area is located 4.3 km. to the west of the Department of Fisheries and Oceans (DFO) research facility, approximately 40 m above L. 302 (Fig. 1). The study area consists of five zero order watersheds (Uplands 1, 2, 3, 4 and 6 and one larger first order watershed Upland 8). Watershed areas are presented in Table 1.

Table 1. Watershed Areas

Upland 1	5,553 m2
Upland 2	4,694 m2
Upland 3	4,006 m2
Upland 4	1,730 m2
Upland 6	not surveyed
Upland 8	71,970 m2

The Upland watersheds are characterised by a thin (0 - 80cm thick), discontinuous soil cover (Figs. 2, 3, 4). Large areas of exposed lichen-covered bedrock are present within each watershed.

A Spruce-Jackpine dominated forest has developed on the isolated soil islands.

Topographic Data

Intensive stadia traverse level surveys were carried out during 1987 and 1988. Detailed contoured mapping exists for watersheds 1, 2, 3, 4. Less detailed level survey data is available for watershed 8 and none for watershed 6. As well, extremely fine scale surveys were carried out to delineate subbasins within watersheds 1 and 3 (U1b, U1c, U3b and U3c, Figs. 2 and 3) during the 1990 field season. Topographic data has been worked up and input into Lotus format data files to be used with such software packages as TOPO and SURFER. Surficial mapping of soil and vegetation was carried out along with the elevational mapping and is available in the same format (Fig 2, 3). A detailed report summarising the topographic data was prepared by this author and given to Drs. David Schindler, Suzanne Bayley and Ray Hesslein of DFO and Dr. Peter Dillon of the Ontario Ministry of the Environment (OME). Large scale (ca 1:5000) aerial photography of the study area was flown during the fall of 1987. Images are available from Mr. Ken Beaty, Hydrologic Studies, DFO, Freshwater Institute, Winnipeg, Manitoba.

Geologic Data

In addition to the above areal mapping a report detailing the surveying, mapping and analysis of the bedrock geology of the Upland study area was produced by Herbert Zier-Vogel during the spring of 1989. Copies of the above report were given to Dr. Ray Hesslein of DFO, Winnipeg and this author. Samples of bedrock outcrops were submitted to Dr. Wayne Nesbitt of the Department of Geology at University of Western Ontario for secondary ion mass spectronomy analysis of the weathered granite surfaces. Preliminary data of two weathered profiles has been prepared by Dr. Nesbitt and forwarded to this author. Additional samples will be collected during the 1990 field season.

Soil Data

At least two soil profiles were excavated from each of the Upland and L 239 NWIF watersheds (15 profiles in all). Soil profiles were documented and samples from each profile layer were submitted to the Ontario Ministry of the Environment (OME) soils lab, Dorset for full chemical and physical analysis. Soil analyses are complete and the data summaries have been forwarded to Dr. Suzanne Bayley, Botany Department, University of Alberta and this author. In addition to the OME soil data, this author has completed several bulk density, field capacity and saturated hydraulic conductivity measurements as well as developed soil moisture characteristic curves for the upland soils. A series of soil and bedrock leaching experiments is planned for the fall of 1990 to delineate the source of mobile Aluminum within the study watersheds.

Vegetation Data

Dr. Dale Vitt of the Botany Department of the University of Alberta has conducted an initial survey of the Upland vegetation and collected needle, leaf and root samples for chemical analyses. Chemical analyses are complete and data summaries have been forwarded to Dr. Ray Hesslein and this author. A preliminary draft of a paper by Drs. Vitt and Bayley comparing the Upland and L 239, NEIF Bog vegetation has been received by this author. Tree counts have been conducted for Watersheds' 1,2,3 and 4 and detailed vegetation maps of sub watersheds U3b, U3a, U1a and U1b are being prepared by this author.

Hydrometeorologic Data

The first order Upland Watershed (#8) is monitored by Mr. Ken Beaty DFO, Winnipeg. Flow records from this station are kept as part of the ELA hydrologic data base. The continuous flow record from this station begins in the fall of 1986 and continues to present. In addition recording and standard rain gauges are operated at the gauging station. The gauging station consists of 120° V-notch weir combined with a Stevens Type A float activated recorder. Watersheds 1, 2, 3, 4, 4b (a second outflow from watershed 4, Fig. 4) and watershed 6 are instrumented with small 60° V-notch weirs combined with electronic or float activated water level recorders. The periods of record for each are listed in Table 2.

Table 2. Length of Hydrologic Record for the Upland Watersheds.

	Manual "Spot" Measurements	Continuous Measurements
Upland 1	June 1987-Sept. 1987	Sept. 1987-present
Upland 2		July 1988-Dec. 1989
Upland 3	June 1987-Sept. 1987	Sept. 1987-present
Upland 4	June 1987-Sept. 1987	Sept. 1987-present
Upland 4b		April 1988-present
Upland 6		Aug. 1988-Dec. 1989

The hydrologic flow record is stored in lotus format as mean hourly and mean daily flow in L/sec. In addition to the above data a continuous discharge record is available for the two subbasins of Watersheds 1 and 3. These subwatersheds represent different landscape units. U1b and U3b are lichen-bedrock dominated subbasins while U1c and U3c represent forested subbasins (Figs 2, 3).The hydrologic record for these watersheds extends from June 1989 to present. A continuous record for shallow ground water levels in Watershed 1 exists at two sites, RW1 and RW2. The period of record for these stations is June 1989-present and May 1990-present, respectively. Daily manual measurements of ground water elevations are available from two locations each in Watersheds 1, 2, 3 and 4. The period of record extends from June 1987-present (Watersheds 1, 3, and 4) and June 1988-Dec 1989 (Watershed 2). Daily measures of soil moisture as recorded by soil moisture tensiometers are available from July 1988 to present.

An AES standard rain gauge and a electronic tipping recording rain gauge was operated in Watershed 3 in 1989 and moved to Watershed 1 for the 1990 field season. During the 1989 and 1990 spring snowmelt period (March - April) net solar radiation, air temperature, relative humidity and wind speed were electronically recorded as hourly averages at Watershed 3. Daily measurements of snowpack and soil temperatures at 10 cm depth intervals, are available from watershed 2 from March 1989 to present. Detailed snowcourse measurements for the Upland watersheds (30 - 60 sites) were made prior to snowmelt for 1988, 89 and 90 field seasons. During the 1989 and 1990 snowmelt period a daily measure of snowpack depth, density and water content was kept through the melt period.

Water Chemistry

An extensive water chemistry data base exists for the Uplands project. In addition to streamwater samples, samples of bulk precipitation, snow, throughfall and soil leachate samples have been collected. Most water analyses have been performed by the ELA and Freshwater Institute analytical labs and are part of the ELA chemical data base. In addition to the regular analyses (Table 3), Total Aluminum (TAl) determinations were made on all samples by the DFO Trace Metals lab from April 1988 to present. Speciated Aluminum measurements were performed by the author on all samples from March 1989 to present. A replicate subset of water samples from the 1989 snowmelt runoff period was submitted to the OME lab Dorset for cross calibration of the Aluminum speciation analyses. Fluoride determinations were also made on this same sample subset. This author has merged the Aluminum and field data (time, discharge, etc.) with the ELA chemistry data as it has become available. The chemistry data set is complete to the end of the 1989 field season and stored in Lotus format data files. Aluminum analyses are complete to present and stored in the same format.

Table 3. Upland Watersheds Sampling Stations (1,2)

Watershed 1

Site	Sample Type	Period of Record
U1	Stream	May 1987-Present
U1B	Stream	March 1989-Present
U1C	Stream	March 1989-Present
TL1a	Tension Lysimeter Soil Leachate	Sept 1987-June 1989
TL1b	Tension Lysimeter Soil Leachate	Sept 1987-Present
TL1c	Tension Lysimeter Soil Leachate	Sept 1987-Present
TL1T	Tension Lysimeter Soil Leachate	Aug 1988-Present
TL1M	Tension Lysimeter Soil Leachate	Aug 1988-Present
TL1BB	Tension Lysimeter Soil Leachate	Aug 1988-present
L1A	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L1B	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L1C	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L1D	Zero Tension Lysimeter Soil Leachate	May 1989-present

Watershed 2

Site	Sample Type	Period of Record
U2	Stream	June 1988-Dec 1989
TL2T	Tension Lysimeter Soil Leachate	Aug 1988-Dec. 1989
TL2M	Tension Lysimeter Soil Leachate	Aug 1988-Dec 1989
TL2B	Tension Lysimeter Soil Leachate	Aug 1988-Dec 1989
L2A	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L2B	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L2C	Zero Tension Lysimeter Soil Leachate	Aug 1988-present

Watershed 3

Site	Sample Type	Period of Record
U3	Stream	May 1987-present
U3B	Stream	March 1989-present
U3C	Stream	March 1989-present
TL3T	Tension Lysimeter Soil Leachate	Aug 1988-present
TL3M	Tension Lysimeter Soil Leachate	Aug 1988-present
TL3B	Tension Lysimeter Soil Leachate	Aug 1988-present
TL3T2	Tension Lysimeter Soil Leachate	May 1989-present
TL3M2	Tension Lysimeter Soil Leachate	May 1989-present
TL3B2	Tension Lysimeter Soil Leachate	May 1989-present
L3A	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L3B	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L3C	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L3D	Zero Tension Lysimeter Soil Leachate	May 1989-present
TF1	Throughfall	May 1989-present
TF2	Throughfall	May 1989-present
BP	Bulk Precipitation	May 1989-present

Watershed 4		
U4	Stream	May 1987-present
TL4T	Tension Lysimeter Soil Leachate	Aug 1988-present
TL4M	Tension Lysimeter Soil Leachate	Aug 1988-present
TL4B	Tension Lysimeter Soil Leachate	Aug 1988-present
L4A	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L4B	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
L4C	Zero Tension Lysimeter Soil Leachate	Aug 1988-present
Watershed 6		
U6	Stream	June 1988-Dec 1989
Watershed 8		
U8	Stream	Sept 1986-present
TL8LFH	Tension Lysimeter Soil Leachate	July 1989-present
TL8A1	Tension Lysimeter Soil Leachate	July 1989-present
TL8A2	Tension Lysimeter Soil Leachate	July 1989-present
TL8A3	Tension Lysimeter Soil Leachate	July 1989-present
TL8B	Tension Lysimeter Soil Leachate	July 1989-present
L239 NWIF WATERSHED		
LNWIF-LFH	Zero Tension Lysimeter Soil Leachate	Aug 1989-present
LNWIF-AE	Zero Tension Lysimeter Soil Leachate	Aug 1989-present
LNWIF-B	Zero Tension Lysimeter Soil Leachate	Aug 1989-present
TLNWIF1	Tension Lysimeter Soil Leachate	Aug 1989-present
TLNWIF2	Tension Lysimeter Soil Leachate	Aug 1989-present
TLNWIF3	Tension Lysimeter Soil Leachate	Aug 1989-present
TLNWIF4	Tension Lysimeter Soil Leachate	Aug 1989-present
TLNWIF5	Tension Lysimeter Soil Leachate	Aug 1989-present
TLNWIF6	Tension Lysimeter Soil Leachate	Aug 1989-present

1. Parameters reported by the ELA analytical unit include pH, Alkalinity, Conductivity, Ca, Mg, Na, K, Fe, Mn, Cl, SO4, S:NO3, NH4, TDN, SUSP N, TDP, SUSP P, DIC, DOC, SUSP C, Organic Acidity.

2. Most zero tension lysimeter samples have incomplete analyses as sample volume is a problem. Suspended values are not reported for tension lysimeter leachate samples.

A great deal of effort and expense has gone into sampling sequential storm and snowmelt runoff from these watersheds. Tremendous variations in concentration occur over short periods of time requiring intensive or integrating sampling programs for accurate mass balance estimates. During the 1987-1989 field seasons intensive sampling was carried out in all the study watersheds. During the 1990 post snowmelt period a simple integrating sampler was installed at each watershed outlet. In addition to quantifying the dissolved flux from the study watersheds, particulate fluxes (>200 u) from Watershed 3 were measured with a simple sediment trap below the watershed outflow. All particulate material has been collected dried, weighed and stored at ELA.

Experimental Manipulations

The Uplands project was designed to operate as a paired basin experiment as per discussions by DFO and OME personel in 1988. It was planned to alter the atmospheric loadings of nitrogen and sulphur for two of the watersheds (3 and 4). Additions were designed to simulate the sulphur and nitrogen deposition levels recorded in south eastern Ontario. An irrigation system was to be installed to deliver the necessary water supply to deliver and dilute the acid loadings to the study watersheds. Watersheds 1 and 2 would also be irrigated to serve as "wet" controls while Watershed 6 was to act as a "dry" control. Unfortunately funding was inadequate to build the irrigation system. Additions of H_2SO_4 and NH_4NO_3 have been made to Watersheds 3 and 4 during both the 1988 and 1989 snowmelt periods. Target additions agreed upon by DFO and OME personel were 50 kg/ha/yr as sulphate with an equimolar addition of nitrogen. The sulphate was to be added as sulphuric acid and the nitrogen as NH_4NO_3. The additions made to the snowpack prior to the 1989 and 1990 snowmelt (late March) were 2.69 and 1.19 l of 36 normal H_2SO_4, and 1,938.5 and 858.6 g of NH_4NO_3 to watersheds

3 and 4 respectively. Additions were adjusted to the yearly proportion of precipitation expected as snowfall (11.6 kg/ha/yr SO4). The sulphuric acid was added to the snowpack by means of a backpack "weed control" type sprayer. The acid was diluted to a pH of approximately 2 and great care was taken to avoid directly spraying the vegetation. The NH_4NO_3 was applied to the watersheds separately in powder form by "sowing" it over the snowpack.

Future Proposal

Initial results from the spring manipulations were spectacular. Cation leaching from the manipulated watersheds increased dramatically in relation to the control watersheds. Aluminum speciation was altered dramatically with inorganic monomeric aluminum becoming the dominant aluminum species. Ammonium was effectively retained by the watersheds while nitrate was not.

With the conclusiveness of the above results, there is no further value of continuing the same type of additions to the study watersheds. The absence of an irrigation system precludes us from making any statements as to the annual changes to the watersheds as a result of increased sulphate and nitrogen loadings. It would be manually impossible to add the H_2SO_4 with the same style of sprayer during the snow free season. With the imminent (?) agreement between the U.S. and Canada to reduce SO_2 emissions I propose that we concentrate our attention to the problem of continuing and possibly increasing NO_x emissions. Two valuable experiments are as follows: Replace the H_2SO_4 additions with HNO3. This experiment could again be a spring addition and would not require an irrigation system. The results from this study would give us some clues as to the effectiveness of NO_3 as a terrestrial acidifying agent.

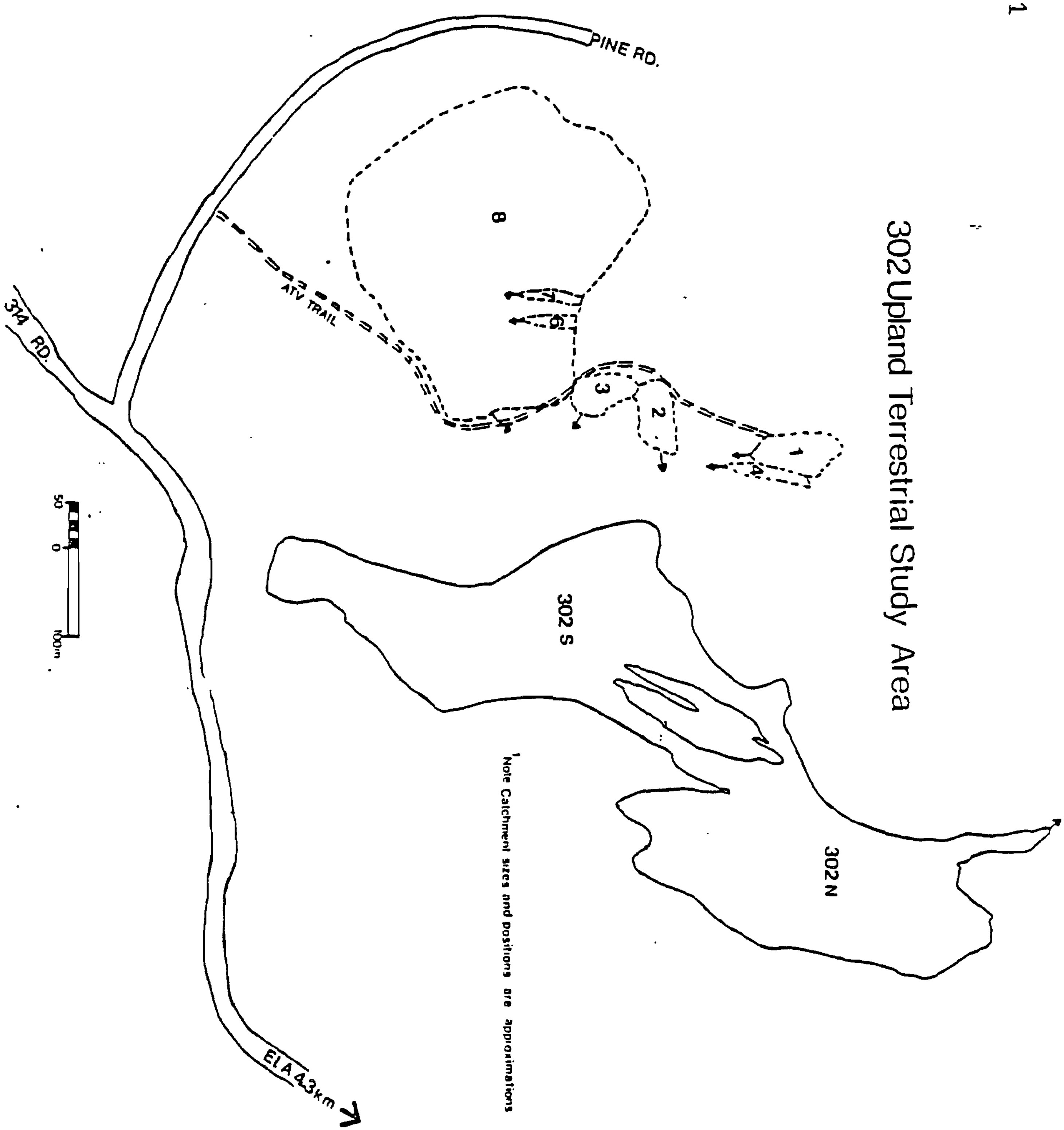
A second experiment would involve the continued additions of NH_4NO_3 to a study watershed. These additions could be added to a watershed year round, without the need for an irrigation system. The results from this experiment would enable us to make some inferences as to a terrestrial ecosystems ability to assimilate increased nitrogen loadings and if and when we could expect nitrogen saturation to occur. This would directly address the critical loading question currently being debated. This second experiment would require input from forestry people to assess changes in plant nutrient status, decomposition and nitrification rates, etc. as a result of increased nitrogen loadings. I propose that watershed 4 (greatest soil thickness and most extensive forest cover), be selected as the study watershed to receive the NH_4NO_3 additions while watershed 3 would receive the HNO_3 additions. Watershed 1 would serve as a control.

The above studies could be operated annually at the same level of funding as received in 1990 (ca $50,000). This budget would include salaries for spring and fall contract personnel ($6,000), a COSEP summer student ($7,000) and $37,000 to cover analytical and operating expenses. Analytical expenses could be substantially reduced with the installation of an integrating sampling system at the basin outflows. The flashy nature of the runoff from these watersheds renders a weekly sampling regime essentially useless. Analytical costs could also be decreased by deleting the subbasins (U1B, U1C, U3B and U3C) from the sampling schedule. I would recommend against this for at least one year.

The UWP study site offers tremendous advantages to assess perturbations to natural terrestrial ecosystems. The response of the Upland systems to perturbation has been shown to be extremely short and dramatic owing to the small size and short residence time of these systems. Treatment costs are relatively cheap and manageable in relation to large scale manipulations. The background physical and chemical data base is available and extensive. There is room to expand the type of manipulations beyond those proposed above. Watersheds 2 and 6 were essentially mothballed at the end of the 1989 field season and both have at least one year of background hydrology and chemical data (table 2,3). Additional perturbations which could be addressed with increased levels of funding include logging, fire and climatic manipulations. This project to my knowledge is unique in Canada and probably North America. The only similar project is the RAIN project in Norway (whose watersheds are not forested!) in which treatments constitute the interception and diversion of polluted rain. Only in the 302 upland site can defined loading be made to boreal forest communities under a natural meteorological regime. It would be shame for Canada and ELA to lose this capability.

Fig. 1

302 Upland Terrestrial Study Area



[1] Note Catchment sizes and positions are approximations

Fig. 2

WATERSHED I

Overburden Thickness (cm)

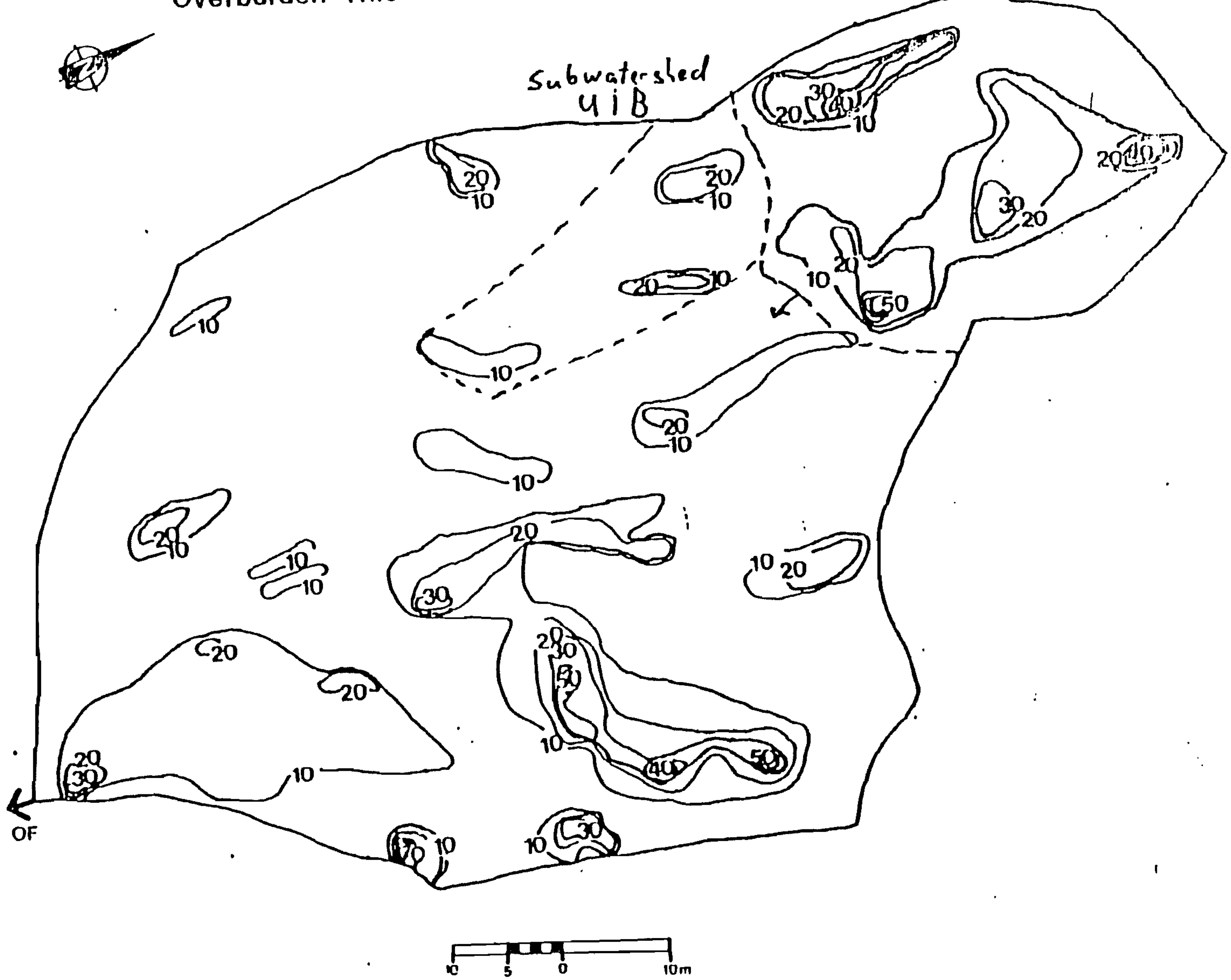


Fig. 3

WATERSHED 3

Overburden Thickness (cm)

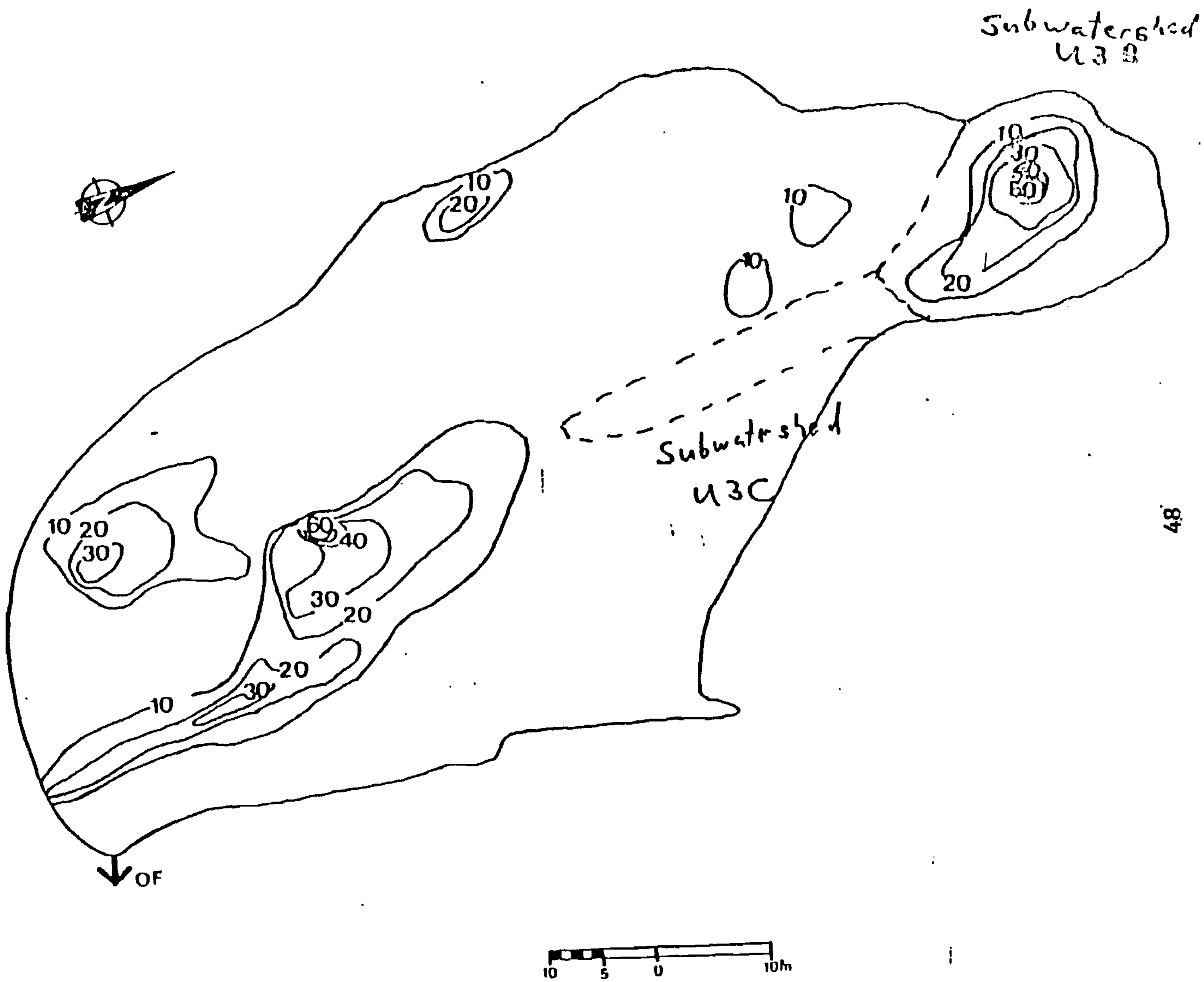
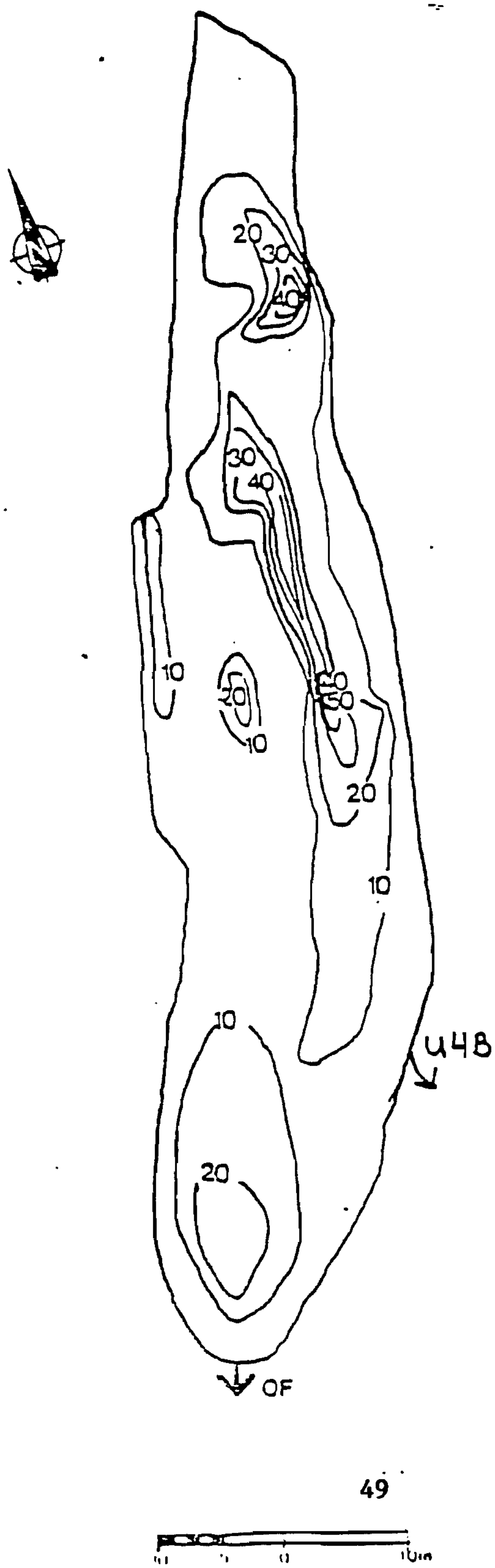


Fig. 4 Watershed 4

Overburden Thickness (cm)



EXPERIMENTAL ACIDIFICATION OF A PEATLAND:

Changes in concentration of acid anions, base cations and dissolved organic carbon.

by

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Poster presented at International Conference on Acidic Deposition: Its Nature and Impacts. Glasgow, 16-21 September, 1990.

ABSTRACT:

Experimental acidification of a 3.6 ha peatland at the Experimental Lakes Area in Ontario, Canada has been studied for seven years. Annual deposition rates of 20 kg/ha SO_4 and 5 kg/ha NO_3-N were applied to the peatland in six monthly events during the ice free season. Immediately after acidification events, surface water concentrations of SO_4 and NO_3 increased, calcium, magnesium and potassium concentrations increased in the bog area, pH decreased and DOC concentrations decreased. Within two weeks most chemical parameters returned to background levels, particularlly pH, DOC, and base cations. In the bog area, mean annual concentrations of calcium decreased and sulfate concentrations increased relative to control areas. There was an increase in mean annual concentration of nitrate in the poor fen area for two of the six years. Annual retention of nitrate remained greater than 98% of inputs regardless of atmospheric deposition. Although sulfate reduction rates increased after acidification events, annual retention of sulfate appeared to be a function of precipitation, depth of water table draw down and unrelated to deposition.

INTRODUCTION

In highly industrialized parts of Great Britain *Sphagnum* bogs which had been wide spread two hundred years ago, have disappeared (Tallis, 1964). Of the 18 species of *Sphagnum* previously present, only one species, *Sphagnum recurvum*, is still prevalent (Tallis 1964, Woodin and Lee, 1987). The *Sphagnum* cover has been replaced by sedge and grass species (Tallis, 1964). Efforts by J.A. Lee and his students to determine the mechanisms causing the *Sphagnum* destruction has focused on both sulfur and nitrogen.

Lee et al. 1987 has shown that while sulfate deposition has decreased in the last century, nitrate concentrations have increased four-fold and the rainfall has remained acidic. Since the sulfur deposition has declined since the early 1900's, present levels of sulfur deposition are not high enough to cause the death of *Sphagnum*. However, *Sphagnum* tranplanted from relatively less polluted sites to the heavily polluted Pennine sites did not survive and tissue concentrations of nitrogen in the transplanted *Sphagnum* increased dramatically (Press, Woodin and Lee 1986 N.P). Summaries of the British experiments are found in Lee et al (1987) and Woodin et al (1987). In the heavily polluted British sites, the effects of nitrogen, sulfur, metals or gaseous polutants on wetland chemistry or *Sphagnum* growth cannot be separated. Our experiments take place in an area that has very low levels of anthrogenic atmospheric deposition (2.3 kg/ha/y of nitrate and 11 kg/ha/y of SO_4). The experiment is designed to isolate the effects of strong acid anions from the confounding effects of other pollutants (heavy metals, gaseous pollutants etc.).

OBJECTIVES OF THE PEATLAND ACIDIFICATION PROJECT

1. To lower the pH of precipitation on th wetland from pH 5 to pH 4, thereb simulating conditions in eastern Canada.

2. To determine effects of acidification c growth of the dominant *Sphagnum* mos species.

3. To determine short term and long ter changes in chemistry of wetland pools an outflow.

4. To determine the fate of added NO_3 an SO_4.

5. To measure changes in methane flu associated with bog and fen acidification.

WETLAND CHARACTERIZATION

Area of watershed 12.43 ha.

Area of wetland 3.67 ha

Bog Area

Surface water pH 4.0; no runoff.

Dominant vegetation is *Sphagnum angustifolium, S.magellanicum, Led groenlandicum*, and *Picea mariana*

Fen Area

Surface water pH 4.5-5.0; runoff from upland.

Dominant vegetation are the above species plus *Alnus rugosa, Salix planifolia, Equisetum sylvaticum*, an *Calamarostis canadensis*

ACIDIFICATION OF WETLAND

- Lowering of pH of precipitation from pH 5 to pH 4

1. Concentrated sulfuric and nitric acids (on a 50/50 basis) are added to lake water and sprayed on the 2.66 ha experimental area.

2. The acid and water mixture is sprayed in six equal monthly "acidification events" each year starting in August 1983. The acid spray is followed by a short period of flushing with lake water.

3. The pH of the spray is 3, and 2 mm of lake water are added during each 4-5 hr. event.

4. Lake water only is sprayed on the 0.85 ha control area.

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Questions and Answers

PAT RYAN: Could you comment on what exactly is the mean annual one meter pH in the Lake waters? What does 'mean annual' mean?

BOB HECKY: We take pH in these systems. One meter is just a standard sample depth. We consider that representative of the epilimnion in the lake no matter what the depth of the epilimnion is. So the amount of acids in the epilimnion may be changing all the time but it is measured always at one meter and we measure that three to five times a week. The lakes are visited quite frequently. So it's a very highly defined sampling regime and that means a great number of analyses. I'm not quite sure if that is the answer you're looking for? We have to do that because we're constantly adding acid. We have to know where the pH is going so we can work against it to maintain a target pH so it requires frequent sampling.

JERRY PAYNE: I was wondering how long you anticipated that these experiments will go on. I notice you are starting off with some pH differences and now you're talking about adding nutrients, phosphorus or what have you, and I can see a never ending stream of experiments for virtually decades if you throw in certain nutrients. You study for five years with pH alone and then you add phosphorus or nitrates or whatever and do you have any feel for how long this program will go on.

BOB HECKY: Well if somebody will tell me when we're going to have control of the atmospheric pollutants, I can probably answer that very definitively. That 302 North experiment which I will talk about under Mitigation I think is an emerging issue. I think that there's a great concern that as we control sulphur, I mean that's where all the international court is right now, sulphur control and that the European experiences they've been bringing sulphur down now for decades essentially and that their problem is nitric acid and I am not sure that North America is going to escape that nitric acid issue and I think the concern of those writing and negotiating accords right now is if we control sulphur and we do nothing about nitrogen that the expected improvement that we see, first of all, may not happen or may be very temporary unless we move on and deal with the nitric acid question. Now that's why I feel that we should be moving into some specific nitrogen issues. The 302 North experiment builds on a couple of things. First of all, we give the acidification of 302 North and learned a lot about nitrogen cycling when we did that experiment which we terminated back in '85. We do stop experiments sometimes. But if we are looking at a future where we are not controlling nitric acid and nitric acid begins to become a problem, we feel quite strongly that phosphorus fertilization could be an interim solution and a very cost effective interim solution to nitric acid. That's directed at what I feel will be an emerging question and perhaps an emerging problem in the very near future. Both the other experiments I've put up there are recovery experiments. I think that's a very relevant topic in terms of what you can expect from the system and how much active intervention we are going to have to put into the systems and getting them back to where we'd like to have them. So, yes, I'm sure the experimental lake areas always does experiments but that's what it's there for in part but we try to make them very directive. Ken.

KEN MINNS: When you were talking about the biological effects in the recovery phase, are you implying that the uncertainty and variability is uniquely attributable to the fact that you've acidified that system or is it just part of the general slewing around of the biological system?

BOB HECKY: No, I think right now we're not real sure. I would say it's probably as much to do with the biological disruption and to stabilize the community that was there and we've extricated some things that are not getting back in right away. In the 223 recovery phase, I think that's a big part of it and I think that's partly why we have this INAUDIBLE in response. When you step down, things drop out when you get to a certain pH but getting back in is not quite as easy as that. They have to come back from somewhere. They have to work against the biotic radiance here and the organisms that have replaced them so I don't think I'm saying that that's strictly a pH phenomenon. It's a destabilization phenomenon. You will probably find a nitrifying system and others that we're more familiar with. But I do think that it could be a continuing problem. We're also worried about that carbon flow aspect. When you get down into the really low pHs that we've actually disrupted some of the

homeostasis. We're having less carbon reserve material and we're becoming more dependent on year to year phenomena and there again that's not necessarily the pH level. It's just a lingering consequence of it. Yes?

JOE KICENIUK: Do you follow the oxygen in these lakes when you do the pH manipulation in adding nitric acid v. sulphuric acid?

BOB HECKY: Yes, we do. And there's a paper coming out, actually that 302 North experiment is just coming out in Limnology and Oceanography and it discusses some of the oxygen. We're are routinely monitoring oxygen in all the lakes. But to date we haven't seen a dramatic disruption in the oxygen concentration. It rises or falls but what we're seeing is more the functioning of anaerobic metabolism in a sense that it's been modified by the addition of these potential electron receptors.

JOE KICENIUK: Did I hear you say you're getting sulphur accumulations in the sediment?

BOB HECKY: What we're seeing now is certainly a lot of sulphur going into the sediment. That's what's generating in part the acidity in the lake. What I'm talking about in 203 North now is there's evidence that we don't have the losses that we had before. In fact, we're getting a return in the fall and winter which we never saw before and that's because that sulphur is not being buried. One of the hypotheses is that this metapyte community which covers large areas of the Lake now, literally covers centimetres or tens of centimetres it is that creates anaerobic microzones in that layer and that's where sulphur reduction is occurring but rather than going into the sediment where it becomes fairly isolated from the water column that metapyte breaks down in the fall, you release that sulphur that has been reduced and taken up. So you've moved the site of that sulphur reduction out of the sediment up into the water column and that is why we're trying to get this sulphur feedback that we hadn't seen before.

JOE KICENIUK: What about phosphates? Are you seeing great differences in phosphate levels between the two regimes?

BOB HECKY: Not dramatically different. There's evidence in 302 South that total phosphorus concentrations have risen slightly but when we look at the other indicators of phosphorus which we have a hard time measuring inorganic phosphate at the best of times. If you look at phosphorus deficiency indicators, the lakes are still phosphorus deficient and that's why nitrogen in 302 North can be an effective acidifier because the algal uptake in the productivity system indicates the organisms like phosphorus and adding more nitrogen saturates the ability of the bloom to use that. If you feel that if we added phosphorus and it would take more nitrogen out and increase the carbon fixation and increase the carbon loading in the sediments such that it would increase the reduction of nitrogen and sulphur compounds.

<u>**JOE KICENIUK:**</u> So this is a case where we shouldn't have taken the phosphates out of the detergents?

<u>**BOB HECKY:**</u> Well in the Great Lakes, you should have but perhaps in acid lakes you might like to have a little bit put back in as a mitigation act not as an active end. Although on the West coast, they add phosphorus and nitrogen to the lakes all the time to grow more sand. There may be other benefits to that.

Cause and Effect Studies: Report on Ongoing Research (1990)

Scotia-Fundy Region

Six separate projects identified as cause and effect studies were initiated or continued in 1990, and a brief summary of recent activities and progress for each follows:

1. Development of Models to Assess the Impacts of Acid Deposition on Atlantic Salmon – LRTAP Project No. 30 (Lacroix, Ritter, Watt, Cutting)

Given the current understanding of acidification effects on Atlantic salmon production, and the economic and social importance of the fishery, the development of a simulation model to study this problem seems warranted. A hierarchy of biotic models describing the impacts of temporal variation in river acidification on production of Atlantic salmon could be used as a tool both for the management of salmon stocks in acidic rivers, and for testing hypotheses concerning the factors controlling production. In collaboration with ESSA Ltd., a workshop will be held in the fall of 1990 to decide on the model's focus, develop the details of its structure, and obtain most of the information required to construct a prototype. Development of a prototype "site" model for one stream, and a prototype regional framework will then follow. The performance of the prototype model will be reviewed, and data sets will be used to further test its assumptions and performance. The model will be structured to be eventually related back to acidic deposition under changing scenarios and to allow prediction of the future status of salmon populations. To that effect, a hydrochemical submodel will be developed in subsequent years. Most effort at this stage will be directed at the biological model and submodels. The resolution is meant to apply to a section of the stream or river, but also be applicable on a regional scale. The model aims to be dynamic, as opposed to steady state. The region of concern for this exercise is that used by Atlantic salmon populations of the Atlantic upland rivers of Nova Scotia.

2. Impacts of Acidity on Salmonid Ecology – LRTAP Project No. 31 (Lacroix)

Density and biomass estimates of juvenile salmon and of other fish communities in ten streams representing a range of chemical and physical conditions were conducted in Nova Scotia as part of a long term study to provide an evaluation of responses to temporal changes in water chemistry. A multivariate analysis of trends through time and space is being done on the data sets available for past years, and to evaluate the sampling scheme presently used to depict changes in productivity in relation to habitat variables including acidification and/or recovery. The annual counts of Atlantic salmon redds will be conducted again this autumn at a number of index sites in several acidic streams. A spring survey of chemical conditions in the salmon rivers of New Brunswick which drain in the Bay of Fundy was conducted to assess the potential for acidification effects in those rivers, and it will be repeated again in autumn after rain episodes that can lead to decreases in pH. An analysis of the distribution and microhabitat selection by juvenile Atlantic salmon and brook trout along a longitudinal pH gradient in a stream is nearing completion, and the findings should be published during 1991.

3. Relationship Between Al and Si Levels in Natural Waters of Atlantic Canada and Scotland and the Toxicity of Such Waters – LRTAP Project No. 32 (Lacroix)

Silicic acid, $Si(OH)4$, present in natural waters as a consequence of the weathering of the aluminosilicates of rocks and soil minerals, has a strong and unique affinity for Al. With an excess of Si over Al at a molar ration of 13:1, and with the formation of hydroxy-alumino silicate species, the bioavailability of Al in acid water (pH 5) is reduced and acute toxicity eliminated. Silicic acid may be, at certain times of the year and/or under a specific set of conditions, an important complexing agent competing with dissolved organic matter and with gill sites for Al binding and reducing the toxicity of Al to fish. This would be most important at times when organic anions are present in low concentrations in streams. Silicon is, therefore, being considered as a possible parameter of importance in evaluating the toxicity of acidified waters.

Silicon, dissolved organic carbon, and total and exchangeable Al were measured at times of potential acid episodes in acidic salmon streams of Nova Scotia and in salmon rivers of New

Brunswick, and on a more intensive monthly scheme in a chronically acidic brook in Nova Scotia. In the New Brunswick rivers, pH ranged from 5.3 to 7.3, total Si ranged from 14 to 85 μmol/L, and total Al ranged from 0.8 to 10.6 μmol/L. The Si:Al ratio ranged from about 3:1 to 50:1, and in many instances it exceeded the 13:1 ratio which is considered necessary for Si to reduce the toxicity of Al. A range of 1.4 to 32.6% of total Al was measured as exchangeable Al in these rivers. In the Nova Scotia rivers, pH ranged from 4.8 to 6.2, total Si ranged from 16.4 to 39.2 μmol/L, and total Al ranged from 2.5 to 7.8 μmol/L. The Si:Al ratio ranged from about 2:1 to 9:1, and was always less than the 13:1 ratio. A range of 0 to 20% of total Al was measured as exchangeable Al in these rivers. Frequent measurements in one acidic stream in Nova Scotia, however, indicated that the concentrations of Si and the Si:Al ratio can fluctuate greatly on a seasonal basis. Total Si concentrations tended to be highest during the summer period of low water discharge when dissolved organic carbon concentrations also tend to be low. An acid episode at this time, and a concomitant increase in total Al concentration could have adverse effects on fish populations if a significant proportion of the Al is not chelated by organic anions. At such a time, the high Si concentrations could be of importance in chelating some of the exchangeable Al and thereby reducing the toxicity of Al to fish.

4. Comparative Ecophysiology of Salmonids in Acidified Rivers of Atlantic Canada and Scandinavia – LRTAP Project No. 33 (Lacroix)

An experiment was conducted in control and acidic sections of a Nova Scotia brook during an episode of decreasing pH. In addition to iono-/osmoregulatory parameters, respiratory parameters such as blood pH, blood gases, and hemoglobin were determined at intervals in salmon parr and brook trout. The premise was that these additional measurements could allow one to differentiate between physiological effects caused by low pH alone from those resulting from Al effects at low pH. The samples and data are presently being analyzed. However, some preliminary results are available and they are considered here briefly. During the 48 d of exposure, pH in the more acidic section was ≤4.5 and generally decreased slightly with time while, in a limed section, pH decreased from 5.2 to about 4.4-4.7 in the last 25 d of exposure. Total Al fluctuated between 200 and 300 μg/L and Fe between 0.5 and 1.0 mg/L, but dissolved organic carbon concentration was between 10 and 20 mg/L and exchangeable Al was <40 μg/L.

For salmon parr, plasma osmolarity and chloride concentration decreased immediately to minimum values within 5 d at pH≤4.5 and more gradually over about 30 d in relation to decreasing pH in the less acidic section. Plasma protein concentration, hematocrit, and hemoglobin increased markedly within several days in the chronically acidic section but they either did not change appreciably or increased gradually over time in the less acidic section. Blood pH and pCO_2 increased significantly in several days in the more severe pH exposure, and after a slight decline in the first week increased more gradually over time in the less acidic section. Blood pO_2 generally decreased rapidly in both sections within the first week. Generally, after about 15 d of exposure hemoglobin concentration, blood pH and pCO_2 did not differ between fish from either types of exposure.

For brook trout, plasma osmolarity and chloride concentration decreased under both conditions of exposure, but the decrease was initially faster and significantly greater under the conditions of chronic acidity and lower pH. Plasma protein concentration, hematocrit, and hemoglobin concentration increased rapidly under the more acidic chronic conditions, and only increased later when pH decreased in the other exposure conditions. Blood pH, and pCO_2 were usually higher under the more acidic chronic conditions but they fluctuated similarly under both exposure conditions, and differences between treatments were only significant for pCO_2. Blood pO_2 initially increased markedly under the more acidic conditions, and then it decreased under both types of exposure.

For both salmon parr and brook trout, physiological responses were generally rapid and indicative of lethal effects under conditions of chronic exposure to pH≤4.5. Under conditions of decreasing pH from 5.2 to a range of 4.4-4.7 from 25 d onwards, the responses were initially slower and sublethal, but after pH levels decreased below 4.5 the responses rates increased and reached lethal levels as in the chronic more acidic exposure. With regards to respiratory parameters, the trends was generally for blood pH and pCO_2 to both increase when conditions became lethal as evidenced by changes in iono- and osmoregulation parameters.

5. Histopathology of Gill Tissues as Influenced by the Effects of Organic Anions on Dynamics of Al Accumulation by Salmonids – LRTAP Project No. 35 (Lacroix)

A qualitative and quantitative investigation of gill tissue morphology and histology using scanning (SEM) and transmission (TEM) electron microscopy and light microscopy (LM) was conducted on juvenile Atlantic salmon and brook trout at intervals during autumn and spring episodes in acid and control sections of a Nova Scotia brook with high concentrations of total Al but also high concentrations of dissolved organic carbon and, hence, high proportion (>80%) of nonexchangeable Al. Morphometric examination revealed that the numbers of chloride and mucous cells in the gills of salmon parr and brook trout generally increased with time of exposure during an episode of decreasing pH in autumn. The increase in number of chloride cells was apparently associated with an increase in resistance and survival time of fish. Primary lamellae width, secondary lamellae length, and the blood–water distance in secondary lamellae all decreased with exposure to low pH. There were no obvious morphological differences between gills of salmon parr from control or acidic sites. The gills of brook trout, however, did show a slight difference in surface irregularity in gills of fish from the less acidic control section of the brook. The effect may be associated with the release of fines associated with limestone in the control section of the brook. During an episode of increasing pH in spring, the numbers of chloride and mucous cells in the gills of salmon parr generally decreased with time of exposure and increasing pH, but the number of chloride cells increased markedly in the gills of brook trout. Primary lamellae width increased slightly with increasing pH, but secondary lamellae length and blood–water distance in secondary lamellae usually did not change significantly, except in the gills of brook trout where primary lamellae width and blood–water distance in secondary lamellae increased markedly. Overall, there were no gross morphological differences observed on the gills of salmon parr from acidic and control sites over time. Gill surfaces were clean with distinct primary and secondary lamellae and no indication of fusion or severe hyperplasia. Ultrastructural examination revealed that there was some vacuolization of the epithelial and chloride cells in gills of all specimens. The gills of brook trout did show some change over time. Gill lamellar surface were initially normal but after a month of exposure, during which pH increased, the gill lamellar surfaces revealed a "bumpy" surface which can be related to the higher chloride cell count, higher blood–water barrier thickness and the variable but shorter secondary lamellar length. Ultrastructurally, the chloride and epithelial cells showed vacuolization similar to that found in the gills of salmon parr. It is difficult to attribute the presence of vacuoles to specific environmental conditions because they were observed in the gills of hatchery control, field control, and acid exposed trout. Of the fish gill lesions that are commonly caused by irritants or toxicants, epithelial lifting, hypertrophy and proliferation of chloride cells was observed in salmon parr and brook trout from control and acidic sections of the brook, whereas lamellar blood sinus constriction was evident only in the gills of salmon parr. Results from these experiments are presently being analyzed in relation to environmental conditions and physiological changes measured in the salmon parr and brook trout, and the findings will be published during 1991-92.

A laboratory experiment to examine the histopathologic changes associated with the effects of organic anions on Al accumulation in the gills of fish was conducted as a joint study with Dr. R.H. Peterson. Atlantic salmon fry were exposed to Al and organic anions (A^-) in different proportions in treatments (4x3 matrix) yielding Al minus A^- values of +10, 0, and -10 μeq/L. Citric acid in concentrations of 0, 10, 20, and 50 μeq/L was used as the organic acid. Also, in a second experiment, gills loaded for 10 days at Al minus A^- of +10 μeq/L were exposed to concentrations of 0, 10, 20, and 50 μeq/L of citric acid (A^-) to examine the rate at which Al is cleared from the gills in the presence of different A^- concentrations. The gills have been analyzed for Al concentrations, and the histopathologic examination using SEM, TEM, and LM, as well as a qualitative microanalysis of gill tissues using SEM with energy-dispersive X-ray analysis is ongoing.

Accumulation of Al on or in gills was time dependent and gradual over 15 days of exposure, and it was progressively greater and faster as Al minus A^- increased from -10 to 0 and +10 μeq/L, i.e., as Al exceeded the organic anion concentration. Increasing Al and A^- by the same proportion did not change the extent of Al accumulation within a treatment. In contrast to the gradual accumulation of Al on gills, the loss or clearing of Al from gills loaded with Al was very rapid, occurring within 24-48 hours. It did not differ greatly among treatments of different A^- concentrations, but the loss of Al was nevertheless generally slightly greater at the highest A^- concentrations. Results from the histopathologic examination should be available by the spring of 1991.

6. Corticosteroid Metabolism, in vitro, as an Indicator of Stress in Juvenile Atlantic Salmon (*Salmo salar*) – LRTAP Project No. 36 (Sangalang, Uthe, Crain)

A number of physiological functions such as reproduction, osmoregulation, and carbohydrate metabolism in vertebrate species, including fish, are under control and regulation of steroid hormones. Changes in the metabolism of these hormones have become useful indicators of stress in fish, thereby serving as early warnings of environmental pollution (Donaldson et al. 1984; Freeman et al. 1984). We use a sensitive biochemical radioisotopic technique to investigate steroid sex and stress hormone metabolism in fish as affected by environmental contaminants. For example, in our LRTAP studies, we have shown that sexually maturing Atlantic salmon (*Salmo salar*) held in an acidic river (pH 4.6-5.2) compared with those held in a less acidic river (pH 5.3-6.0): 1. had abnormal sex and stress hormone metabolism which was reflected in poor reproductive performance and poor post-spawning survival in acidic water (Freeman et al. 1983; Freeman and Sangalang 1985), 2. had somewhat improved reproductive performance when the acidic water was limed (Sangalang et al. 1990) or treated with EDTA. Treatment , however, stimulated production of androgens, particularly testosterone and early gonadal maturation in males (though not in females) (Fig. 1); neither was the chronic stress response observed in acid water holding reversed by treatment (Fig. 2).

In 1990, we have adapted our metabolic methodology for application to juvenile fish with the aim of developing a stress test applicable to caged fish bioassay programs currently underway in Scotia-Fundy. Conditions for tissue handling and field sampling have been optimized along with the analytical procedures to arrive at a reliable and reproducible test. Briefly, head kidney of hatchery-reared or wild salmon were incubated with equimolar amounts of [^{3}H]-pregnenolone and [^{14}C]-progesterone, in vitro, under conditions given in Sangalang et al. (1972). For comparative purposes, only fish of indeterminate sex were used although some precocious males and females were found in the various stocks. Autoradiograms of the thin-layer chromatograms of extracts of steroid metabolites were prepared. Figure 3 shows clearly that the corticosteroid profile in hatchery-reared (Mersey Hatchery) Medway River stock differed from the pattern obtained from hatchery-reared Gold, LaHave, and Annapolis River. The significance of these differences is unknown.

Analysis of the individual corticosteroid metabolites is underway. The results will provide valuable information on hormonal metabolism in juvenile salmon, on which there is little information. Profiling and analysis of corticosteroid metabolites from wild juvenile salmon is also underway.

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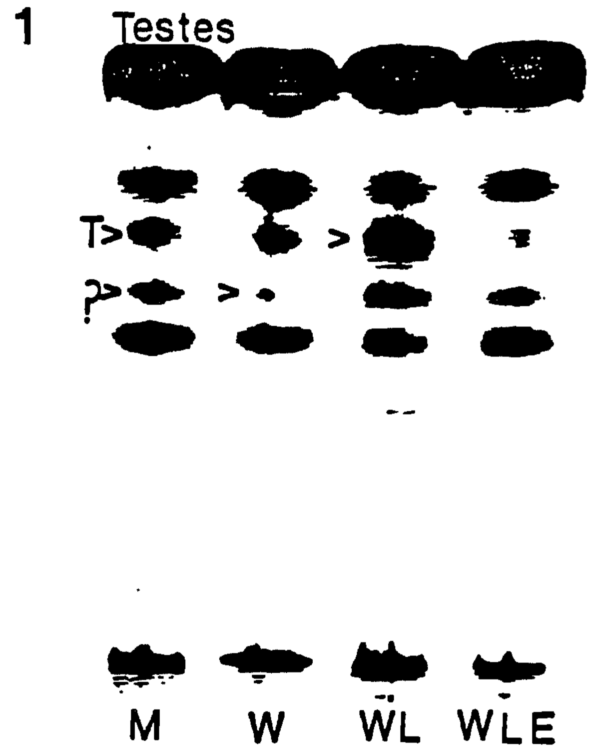

Figure 1. Biosynthesis of steroids from [^{3}H]-pregnenolone and [^{14}C]-progesterone, in vitro, by testes of sexually mature Atlantic salmon (1989 LRTAP Study). Autoradiogram of the thin-layer chromatogram of steroid extracts show increased production of testosterone (T) in fish held in limed acidic water (WL) compared to those held in more neutral water (M) or untreated acidic water (W) or acidic water treated with limestone and EDTA (WLE). Note the similarity of profiles in M, W, and WLE, and the somewhat lower yield of an unknown metabolite (?) in W.

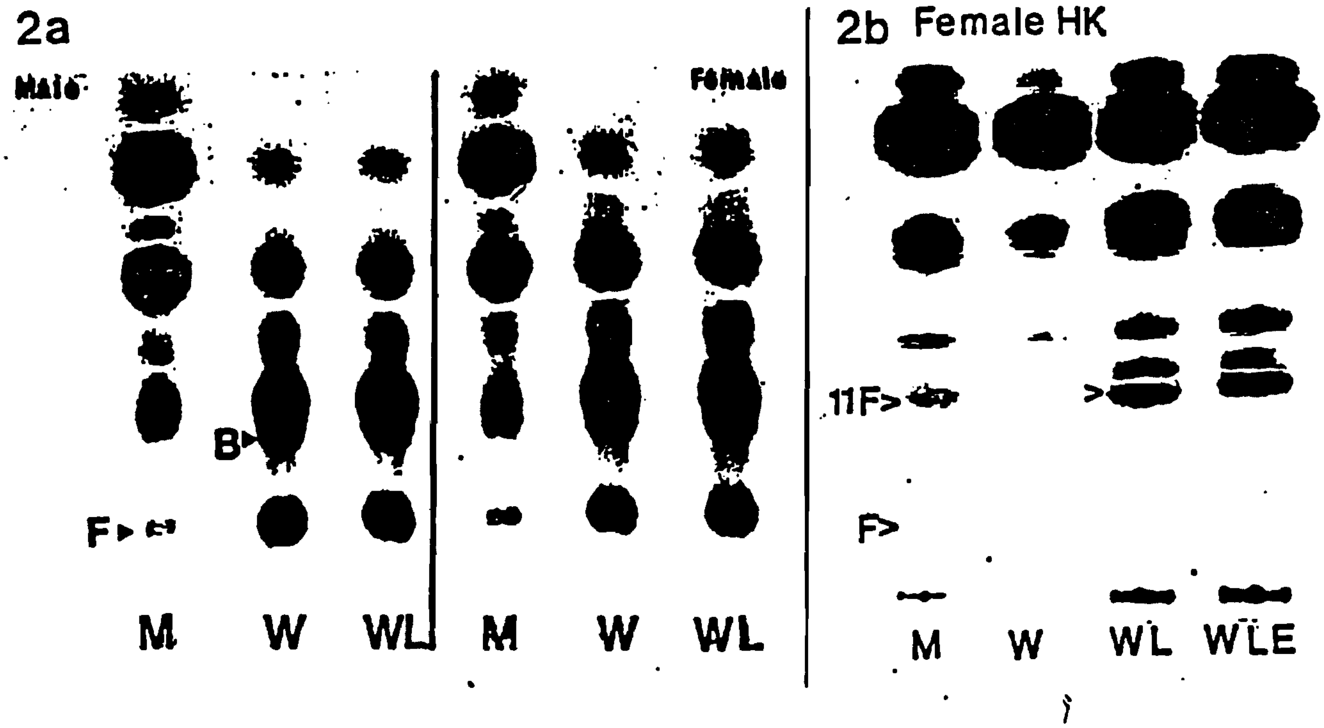

Figure 2a. Biosynthesis of corticosteroids from [^{3}H]-pregnenolone and [^{14}C]-progesterone, in vitro, by head kidneys of sexually mature Atlantic salmon held in acidic and more neutral river water (1986 LRTAP Study). Compare the excessive production of stress hormone cortisol (F) and the appearance of a steroid, 11-deoxycorticosterone (B) which is not normally present in salmonids, in fish held in either acidic or limed acidic water (Sangalang et al. 1990).

Figure 2b. Biosynthesis of corticosteroids from [^{3}H]-pregnenolone and [^{14}C]-progesterone, in vitro, by head kidneys of post-spawned female Atlantic salmon held in acidic and more neutral river water (1989 LRTAP Study). Note the disappearance of cortisol and the higher yields of its immediate precursor, 11-deoxycortisol (11F) ~~and 21-deoxycortisol (21F)~~, in the fish held in acidic water treated either with limestone or limestone + EDTA. Note the low yield of metabolites in fish held in untreated acidic water.

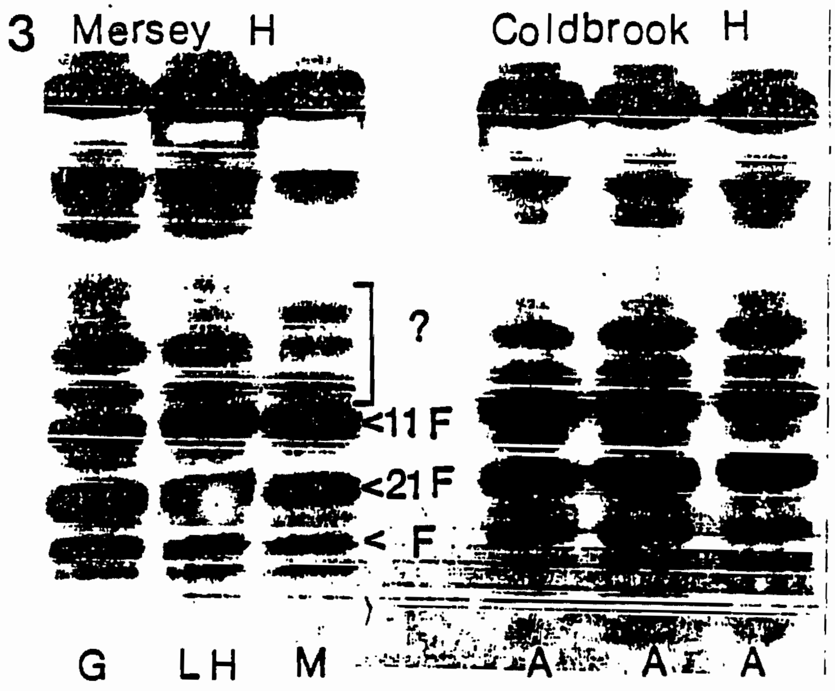

Figure 3. Corticosteroid metabolic profiles in hatchery-reared juvenile Atlantic salmon (1990 LRTAP Study). Note the difference in the metabolic profile (marked with brackets) of the Medway River stock compare with those from Gold (G), LaHave (LH), and Annapolis (A) River stocks. Note the high levels of 11-[illegible] [illegible] and [illegible] (21F) compared to [illegible] in [illegible] (S1) salmon.

Questions and Answers

PAT RYAN: Would your salmon LRTAP model work in Newfoundland?

GILLES LACROIX: Will we try to apply this model to Newfoundland?

PAT RYAN: Yes, and will it work? Can you tell us now if it will work or not or do we have to do it, too?

GILLES LACROIX: Well it's basically being developed for a case site within the Scotia Fundy Region which is a certain group of rivers with a particular chemistry and a particular scenario of acidification and this is going to be a dynamic model so I doubt very much if you could apply it to the situation, the acidification situation, that's been observed in Newfoundland because I don't think you have the same scenarios of fall episodes of acidities and then over winter very low minimal values and different scenarios in the spring, either decrease or increase in the summer highs and that's the scenarios we're trying to incorporate in this model. So I don't think it will be applicable or transferable. But it is meant to apply to all of the rivers of the Nova Scotia uplands.

PAT RYAN: Can we use a peat slurry for mitigation, a slurry of peat, sphagnum bog?

GILLES LACROIX: It would all depend on the conditions that you're trying to mitigate. Organic acids can be used as a buffer to a certain extent but the amount of buffering they can afford in the system is very minimal.

PAT RYAN: What about the precipitation of aluminium or other metals?

GILLES LACROIX: What they find depends on the rate at which you're increasing your pH. In one recent study of liming in Scandinavian rivers they found that when they used limestone slurry in a stream to rise up the pH they're releasing incredible amounts of aluminium because of the increase in pH and they're actually creating very toxic conditions in the area of mixing where they're actually increasing the pH. This recovers further downstream but right in the slurry area they've had some very bad effects with metal toxicity.

PAT RYAN: So would this be a benefit to add the peat?

GILLES LACROIX: Basically the organic acids if they're present in high enough concentration should act as chelators of any free aluminium that you have, if you're dealing with systems that are not very organic to start with. If they're ground water systems to start with, most of your aluminium, 80%, is probably bound throughout the year unless you have episodes of snow melt in the spring and you have a layer more dilute clear water with high aluminium from atmospheric sources rather than slow processes.

IAN DAVIES: Just a couple of quick questions. I didn't understand the histopathology work. That was all at the same pH. The citric acid had been neutralized, had it? So that's not a pH effect with recovery..organic binding.

GILLES LACROIX: No, it's all 5.0 I think. Actually, pH 5.4, those experiments were conducted.

IAN DAVIES: The other thing that confused me a little bit was in the corticosteroid metabolism work was that..you say it was an indicator of stress. Was that an acid specific or was it a handling stress or is it a specific or a non-specific stress that would...

GILLES LACROIX: Well steroids are usually general indicators of stress but in terms of the specific responses here I'd rather that Gloria answer the question because I'm not too familiar with the experiment.

GLORIA SANGALANG: Whether it's due to the acidity per se we don't know but we would like to be able to have a detection method which can spot any differences in these various fish, fish from various rivers. Generally we know from our past work that acid stressed fish do come up with changes in corticosteroid metabolic profiles. For example, excessive production of cortisone in the head kidneys. That's not due from handling or anything because you see we are dealing with tissues. The production of the metabolites in tissues is an ongoing thing not dependent on handling or anything like that. It's a cellular mechanism that is not dependent on.. so we don't know. There's little information on corticosteroid metabolism in fish right now.

IAN DAVIES: I guess just as a supplementary to that I've listened for several years to comments of what happens on the histopathology of fish and the changes of hormone levels up and down and cellular electrolyte changes. I'm still confused. There doesn't seem to be a broad predictor that pulls all these things together. Is that the eventual goal of this or is it the various responses are confounded by the conditions that we find or the amount of organic acids and the particular pH, the handling stress?

GILLES LACROIX: Well there are a whole number of various responses you could have depending on the factors, the stressors acting on the fish. All the initial work was conducted in laboratory situations and now over the past few years we've been trying to see if the same physiological responses do occur in the field and we find often the reactions can be similar but also quite different and we have to try and interpret these and this usually gives us some insight into the mechanisms involved and the responses often and the complexity of the nature of interacting factors in a natural situation compared to a laboratory situation where you can usually rely on plasma sodium or chloride and just use that as an indicator and you'd basically define your reaction. You can use that to a certain extent. In the field, that won't give you any indication of what the factors are that are acting on your fish and what the mechanisms...it won't separate the various mechanisms involved. It tells you that one mechanism is involved and that's usually involved in a lethal response to many stressors you'll get this same reaction. A lot of these indicators are broad responses to sub-lethal and lethal stress. I don't think there's any attempt here to really isolate one physiological or histopathologic or metabolic parameter to define all the responses of fish under the various scenarios that you could observe in the field. They are all applicable under various situations and using a combination of them can allow you to elucidate what is actually going on in your stream.

IAN DAVIES: I guess what I'm looking for is some broad synthesis that would be unambiguous where a number of these factors could be pulled together either as a model or where you would have some predictive or interpretative power. Is the eventual goal of this work to bring together this large synthesis?

GILLES LACROIX: Well once you've defined all the variability you can usually narrow down your factors that are important in revealing the effects and use those but that is an outcome of this type of work not necessarily a primary goal, no, because we are looking at cause and effect. We're not trying to just establish indicators.

Episodic Acidification Study on Selected River Systems in Newfoundland, Canada

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This presentation contains preliminary results from a manuscript, in preparation, by D.A. Scruton, P.M. Ryan, and A.M. Cook.

Abstract

The Department of Fisheries and Oceans (Canada) initiated a study in November 1985 to ascertain the extent, magnitude, timing, duration, and causes of seasonal declines in pH and alkalinity on geologically sensitive river systems on the island of Newfoundland. This 'Episodic Acidification Study' involved sampling the water chemistry of fourteen selected rivers on a weekly basis (twice weekly during peak discharge periods). The program included a total of fourteen systems and consecutive sampling periods ranged between 7 and 41 months.

Acidification episodes (samples with pH values less than or equal to 5.0 and/or alkalinity values less than or equal to 0.0) were evident on six of fourteen systems. Single episodes occurred on two rivers while frequent episodes were evident on four study rivers on the southwest coast of the island. On these four rivers, pH values less than or equal to 5.0 occurred from 7 to 27% of the time while total depletion of alkalinity was evident in from 6 to 31% of the samples. Weighted mean pH and alkalinity values for these four rivers were low but none demonstrated chronic acidification (mean pH $<=$ 5.0). Alkalinity exhaustion and pH depression were most pronounced in the late fall (November and December, with either onset in October or lasting into January). Spring pH declines were also evident but were not as extensive or as long in duration. Extended periods of pH depression were evident with the most extreme case being a twelve week period. Deficits in alkalinity and pH decline were associated with chloride, non-marine sulphate and, to a lesser extent, dissolved organic carbon indicating marine aerosol, natural and anthropogenic contributions to the acidification episodes. Watershed features (eg. bedrock geology, soils, drainage area, elevation and slope) and meteorological conditions (eg. annual precipitation, evapotranspiration rate, runoff and hydrology) also govern the relative susceptibility of study systems and the interaction of acidifying and buffering components.

Introduction

Considerable effort has been expended since 1980 to determine the sensitivity and status of freshwaters and associated biota in the province of Newfoundland and Labrador in relation to the long range transport of air pollutants. Assessments have been based on large scale synoptic lake surveys, paleoecological reconstruction of lake pH histories, multivariate analyses of relationships between plankton and lake physical/chemical properties, and temporal sampling (monthly) of acid sensitive river systems and long-term bilogical monitoring of reference watersheds. Assessments have confirmed the extreme sensitivity of the region's freshwaters, related primarily to geochemistry and natural organic acidity, and have provided indications of alteration of chemical status in response to acid loading (sulphate deposition) as evidenced by an erosion of buffering capacity (alkalinity). Research studies have established relationships between biota and lake pH, while fossil diatoms have been used to infer recent pH changes in several of the region's lakes, however there is no definitive evidence of the adverse effects of acidic deposition on biota.

Initially, regional research programs were directed at efforts to understand the effects of anthropogenic deposition on average (steady state) condition of the region's freshwaters and biota. Research priorities now include the investigation of temporal changes in chemical and biological systems including the potential for short term, episodic changes to chemistry and potential adverse effects on resident biota. Previous temporal surveys (monthly) of the water chemistry of sensitive rivers in 1981/1982 provided evidence of pH depressions and alkalinity exhaustion on some river systems during one or two peak periods in the hydrological cycle. These 'episodes' were of sufficient magnitude to adversely affect resident salmonids, however, the sampling frequency was inadequate to evaluate the degree, duration, and frequency of exposure of resident fish to these periods of high acidity. The current study was initiated to address these shortcomings in our understanding of the potential magnitude of episodic acidification.

Study Rivers

The Episodic Acidification Study was initiated in the fall of 1985 with sampling of four acidic rivers on the southwest coast of the island. The sampling regime grew over the next 15 months to include a total of 14 systems spread across the island (Fig. 1). Rivers in the sampling regime included watersheds involved in the Departmental acid rain biomonitoring program (2 systems), 5 rivers included in community-based salmon enhancement projects and three rivers in the Department's 'Experimental Rivers' program directed at research on habitat-stock interactions.

Table 1 provides detail on the location of study rivers and selected biophysical characteristics. Table 2 provides details on the sampling regime for each river and cooperating agencies involved in sample collection. The sampling regimen was intended to be weekly with twice weekly sampling during the high runoff periods. In several instances, and for a variety of reasons, the weekly (or bi-weekly) sampling protocol was not adhered to. Periods of missing data have been identified in Table 2.

Methods

Samples were collected on the mainstem of each river, near the mouth, upstream of the nearest road acess with the exception of the Gander River (sample location in the headwaters of the Northwest Gander River). Samples were shipped monthly to selected analytical laboratories for analyses. Samples were analyzed for the following parameters: pH, alkalinity, calcium, magnesium, sodium, potassium, chloride, sulphate, colour (TCU), turbidity (TCU), dissolved organic carbon (DOC), conductivity, total aluminum, and total manganese. The following parameters were calculated from the measured variables: total dissolved solids (TDS), bicarbonate, hardness, organic anions, hydrogen ion, total cations and anions, ion balance, and non-marine ('excess') concentrations of calcium, magnesium, sodium, potassium, and sulphate.

Hydrological data (daily discharge m^3s^{-1}) for four of the study rivers (Isle aux Morts R., Grandy Bk., Gander R., Rocky R.) were available from Environment Canada's hydrometric survey operations. For ungauged systems, daily discharge was extrapolated from the nearest gauged river of similar drainage area and adjusted for relative basin size.

Results

Six of fourteen rivers experienced pH depressions (less than or equal to 5.0) and alkalinity exhaustion at some point in the study program (see Table 3). Two rivers (Terra Nova and Freshwater Rivers) experienced single episodes of acidification while 3 of the 4 study systems on the southwest coast of the island (Otter Bay Bk., Grandy's Bk., and Rose Blanche R.) demonstrated frequent and often prolonged episodes of pH depression and alkalinity exhaustion (see Figure 2). The Isle aux Morts River, the other southwest coast system, also demonstrated acidification episodes but not to the same degree as the other 3 rivers.

Acidification episodes were most pronounced in the late fall and early winter of 1985/1986 (November through January), spring of 1986 (March-April), and the fall of 1987 (October-November) with single episodes occurring at other periods (see also Figure 2). Figure 3 demonstrates the seasonal variability in key water quality parameters in relation to acidification episodes for the Rose Blanche River.

After transformation, the sea salt acidification factor is the best predictor of seasonal variation of H^+ in seven of the watersheds and contributes significantly to a total of eight (Table 4). This includes the four southwest coast rivers, the two other watersheds on the south coast (Grandy Br., Little R.) and two Avalon Peninsula rivers. Excess sulphate is the best predictor in six watersheds (contributing to ten rivers), including four of six on the Avalon Peninsula. The anthropogenic sulphate indicator contributed significantly to the seasonal variation in acidity on three of four southwest coast rivers experiencing acidification episodes, but much less so than the sea salt indicator (partial r^2 of 0.04 to 0.10 for excess sulphate as compared to 0.22 to 0.34 for S.S.A.). Organic acidity (D.O.C.) contributed to seasonal H^+ variation in nine rivers and was an important predictor on only two extremely small Avalon Peninsula rivers (Drook Br. and Northeast Br, 15.1 and 21.2 km^2 drainage area, respectfully). Dissolved organic carbon was also a minor contributor to three of four southwest coast rivers (partial r^2 from 0.03 to 0.07). It is also important to note that a large component of the seasonal variation in H^+ on several of the watersheds has not been accounted for by these three predictors, as potential sources for acidity. A similar stepwise approach including base cations as a predictor (representative of soil weathering and bicarbonate buffering potential) resulted in much higher model r^2s and the base cation predictor was included in nine of the models and was the best predictor for four watersheds.

Conclusions

Rivers in insular Newfoundland, despite being geographically distant from concentrations of emission sources of acidic precipitation and receiving modest levels of sulphate deposition (less than 15 $kg.ha^{-1}.yr^{-1}$ in 1985, 1986 and 1987), are being impacted by acid rain. While chronic acidification is not apparent, extremely sensitive rivers in the southwest corner of the island are experiencing episodes of acidification. These episodes are often prolonged and extensive. Episodes are most pronounced in the late fall months in association with heavy fall rains and the flushing of sulphate/organics which had accumulated in the watersheds during the vegetative growing season. Sea-salt deposition from precipitation and aerosols contributes significantly to these episodes.

The four southwest coast rivers experiencing acidification episodes possess biophysical characteristics that contribute to their susceptibility. These include predominantly granitic bedrock in the watershed with extremely thin non-calcareous overburden, high slopes contributing to rapid runoff, low evapotranspiration rates (high frequency of fog) and high amounts of precipitation (up to 2 m annually).

This study provided evidence that, in acid sensitive watersheds in coastal regions, episodes of acidification can occur, primarily driven by natural processes (H^+ generation from organic acids and through cation exchange with neutral sea salts) but with minor contribution from anthropogenic sulphate deposition, particularly as a result of seasonal patterns of storage and release. Natural sources of acidity are particularly important during periods of high discharge and snow melt. It is important to consider natural acidification processes, operating seasonally and in steady state, in establishing target levels for deposition.

Table 1. Location and selected biophysical characteristics of the study rivers.

Name	Lat.	Long.	Basin Area(km)	Slope (m/km)	Bedrock Geology* (%)
Isle aux Morts R.	4737	5901	214.2	17.8	Gneiss/granite(100)
Grandy's Br.	4737	5851	273.2	15.4	Gneiss/granite(100)
Rose Blanche R.	4737	5842	83.7	26.5	Gneiss/granite(50); Acid volcanics(50)
Otter Bay Br.	4737	5856	44.0	28.8	Gneiss/granite(100)
Grandy Br.	4746	5739	263.7	15.1	Acid volcanics(100)
Little R.	4754	5536	183.4	7.5	Quartzose/sandstone(100)
Terra Nova R.	4827	5422	1883.0	3.6	Siltstone/metamorphics(63); granite/acid volcanics(37)
Gander R.(NW.)	4820	5529	6398.0	2.7	Granite/acid volcanics(63); siltstone/metamorphics(25); gabbros(12)
Colinet R.	4713	5333	158.0	6.9	Siltstone/conglomerates(48); acid volcanics(52)
Rocky R.	4714	5334	296.0	8.2	Siltstone/conglomerates(100)
North Harbour R.	4714	5336	78.2	20.9	Siltstone/conglomerates(100)
Freshwater R.	4639	5306	16.8	15.8	Siltstone/sandstone/quartzite(100)
Drook Br.	4640	5314	15.1	25.9	Siltstone/sandstone/quartzite(100)
Northeast Br.	4646	5321	21.2	20.9	Siltstone/sandstone/quartzite(100)

*Geological sensitivity to acidic deposition (after Schilts 1981) as follows: (1)gneiss/granite - highly sensitive, (2) acid volcanics - highly sensitive, (3) granites/acid volcanics - highly sensitive, (4) quartzose/sandstone - moderate sensitivity, (5) siltstone/metamorphics - moderately sensitive, (6) siltstone/conglomerates - moderately sensitive, (7) siltstone/sandstone/quartzite - moderately sensitive, and (8) gabbros - moderately sensitive.

Table 2. Sampling regime, extended periods of missing data and collectors involved in the Episodic Acidification Study.

River Name	Sampling Period	Periods of Missing Data		Collectors
		(n)	Dates	
Isle aux Morts R.	11/85-04/88	90	3/86;1/87-3/87;1/88-3/88	1
Grandy's Br.	11/85-04/88	84	3/86;1/87-3/87;1/88-3/88	1
Rose Blanche R.	11/85-04/88	93	3/86;1/87-2/87;1/88-3/88	1
Otter Bay Br.	11/85-04/88	92	3/86;1/87-3/87;1/88-3/88	1
Grandy Br.	04/87-04/88	33	12/87-03/88	2
Little R.	07/86-02/88	85	-	3
Terra Nova R.	11/85-06/88	158	03/87	4
Gander R.(NW.)	04/87-07/88	51	06/87;11/87	5
Colinet R.	11/85-06/88	86	10/86-12/86;5/87-10/87	6
Rocky R.	11/85-06/88	108	10/86-12/86;8/87;4/88	6
North Harbour R.	11/85-06/88	109	10/86-12/86;8/87;4/88	6
Freshwater R.	05/87-04/88	43	10/87	7
Drook Br.	05/87-04/88	18	10/87;12/87-03/88	7
Northeast Br.	05/87-11/87	23	-	7

Collectors:
1. DFO (Port aux Basques); D. Butt
2. DFO (Burgeo); A. Hann
3. Conne River Indian Band; R. Hinks
4. Contracted collector; S. King
5. DFO (Grand Falls) and contracted collector; E. Crant
6. Salmon Association of Eastern Newfoundland and contracted collector; G. Linehan
7. DFO (St. John's, Science Branch);Dr. J. Gibson and staff.

Table 3. Summary of minimum, maximum and weighted mean values of pH and ANC for the 14 study rivers. Number and frequency of low pH/ANC exhaustion episodes are also included.

	pH				ANC			
River Name	**Mean**	**Min.**	**Max.**	**<=5.0 n (%)**	**Mean**	**Min.**	**Max.**	**<=0.0 n (%)**
Isle aux Morts R.	5.73	4.74	6.92	6 (7)	24.7	-11.7	80.8	4 (4)
Grandy's Br.	5.57	4.50	6.56	12 (14)	17.6	-26.3	73.2	3 (4)
Rose Blanche R.	5.34	4.62	6.46	25 (27)	5.8	-19.9	34.6	13 (14)
Otter Bay Br.	5.32	4.48	6.59	24 (26)	7.5	-27.5	76.2	10 (11)
Grandy Br.	5.94	5.08	6.82	0	30.0	3.6	79.9	0
Little R.	6.33	5.71	7.05	0	52.2	9.2	110.1	0
Terra Nova R.	6.14	4.99	6.74	1 (<1)	41.4	6.0	75.9	0
Gander R.(NW.)	6.58	5.89	7.10	0	77.2	41.8	142.3	0
Colinet R.	6.37	5.72	7.30	0	64.3	4.8	174.0	0
Rocky R.	6.26	5.41	7.00	0	64.8	9.2	132.0	0
North Harbour R.	6.08	5.02	7.22	0	52.9	-1.6	157.8	1 (2)
Freshwater R.	6.03	4.98	7.10	1 (2)	25.6	-1.6	147.9	1 (2)
Drook Br.	7.09	6.44	7.30	0	128.0	56.5	171.4	0
Northeast Br.	6.66	5.74	7.05	0	83.6	23.8	135.1	0

Table 4. Partial correlation coefficients and model r^2 for stepwise regressions between hydrogen ion (H^+) concentration and each of three predictors: dissolved organic carbon (mgL^{-1}, indicator of natural acidification); excess sulphate (indicator of anthropogenic acid deposition), and SSA (sea salt acidification indicator as previously described). Significance level for entry into the models was set at $p=0.10$.

River	D.O.C.	$*SO_4^{-2}$	S.S.A.	Model r^2
Isle aux Morts R.	0.06(3)	0.10(2)	0.23(1)	0.38
Grandy's Br.	0.03(2)	-	0.22(1)	0.25
Rose Blanche R.	0.07(2)	0.04(3)	0.34(1)	0.45
Otter Bay Br.	-	0.07(2)	0.31(1)	0.38
Grandy Br.	-	-	0.32(1)	0.32
Little R.	0.04(3)	0.32(1)	0.05(2)	0.41
Terra Nova R.	0.03(1)	-	-	0.03
Gander R.	0.06(2)	0.13(1)	-	0.19
Colinet R.	0.07(2)	0.12(1)	-	0.19
Rocky R.	-	-	0.08(1)	0.08
North Harbour R.	-	0.02(2)	0.29(1)	0.31
Freshwater R.	-	0.39(1)	-	0.39
Drook R.	0.19(2)	0.50(1)	-	0.69
Northeast Br.	0.21(2)	0.22(1)	-	0.43

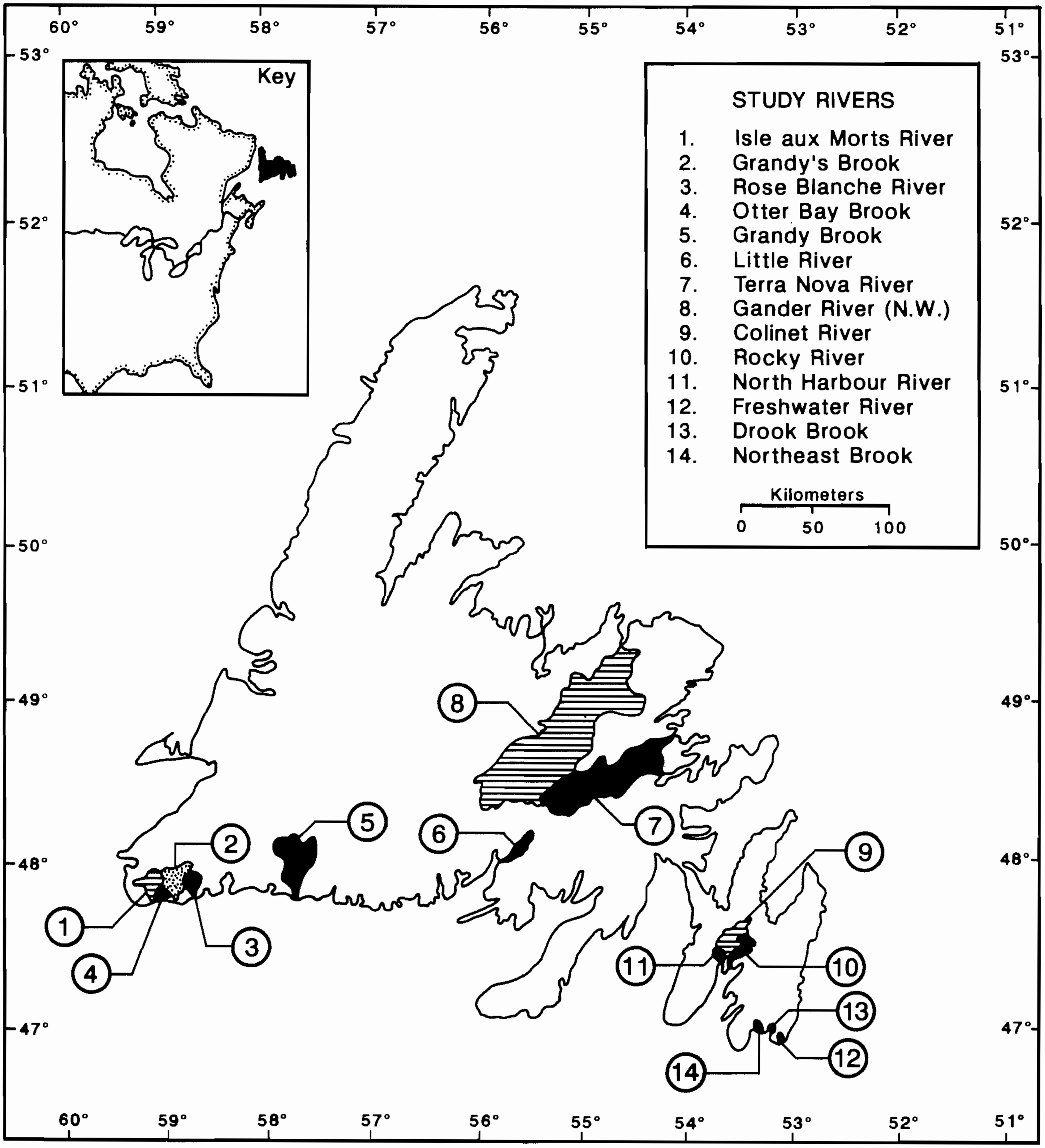

Figure 1. The location of the 14 study rivers included in the 'Episodic Acidification Study'.

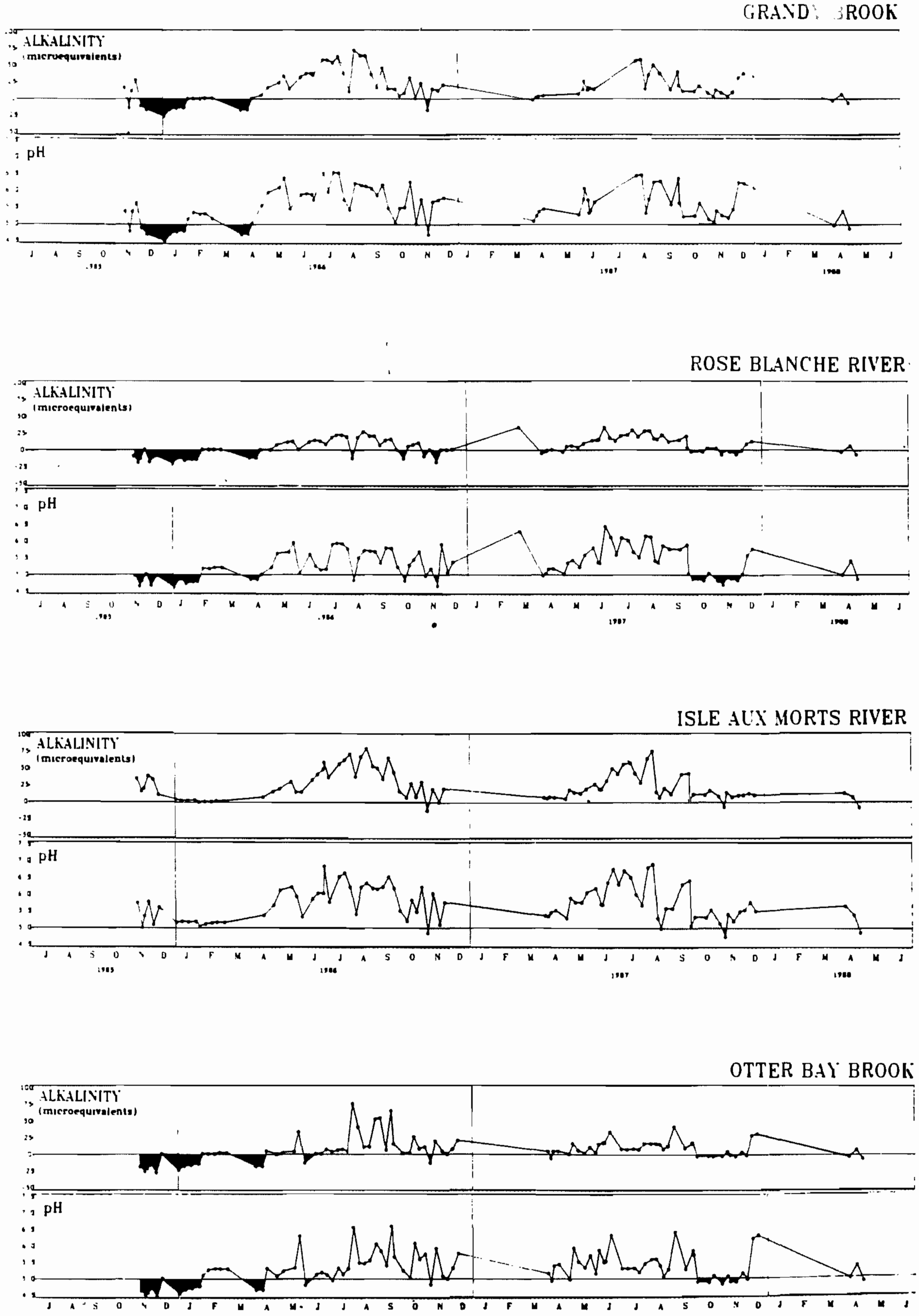

Figure 2. Seasonal variability in pH and alkalinity (ugL^{-1}) for four rivers on the southwest coast of insular Newfoundland.

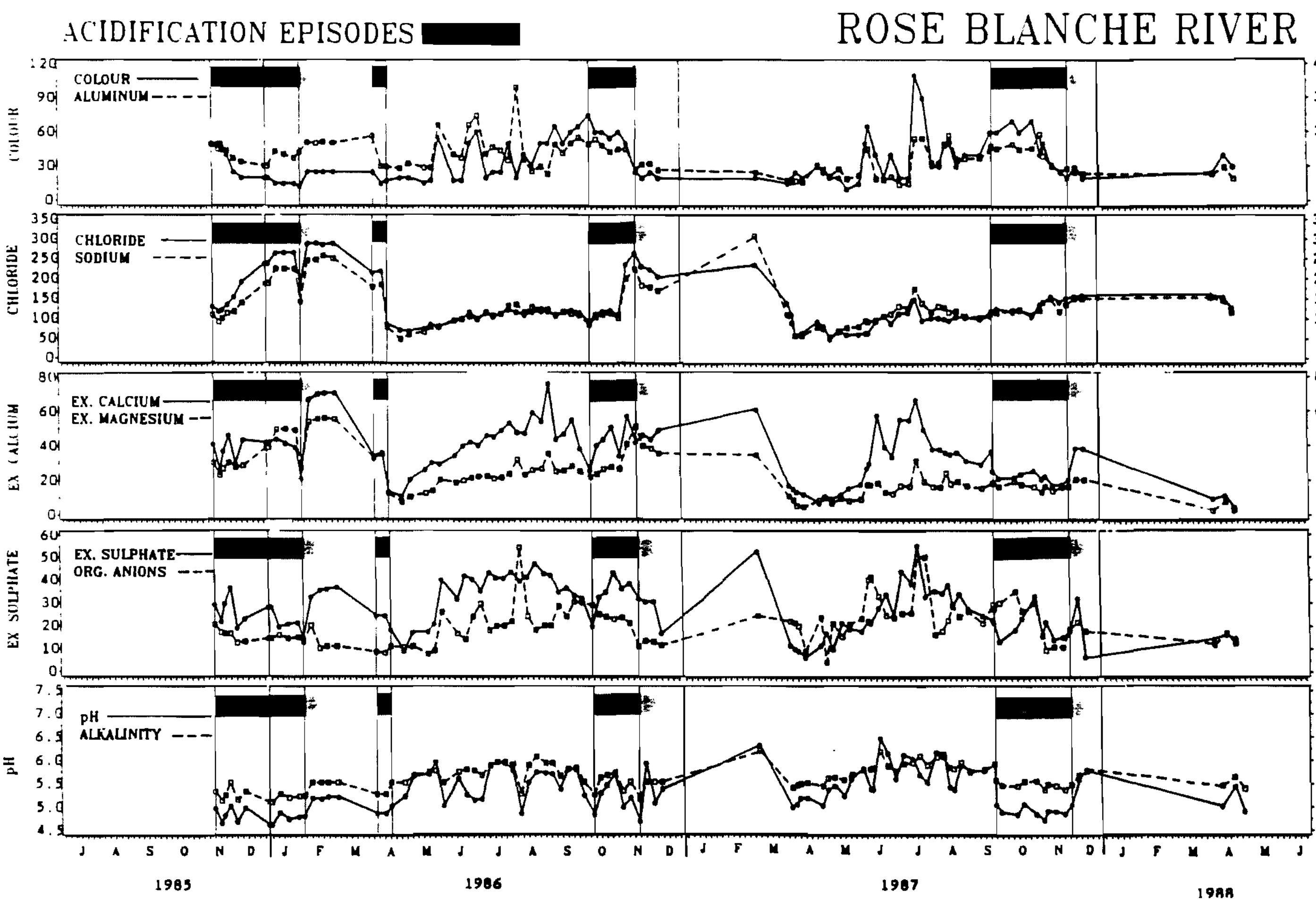

Figure 3. Seasonal variability in key water quality parameters for the Rose Blanche River.

4.2. MITIGATION STUDIES

Scotia-Fundy Region W. Watt

Creating a De-acidified Atlantic Salmon Refuge in the East River, Nova Scotia

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Introduction

Acid rain is causing serious environmental damage in North America and Europe. Numerous scientific publications have documented the acidification of lakes and streams in these areas with subsequent damage to fish and to other components of aquatic ecosystems. The problem of acid deposition is not expected to be resolved in the near future because of the serious political and economic problems involved.

Most scientists believe that the only effective way to control acid deposition is to restrict the emission of NO_x and SO_2 at their sources. However, due to delays in achieving the international agreements necessary to control acid emissions, other techniques and strategies designed to mitigate the impact of acid deposition need to be investigated. On an international scale, the most commonly used approach for mitigating the impact of acidification of inland surface waters on the fishery resources involves the application of limestone or other alkaline materials at the receptor sites (i.e., lakes and rivers) to neutralize the acid input. The generic term for this particular approach is "liming". Liming is not a panacea for neutralizing acid deposition. The increased pH and increased alkalinity resulting from liming are only temporary effects, and continuous reapplication is required as long as the lakes and streams continue to be subject to atmospheric acid deposition.

Several countries have already adopted policies to mitigate surface water acidification through experimental and/or operational liming programs. The largest operational liming program is in Sweden, where 5000 surface water sites were limed in 1988. In the United States liming is practised on a relatively small scale, with operational programs in West Virginia and New York, and numerous experimental programs. Past liming experiments in Canada involve the experimental application of alkaline materials to four lakes and a stream near Sudbury, Ontario (1973-77), liming four lakes and six rivers in Nova Scotia (1981-85),and the liming of Bowland Lake, Ontario in 1983. The partial success of these projects has led to further studies.

The Need for Mitigation in Nova Scotia

During 1978-80, a survey of water chemistry in the Atlantic salmon rivers of the Maritimes region (Watt, 1981) revealed severe acidification in the Atlantic coast rivers of Nova Scotia. This is an area of shallow soils and poor drainage, underlain by granites and metamorphic rocks lacking in basic minerals. The area contains 60 known salmon rivers, of which 13 have been reported by Watt (1987) to have mean annual pH's <4.7 and no surviving salmon, and 18 have pH's ranging from 4.7 to 5.0 and only small remnant salmon populations. Atlantic salmon production losses that have resulted from the acidification of Nova Scotia's rivers are estimated to be between 5,000 and 22,000 fish per year (Watt, 1986; and Anon., 1988).

The loss of Atlantic salmon from so many rivers was sufficiently alarming to prompt studies of local mitigation measures that could be applied immediately to prevent further losses, to preserve the remaining genetic diversity, and, if possible, to restore the damaged habitat.

Previous Studies

Liming studies described by White et al. (1984), Watt et al. (1984) and Watt (1986) evaluated several different approaches (river dosers, in-stream limestone gravel and headwater lake treatment) to the liming of acidified Atlantic salmon streams, and concluded that liming the headwater lakes was the most practicable and economical approach for temporary rehabilitation of acidified Atlantic salmon habitat in Nova Scotia. The treated lakes release alkalinity to the downstream habitat, and compensation for freshet conditions is automatic. The lakes are limed in winter to prevent surface layers of low pH runoff from forming on the lakes during the period of inverse stratification. The major disadvantage is that most Nova Scotian lakes have a turnover time of less than one year, hence annual liming is required.

Although headwater lake liming is the most economical of the habitat rehabilitation approaches studied, fishery restoration by headwater lake liming would still cost approximately $200 per restored caught salmon (Watt, 1988). At present, this cost is judged too high for general mitigation.

Establishing the Refuge

Study Objectives - Since 1980, the Department of Fisheries and Oceans has been monitoring the Atlantic salmon (electrofishing) in nine Nova Scotian rivers where the populations are threatened by acidification. By 1986 four of the nine (East, Gold, Sackville and Salmon rivers) showed significant pH declines, and there was fear that the native salmon populations of these rivers would soon be lost. A liming operation to establish a deacidified refuge commenced on the East Branch of East River in 1986. The objective of the program is genetic salvage, and to demonstrate the practicality (technical, social and bureaucratic) of preserving a native wild Atlantic salmon stock within a deacidified refuge until the acid rain problem is resolved and the rivers revover.

The Atlantic salmon angling record for East River (Watt et al., 1983) shows a decline from about 50 fish per year prior to 1950, to zero from 1971 on. Electrofishing surveys indicated that a small number of Atlantic salmon juveniles were still to be found in the East Branch tributary, which has a higher pH than the rest of the system. If the pH of East Branch could be raised and stabilized against episodic depressions, then the remnant population in the East Branch could be enhanced and its survival as a wild stock would be ensured.

Raising the pH of East Branch was accomplished by the annual liming of four lakes (Table 1). Officer Camp and Square lakes are true headwater lakes fed by seepage and intermittent streams. They have relatively large drainage areas and mean residence times of less than one year. Timber Lake is the largest in the system. It is immediately downstream of Officer Camp Lake, and the other inlets are first order or intermittent. Timber is a deep (max 40 m) lake with a relatively small drainage area and a mean residence time of about three years. Coolan Lake is more a widening of the river than a lake. It is shallow (max 7 m) and has an average mean residence time (depending on river discharge) of about one month. Timber, Coolan and Square lakes are oligotrophic with pre-liming pH's slightly above 5. Officer Camp Lake is a large pond in a peat bog, typically dystrophic, with high colour and acidity and the lowest pre-liming pH (4.5) of the four treated lakes.

The lime (calcite limestone ground to a mean particle diameter of 30 micrometres) is applied to the lakes by spreading over the ice each year in Jan-Feb (Watt, 1986). In the first year of liming (1986) only Officer Camp and Timber lakes were treated. In subsequent years all four lakes were treated. The effective lime dose units are tandem dump-truck loads averaging about 15 tonnes each. Actual treatment levels have varied somewhat from year to year, the averages are listed in Table 1, along with the dose rates per hectare and as whole-lake acidities (Watt et al., 1984).

The frequency of sampling required to establish reliable estimates of lime export (and other river chemistry parameters) was an issue of concern. To resolve it, daily water samples were collected (1983) for chemical analyses (all major ions) at a gauged site on East River (St. Margarets), which has a 27 km^2 drainage area and is within 20 km of the liming project. "Lime" export was calculated by summing the normalities of calcium and magnesium (hardness) and expressing the quantity as mg/L of $CaCO_3$. Each months daily values were sub-sampled 30 times, randomly, with replacement. Sub-sampled monthly concentrations were multiplied by mean monthly discharge, and these were summed over months to give estimates of annual export (expressed as tonnes of $CaCO_3$). Fig 1 is a histogram of the results. The mean for the thirty randomized monthly samples was 39.46 tonnes per year. The estimate calculated directly from all daily analyses and daily discharge rates is 39.37 tonnes per year. The 90% confidence interval for the monthly sampling is $\pm$5%, which is considered to be within the limits of acceptable error. The concentration of most major ions does not vary widely on a day-to-day basis, probably because of the high natural storage capacity (lakes and wetlands)in most Atlantic Upland drainage systems. Export estimates are far more sensitive to discharge, which typically varies by a factor of near 100 over the year.

The East Branch was sampled at seven stations, two below Officer Camp, two below Timber, one below Coolen, one just below the Square Lake outlet and one just before the confluence with the main East River. The East River was sampled at a station near the mouth, and Canaan River (the other major tributary of East River) was sampled to provide a local untreated control. Water samples were usually taken on a monthly basis. During periods of rapid change (late Autumn) and anticipated sensitivity, weekly or biweekly samples were sometimes taken. In addition, water samples from the two stations below Officer Camp Lake and the two stations below Timber Lake were collected at staggered times during the month (usually two weeks apart).

The efficiency of a lake liming project is usually measured in terms of percent dissolution of the limestone dose into the lake water. The lake liming dissolution efficiency estimates for the project are presented in Table 2. Efficiency to date is about 30% for Timber, Coolan and Square lakes and 43% for Officer Camp Lake. The dissolution efficiency appears to relate more closely to the lake's pre-liming pH and acidity (Table 1) than to mean residence time or dose rate. Lake liming efficiencies reported in the literature involve single doses of lime which then dissolve over several years (Watt et al., 1984), hence the efficiencies of Table 2 are not directly comparable with the literature values. The lake dissolution efficiencies given in Table 2 include both export and the amounts that remain behind dissolved in the lake water, and they have been corrected (where appropriate) for imports from limed lakes upstream. The values for tonnes of lime spread on the ice and exported are accumulative (summed over all years since liming began). The fact that dissolution efficiencies have not declined is taken to indicate that the current dose rates are not yet in excess of the system capacity to dissolve limestone.

Watt (1986) reported a lower dissolution efficiency of 45% (after two years, with 5% dissolution in the second year)) for a single treatment of calcite limestone spread over the ice, as compared to 59% for spreading as a slurry in the summer, so the observed lower dissolution rates on East River were anticipated. They are compensated for by the improved efficiency and economy of winter limestone spreading. The annual spreading of about 370 tonnes usually occupies ten days (of good weather). Total cost (1986-1989) for all equipment, supplies, road and bridge maintenance, snow ploughing, and labour (four person crew) averaged $100 per tonne.

In comparison, White et al (1984), using boats and a similar work force, required 23 working days to spread 135 tonnes as a slurry on Sandy Lake, N.S. The total cost in 1989 dollars was $202 per tonne.

Although the lime is being added to lakes, this is not a lake liming project. The target is the Atlantic salmon habitat of the East Branch from the outlet of Timber Lake to its confluence with the main river, about 12 km. Of more direct concern to the river liming project is the overall dissolution efficiency (for all four lakes) and the efficiency with which dissolved lime is delivered to the river. Table 3 looks at the efficiency of river liming, downstream of all four treated lakes. Dissolution efficiency was highest (35%) in 1986, when only two lakes were limed, but this reflects the higher efficiency associated with Officer Camp Lake rather than any efficiency benefit from a lower dose to the system. With four lakes limed (since 1987) the dissolution efficiency has remained constant at about 30%. The efficiency with which lime is delivered to the river has grown annually from 5% in the first year (when most of the dissolved lime went into raising the alkalinity of Timber Lake), to 16% after four years of liming. Because of the large amounts of limestone that remain behind in the lakes (dissolved and on the bottom), it is not possible to estimate efficiencies for single years after 1986. The actual tonnages of limestone passed down the river in each year are given in the right hand column of Table 3. They suggest a levelling off at about 75 tonnes per year, which represents about 20% of the present total annual dose. About three times this amount is stored as alkalinity in the upstream lakes, and more is still dissolving (probably another 20 tonnes; Watt, 1986) from the previous year's liming.

Fig 2 shows the pH response relative to the tonnes of dissolved limestone transported past water sampling stations below each of the limed lakes. The effect of dissolved limestone on river pH appears to be a straight line relationship over the pH ranges encountered in East Branch. This is to be expected, given the dissolution chemistry of limestone (i.e. we are primarily working within the linear portion of the titration curve), and so Fig 2 lends further credibility to the adequacy of the level of observation.

Chemical Environment Within the Refuge

A time series showing the impact of liming on the pH of East Branch (at a station below Timber Lake) is shown in Fig 3. Liming began early in 1986. Also depicted is the time series for the station on the main East River at the mouth, where the effect of upstream liming on pH is also apparent. The pH of the main river has risen in response, but the range of annual variation has also doubled from an annual fluctuation of 0.5 pH units in 1981-85 to 1 unit in 1987-89.

Fig 4 shows the effect liming has had on mean annual pH's over the length of the East Branch from the outlet of Officer Camp Lake to the confluence with the main stem, and down to the mouth of the East River. Prior to liming, most of the East Branch had a mean annual pH slightly above 5, and it functioned an a precarious refuge for the last remnant population of Atlantic salmon in the East River system (Tables 4-6). Fig 4 shows the profiles of mean annual pH for the pre-liming condition (1982 data), for the first year of liming (1986), and after four consecutive years of liming (1989). For most of the Atlantic salmon habitat in the East Branch the pH is now 6.4 ± 0.2, a level and range that should be optimal for juvenile salmon production (Lacroix, 1987, 1989).

Biological Responses

Table 4 shows the estimated densities of juvenile salmon at three sites on the East Branch. Too few fish were taken on some occasions to allow valid estimates of population to be made. Each instance where juvenile salmon were present but their populations could not be estimated is designated with an 'X'. Fry densities rose immediately after liming in 1986 and remained at about the same level in 1987. In 1988 estimated fry densities at the sites surveyed fell to zero, possibly owing to an absence of adult spawners in the previous autumn. If the 1984 and 1985 year-classes were very weak as suggested by the virtual absence of fry in 1984 and 1985, there would be few adult spawners in 1987 and correspondingly few fry in 1988 despite improved water quality in that year. In 1989, the fry densities rose again, these fry are presumed to be progeny of fish which were parr when liming was begun in 1986. In 1990 the fry densities remained about the same as in 1989 and parr densities rose. These parr were survivors of the successful 1988 year-class.

The increased population densities of juvenile salmon since liming began were not accompanied immediately by more widespread distributions in East River. Before liming started, Atlantic salmon fry and parr were found at only one or two sites on East River (Tables 5 and 6). No fry were found in 1984 or 1985. After liming was started, fry remained sparsely distributed and again no fry were found in 1988. By 1990, fry were still found at only two sites. Salmon parr were only slightly more widespread than fry in the limed portion of East River until 1990 when they were found at six out of eight limed sites. No salmon were caught at any time in the un-limed Canaan River (the bottom five rows in Tables 5 and 6).

The distribution of salmon fry in East River depends on where spawning has occurred in the previous autumn. The spawning run of salmon which returned to the river before the liming project was very small, and consequently some portions of the river may have been without spawners. This situation would continue for several years after liming began until the increased survival of fry and parr was reflected in a larger spawning run of adult fish. This may explain why population densities of salmon fry in 1989 and 1990 are quite high and comparable to those in unpolluted rivers at some sites, while fry are virtually absent from other sites. The more widespread distribution of salmon parr in 1990 is owing to the dispersal of these larger fish throughout the river.

The biomonitoring site between Bad and Big Whitford lakes is downstream of all four limed lakes. Juvenile Atlantic salmon have been monitored at this site since 1981 with the same electrofishing procedure (barrier nets at marked spots on the river, lip seine and three electrofishing passes without replacement. The total number of salmon juveniles caught each year at this site (Fig 5), including years when salmon were present but no density estimate could be made (the X's in Table 4), can be used to examine the relative changes in juvenile density that have been achieved thus far (at this site) by the liming program. We estimate that the other stations on East Branch, into which salmon parr moved in 1990, will show similar density increases over the next five years. When the salmon rearing habitat of East Branch (40,000 m^2 of riffle/run) becomes fully stocked with juveniles we hope to achieve an annual production rate of 2000 smolts per year from the limed refuge.

Brook trout were present but at very low population densities, throughout East River including the Canaan tributary. Valid estimates of population could seldom be made. The distribution of brook trout in the river has not changed perceptibly with liming, but this may be an artifact of our sampling procedure which emphasizes salmon rather than trout habitat.

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Table 1. Lake physical and chemical characteristics and average (1986-90) lime dosage.

Lake	Officer Camp	Timber	Coolan	Square
Area (km^2)	0.46	3.4	0.41	0.22
Volume ($10^6 m^3$)	1.2	39.7	1.3	0.8
Mean Residence Time	3 Months	3 Years	1 Month	6 Months
Pre-liming pH	4.5	5.2	5.1	5.2
Pre-liming Acidity	14.9	4.5	4.3	4.2
Tonnes of Lime (Ave.)	51	229	49	31
Dose Rate as (Tonnes/ha)	1.1	0.7	1.2	1.4
Dose Rate as Acidities *	2.9	1.3	8.8	9.2

* Average dose of lime expressed as a multiple of whole lake acidity.

TABLE 2
Efficiency of Lake Liming

Year	Tonnes of Lime (Accumulative) Spread on Ice	Dissolved Stn. 1	Dissolved Stn. 2	% Dissolved (Efficiency) Stn. 1	% Dissolved (Efficiency) Stn. 2
(Officer Camp Lake)					
1986	43	21	19	49%	44%
1987	98	41	44	42%	45%
1988	150	67	65	45%	43%
1989	208	92	90	44%	43%
(Timber Lake)					
1986	242	73	77	30%	32%
1987	447	117	119	26%	27%
1988	665	188	202	28%	30%
1989	898	235	258	26%	29%
(Coolan Lake)					
1987	68	26		38%	
1988	143	51		36%	
1989	215	70		33%	
(Square Lake)					
1987	55	15		27%	
1988	81	27		33%	
1989	125	39		31%	

Table 3. Efficiency of Tributary Liming

Computed from the East Branch station below all four limed lakes. Values are in metric tonnes of lime, and are accumulative except for the third and last colums.

Year	Spread on Ice (Jan-Feb)	Dissolved in Lakes at yr end	Exported Down River	% Dissolved in Lakes and River	% Exported Down River	Annual Tonnes Down River
1986	285	86	15	35%	5%	15
1987	668	127	72	30%	11%	57
1988	1051	184	149	32%	14%	77
1989	1434	213	223	30%	16%	74

TABLE 4
Population Densities of Juvenile Salmon in
East Branch of East River, 1981-90.
Fish present but population not estimated - X.
(fish per 100 square m.)

Fry

	Between Bad and Big Whitford Lakes	Between Coolen and Bad lakes	Timber Lake Outlet
1981	X		0
1983	0.5 + 0.1		0
1984	0		0
1985	0	0	0
1986	5.9 + 1.7		0
1987	6.3 + 1.3	0	0
1988	0	0	0
1989	26.2 + 1.2	X	0
1990	28.1 + 2.3	0	0

Parr

	Between Bad and Big Whitford Lakes	Between Coolen and Bad lakes	Timber Lake Outlet
1981	X		X
1983	4.0 + 0.2		0
1984	X		0
1985	X	0	0
1986	6.8 + 6.2		1.9 + 0.7
1987	4.9 + 2.6	X	X
1988	5.5 + 4.3	0	X
1989	0	0	0
1990	14.6 + 7.8	4.3 + 5.6	2.7 + 0.2

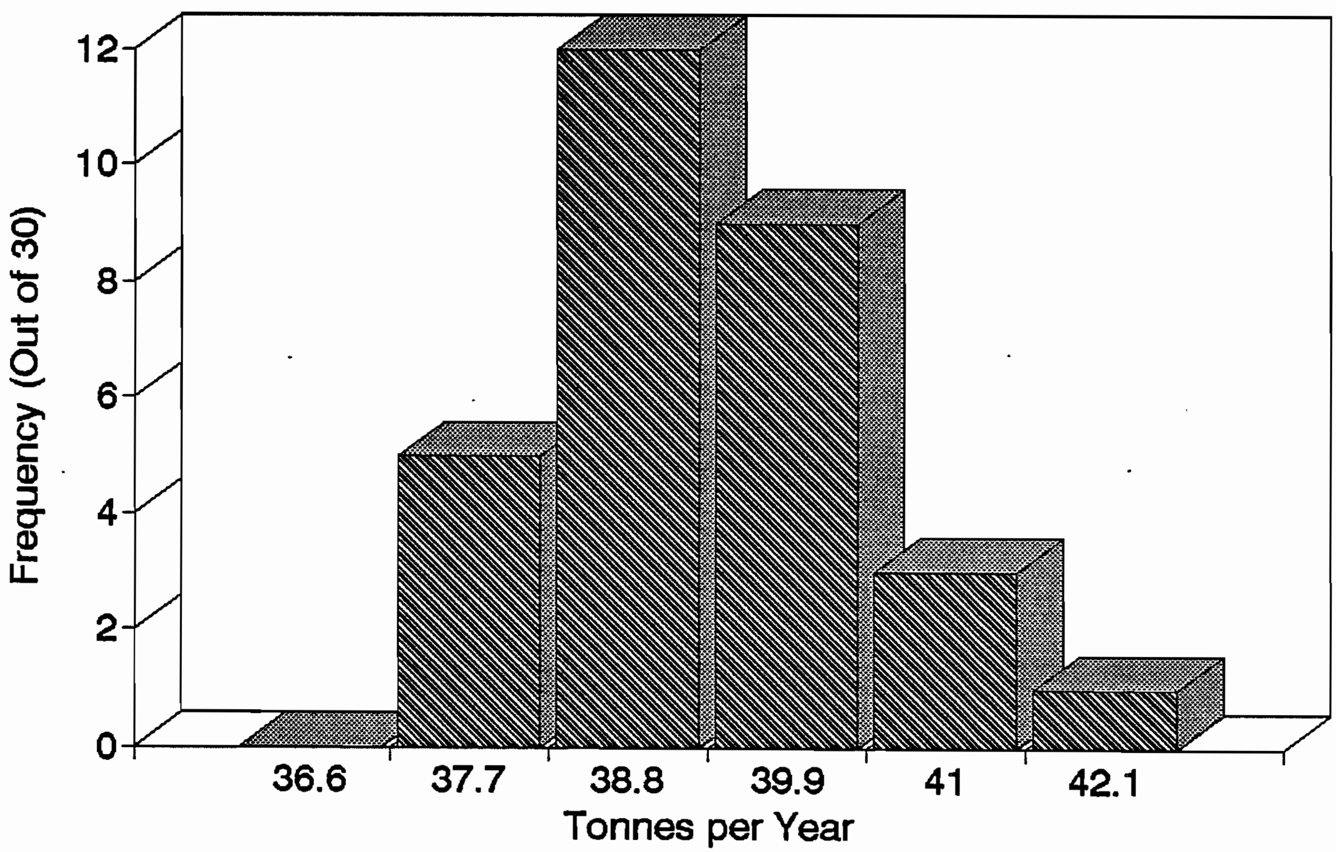
TABLE 5. Distribution of Atlantic Salmon Fry, East River, Chester, N.S. 1981-90. Present - X, Absent - 0.

LOCATION	YEAR 81	83	84	85	86	87	88	89	90
East R. at Hwy 103				0	0	0	0	X	X
Barrys Bk at Hwy 103					0				
Below Whistler L.				0		0	0	0	0
Below Little Whitford L.				0	0	0	0	0	0
Between Bad and Big Whitford Lakes	X	X	0	0	X	X	0	X	X
Between Big and Little Whitford Lakes					X	0	0	0	0
Between Coolen and Bad Lakes				0		0	0	X	0
Between Westhaver and Coolen Lakes							0		
Timber L. Outlet	0	0	0	0	0	0	0	0	0
Officers Camp L. Outlet				0	0	0	0	0	0
Canaan R. 3.3 Km. below Connaught L.					0	0	0	0	0
Canaan R. 1.7 Km. below Connaught Lake				0	0	0	0		0
Canaan R. 1.0 Km below Connaught Lake							0		0
Canaan R. at Connaught L. Outlet	0			0	0	0	0	0	0
Connaught L. Inlet							0	0	

TABLE 6. Distribution of Atlantic Salmon Parr, East River, Chester, N.S. 1981-90. Present - X, Absent - 0.

LOCATION	YEAR 81	83	84	85	86	87	88	89	90
East R. at Hwy 103				0	0	0	0	0	X
Barrys Bk at Hwy 103					0				
Below Whistler L.				0		0	0	0	0
Below Little Whitford L.				0	0	0	X	0	0
Between Bad and Big Whitford Lakes	X	X	X	X	X	X	X	0	X
Between Big and Little Whitford Lakes					0	0	0	0	X
Betwen Coolen and Bad Lakes				0		X	0	0	X
Between Westhaver and Coolen Lakes							0		
Timber L. Outlet	X	0	0	0	X	X	X	0	X
Officers Camp L. Outlet				0	0	0	0	0	X
Canaan R. 3.3 Km. below Connaught L.					0	0	0	0	0
Canaan R. 1.7 Km. below Connaught L.				0	0	0	0		0
Canaan R. 1.0 Km. below Connaught L.							0		0
Canaan R. at Connaught L. Outlet	0			0	0	0	0	0	0
Connaught L. Inlet							0	0	

Fig 1. Estimates of Lime Export for East River
Random Monthly Sub-samples from Dailies



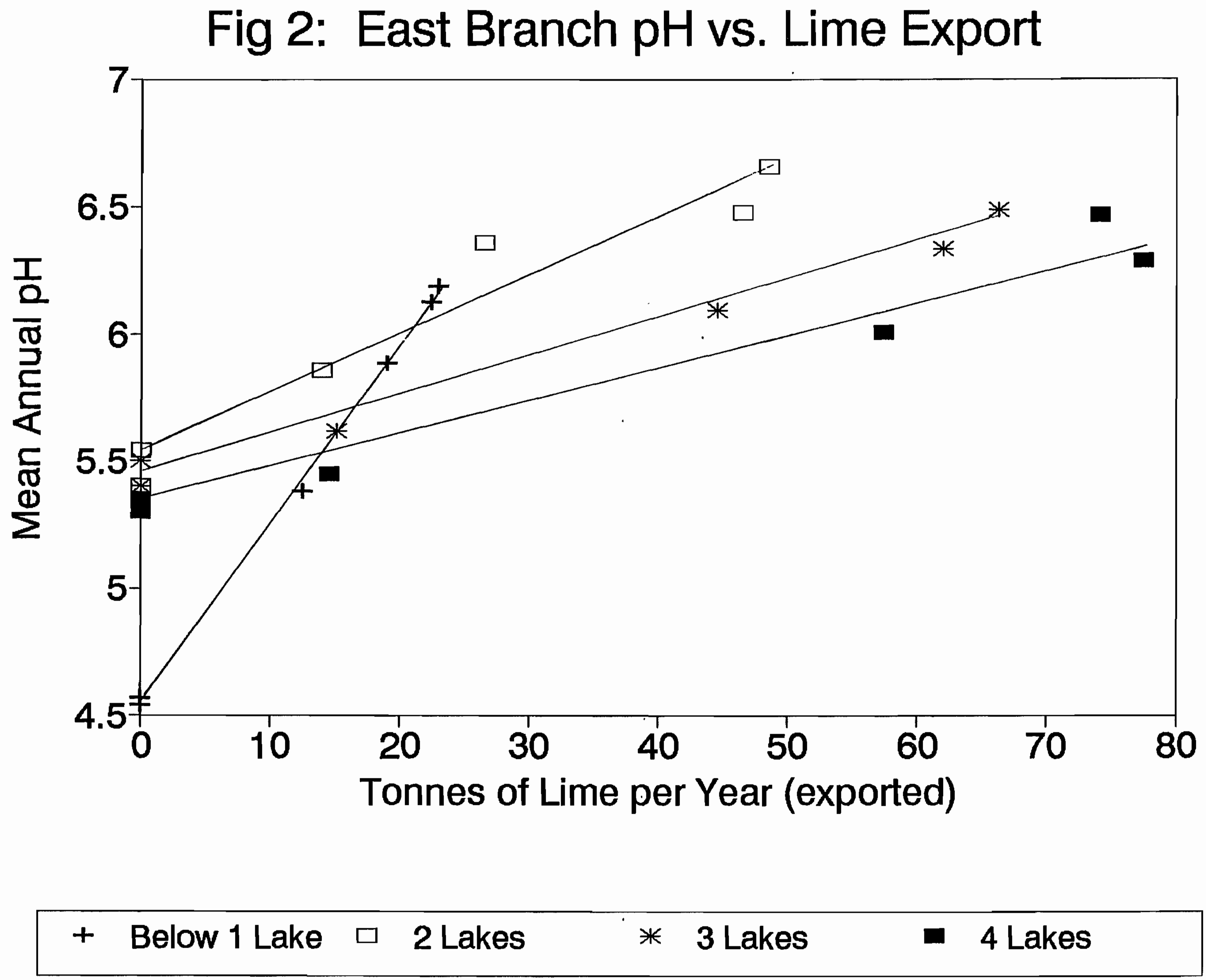


Fig 2: East Branch pH vs. Lime Export
Mean Annual pH
7
6.5
6
5.5
5
4.5
0
10
20
30
40
50
60
70
80
Tonnes of Lime per Year (exported)
Below 1 Lake
2 Lakes
3 Lakes
4 Lakes

Fig 3: Main River and Limed Tributary
Monthly pH's

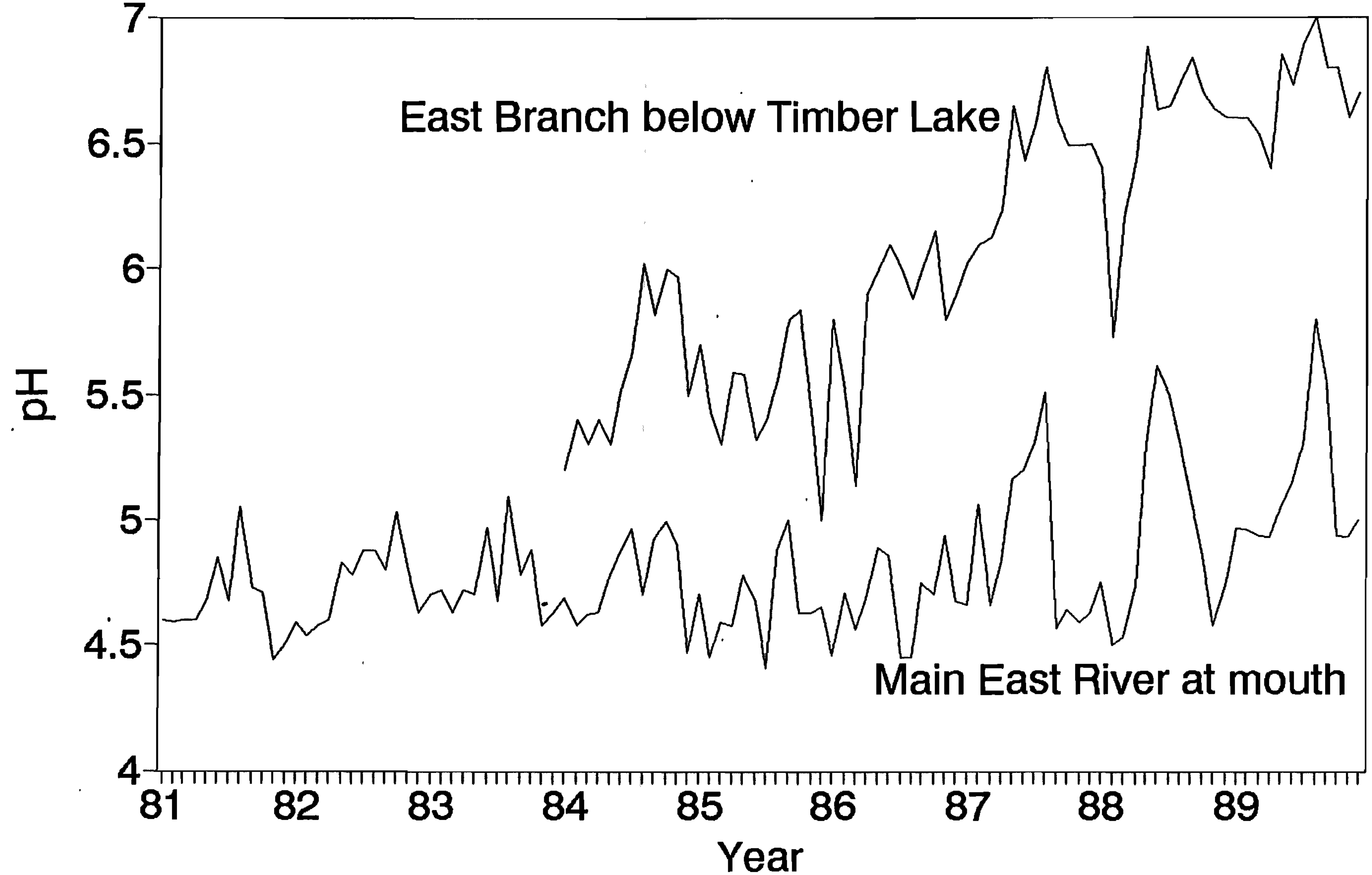


Fig 4: East River (East Branch) Nova Scotia

Pre- and Post-liming pH's

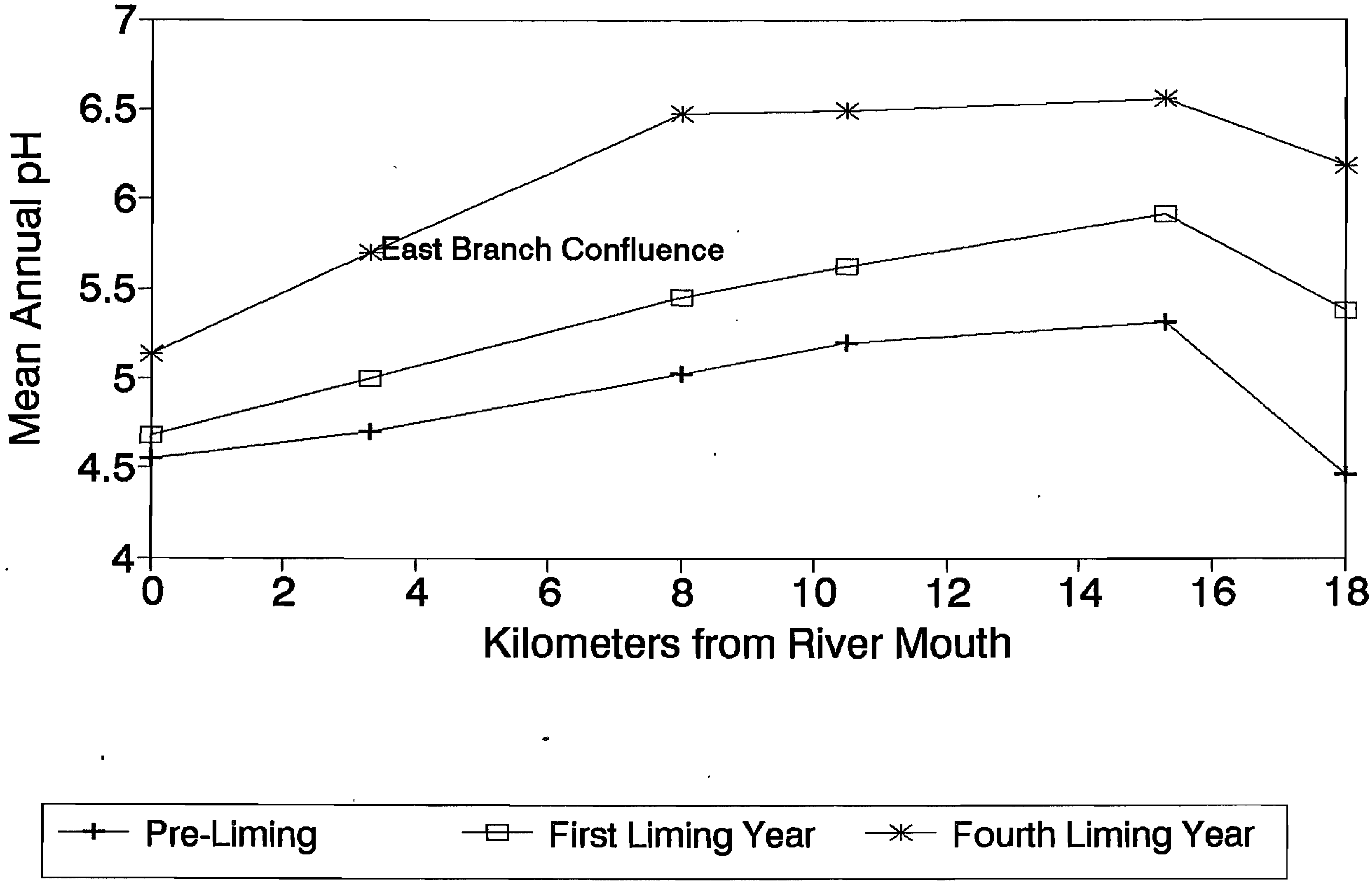
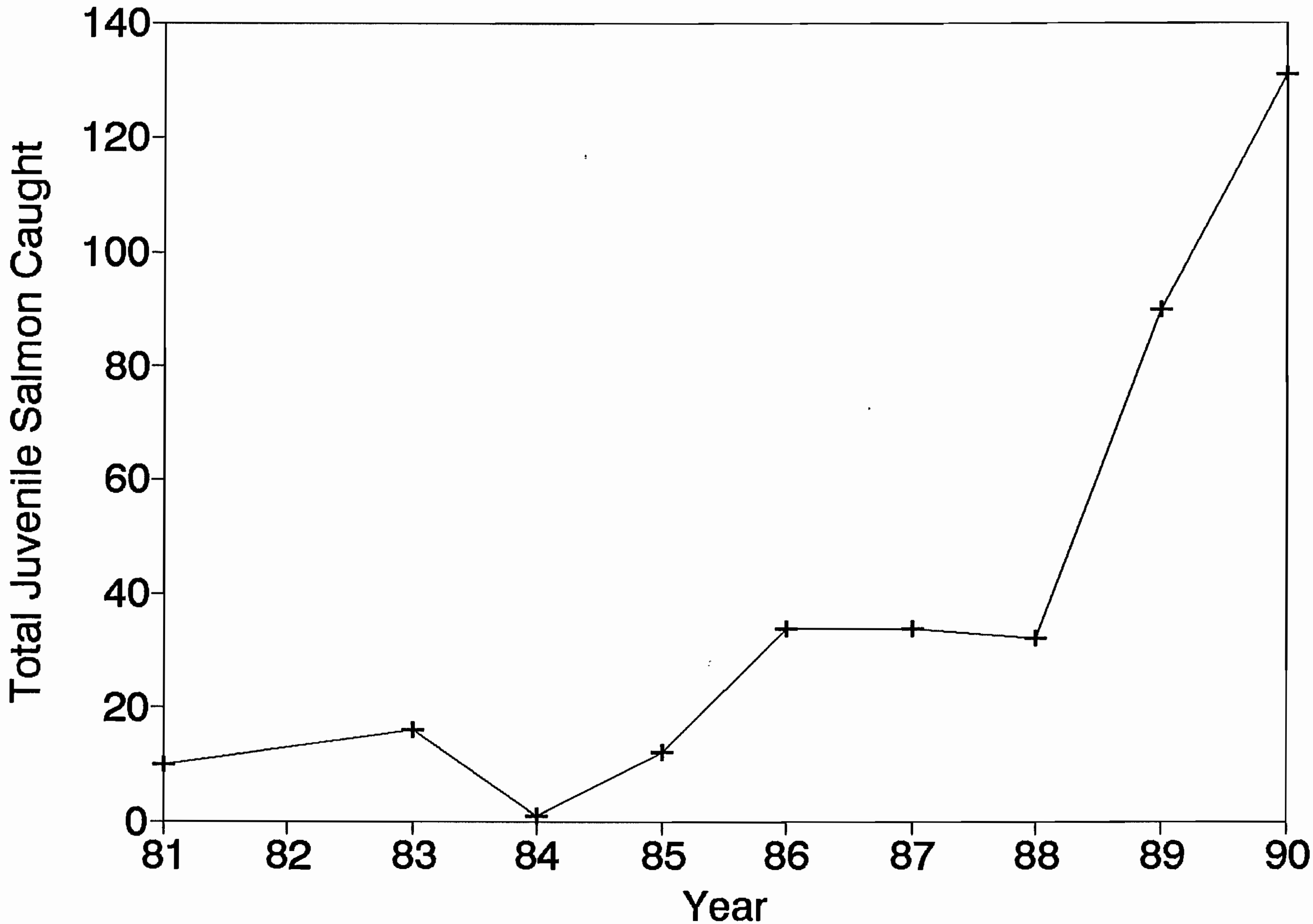


Fig 5: East Branch - below Bad Lake



Questions and Answers

<u>**QUESTION:**</u> I was going to ask if there were any brook trout or any trout native and if so have you noticed any increase in population throughout the same time period?

<u>**WALTON WATT:**</u> Yes. There are small numbers of trout present at most of the stations including the unlimed tributary which has very low pH. There has been no change, no detectable change, in the brook trout population at all. In fact, none of the other species appear to have responded except well some of the...one or two of the minnows appear to have responded not in population density but they appear to be occurring at more sites. We haven't done the statistics on that so I can't say if it's real or not. They may have increased their distribution. But the target species is the one that has responded and the only one so far.

<u>**IOLA PRICE:**</u> Walton, are all the fry and parr in that river the progeny of the adults of that river or do you have any indication that there might be some strains?

<u>**WALTON WATT:**</u> No. They're all natural progeny from fish that were in the river when we started. There has been no stocking either prior or since. Historically, there may have been stocking but that would have been back in the '50s and it probably wasn't effective. Strains, I can't say but there are no large... No, I can't say that either. It's possible.

<u>**IOLA PRICE:**</u> Are they not marked?

<u>**WALTON WATT:**</u> They're not marked at all. These are wild fish. The electrophoretic work we've done so far which was on a result of a recommendation from an earlier Workshop to see just how much genetic variation there was from river to river in this area indicates that it's not as great as the variation is from year to year and even within river, in the bigger rivers. So it looks as though our concerns with wild genetic strains may be unwarranted. Maybe just keeping one or two rivers going is all we need. We don't have to preserve every threatened river. There is an aside comment on this. The local fishing population is convinced we're doing fantastic things to the trout in the lakes which we're not monitoring because we didn't have the resources to do that. But the fishing pressure on the lakes have increased a lot and they seem to be very happy with it. There's a lot of local enthusiasm for this project so we've had very, very good local cooperation, people who provide all kinds of help for us in terms of storing equipment down there all winter, helping us overcome problems of vandalism and that sort of thing. Even providing camps for us to use in the wintertime in there.

<u>**IOLA PRICE:**</u> How much more resources would you take to monitor the trout population? Is that part of the mandate? Would there be any problem with DFO doing that?

<u>**WALTON WATT:**</u> We're monitoring it at the electrofishing sites but we're electrofishing salmon habitat not trout habitat. The problem is not money it's manpower which is chronically short. You could throw more money at it and give a contract probably to a consultant group to go in and look at the trout populations. We have done minimal. Mainly...the trout fishery is in the lakes and we in the first year we did a creel census and last year we repeated the creel census. Now looking at the trout population in a lake is a very awkward thing, okay. That would be a big project but this will give us

growth rates and age structure when we get enough, sort of, man power to actually work up the scales and the otoliths. We have them but we haven't had a chance to do anything with them yet. Yes?

QUESTION: Do you foresee any interaction between the trout and the salmon if both populations both actually pick up and continue to grow in terms of food limitation or age perhaps?

WALTON WATT: No. I've seen too often happen in streams like this that if there are no salmon there the trout may be occupying the salmon habitat which is typically much more open and faster but you'll find trout in open, fast water if there are no salmon there. But when salmon is present, it displaces the trout out of that habitat. The trout is then found in areas with more cover, deeper water, pools and in the lakes. In Nova Scotia, we never find juvenile salmon in lakes or stillwaters. That's where you find trout. So in Newfoundland, you find salmon in lakes and stillwaters but not in Nova Scotia. The niche is separate. I'm a bit surprised that I have not seen any response from the trout in this situation but the trout is much more tolerant to acidic conditions and I guess the conditions were not that bad for the trout in that system so there hasn't been any noticeable increase. But as I say, this may be an artifact of our sampling. We are not looking in trout habitat but we have converted the stream which basically what we've done is we've taken the stream and you could say it was barren before with a few trout and small salmon in uncatchable numbers, they were so small, we've converted it back to a salmon stream which I find very gratifying but you have to keep it in perspective. It's a very small salmon stream and it costs a lot of money to do it.

SANKAR RAY: How much of the habitat are they losing, if at all, because of the position of liming the riverbed?

WALTON WATT: None, because you see the lime deposition is in the lakes and the habitat is in the river. There's no lime deposition in the river at all. What goes down the river is all dissolved, okay? We checked that out with filtration and we could almost never detect except immediately after liming for a day or two could we detect limestone in the river so it either settles out or goes downstream. What's happening in the lake is that you get about 1/3 of the limestone, this limestone goes into solution immediately and then another 1/3 of it comes into solution over a period of time and the remainder goes into eliminating what the acid absorption capacity of the sediment. It seals of the acidic sediment. Calcium gets grabbed onto by the clays quite fast.

4.3. ORGANIC CONTAMINANTS

Central and Arctic Region R. Hecky

Overview of LRTAP Aspects of Organic Contaminants in Aquatic Environments

Prepared by R.E. Hecky

Although no funding was forthcoming from the DFO LRTAP program in 1990-91 for organic contamination studies, there were a number of research initiatives and results in Central and Arctic Region relevant to LRTAP. The latitudinal survey of contaminant fluxes and concentrations in sediments and fish has established that a broad range of organic and inorganic contaminants are being atmospherically transported into even the most remote areas of Canada (see attached summary by Brunskill). At the ELA there is evidence from precipitation monitoring that agricultural pesticides are being transported hundreds of km (see Muir et al., Abstract). This demonstrates that long range transport of organics occurs from many different types of sources and is a broader issue that just fossil fuel combustion which is a major source of polyaromatic hydrocarbons. To date, the latitudinal studies in central Canada do demonstrate that depositional rates for most contaminants do decline at higher latitudes. These studies which are creating depositional maps for Canada are essential to defining the scope of the problem and are the first step in development of risk assessment models. The latitudinal survey should develop a longitudinal aspect with LRTAP funds and examine areas of eastern Canada where deposition rates may be maximal for Canada.

The latitudinal studies and others (see attached figures and tables) are also establishing that the hazard posed to aquatic organisms, fish and humans is not a simple function of depositional patterns. PCB concentrations in northern fish and human populations are as high or higher than in southern populations even though depositional rates are lower. These data indicate that aquatic and terrestrial ecosystems modify the input in significant ways and that northern systems may be at greater risk given equal deposition. What the modifying factors are require careful elucidation, submodel construction and verification before atmospheric deposition rates can be interpreted in risk assessment models. Also, it is necessary to determine synergistic or antagonistic effects on pollutant availability and physiological effects of the many atmospherically transported pollutants. These aspects, ecosystem submodel construction and verification, and possible synergisms and antagonisms, can best be addressed through whole ecosystem experimentation. LRTAP should address these issues and fund whole system experimentation on these topics. Central and Arctic has been developing experimental protocols for a whole lake PCB addition. Some funding has been identified from the Great Lakes Action Plan but these funds are likely inadequate at present and would not ensure that LRTAP aspects such as contaminant pathways, sinks, and ecosystem modifying factors would be adequately addressed compared to physiological effects and pathologies research.

Latitudinal Fluxes and Histories of Deposition of Atmospheric Pollutants in Temperate, Subarctic, and Arctic Canada, Related to Fish Contamination and Stress

Prepared by G.J. Brunskill, D. Muir, L. Lockhart, R. Hunt and J.F. Klaverkamp

Our initial hypotheses are illustrated in Fig. 1 which indicates that we expected to discover some relationship between the rate of supply or the sediment burden of atmospheric contaminants and fish bioconcentration or stress over a gradient of latitudinal sampling sites (and presumably a gradient of pollutant supply rates). Our sampling sites extend from 49°N Lat. (ELA, NW Ontario) to 82°N Lat. (Lake Hazen, Ellesmere Island). We were successful in raising 3 box cores and 3 large KB cores from Lake Hazen this spring and the analyses are now being completed. Data is available for the ELA lakes, Saqvaqjuac, and the Cornwallis Island lakes.

Analytical procedures for the measurement of organochlorines (OC) and polycyclic aromatic hydrocarbons (PAH) in remote lake sediments and fish, requires large samples as the concentrations are very low. We have designed sediment sampling equipment to supply large samples of thinly sliced sediment for radiochemical measurements (Be-7, Cs-137, Pb-210) and contaminants. Our box corer has been rebuilt several times to operate from ELA to Lake Hazen. Our large KB corer allows us to observe laminations in some of the Arctic lakes and slice very thin layers of sediment.

The history of lead deposition from ELA to the High Arctic is similar: excess lead appears around 1900, and sometimes shows a decline near the surface sediment slices (Fig. 2). Current rates of supply of excess contaminant lead are everywhere greater than background Pb deposition but they do decline as we go north. We are also measuring Cd and Hg in these cores (and fish samples).

Polycyclic aromatic hydrocarbon (PAH) concentrations, fluxes and history of deposition are similar from ELA to the High Arctic (Fig. 3): industrial PAHs appear in the late 1800s, peak in the 1950-60s, and begin to decline near the sediment surface in most cores. Sediment burdens and current deposition rates of PAHs decline with more northerly degrees of latitude.

The history of deposition of the organochlorine family of contaminants in our series of cores is in general agreement with the known history of production of these compounds (Figs. 4a, b). In most cores, DDT, PCB, HCH and other OCs appear in post-1950 sediment slices, although some of the more soluble members do diffuse down the core profile. Some OC contaminants decline with northerly latitude, but some OC have similar fluxes and concentrations in sediment from ELA to the High Arctic, especially the PCBs and HCH.

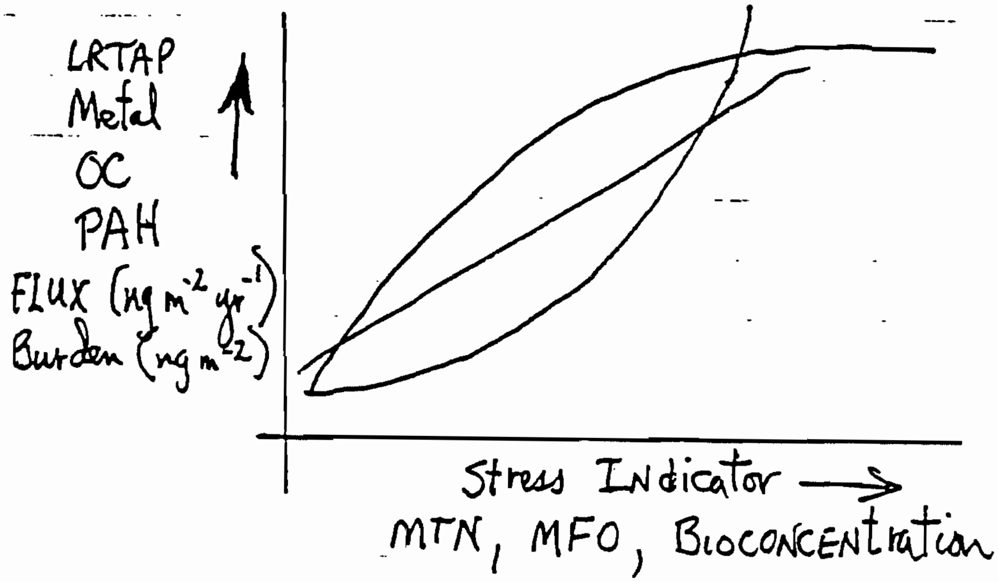
Organochlorine residues in lake trout and Arctic charr appear to actually increase as we go north (Fig. 5). This might be due to the fact that Arctic fish are usually older and carry more fatty tissue. Fig. 6 shows the distribution of the different conjenors of PCBs in fish tissues from our sampling sites. These observations do not support our initial hypotheses.

Mixed function oxidase enzyme activity is thought to be a response to some OC (PCBs) and some PAH contamination. We have found that MFO activity in fishtissues does not vary with supply rate to the sediments or sediment burdens of these contaminants (Figs. 7a, b).

Metallothionein is a protein found in kidney, spleen, gut, and gill tissues that is thought to respond to contamination with some group 2 metals. Our limited data base indicates that MTN concentration in fish tissue does decline with decreased rate of supply of Cd to lake sediments.

The Lake Hazen cores and fish samples are now being analyzed and we suspect that the deep water (254 m) sediments of this High Arctic lake have been subject to petroleum seeps or petroleum contamination from military activities.

Continued, stable funding for this project will allow the construction of a map of deposition histories of organic and metal contaminants in the Arctic. This data base can be used to evaluate the level of contaminants in remote Arctic ecosystems and in visualizing the source of the contaminants. Mechanisms and proportions of total pollutant supply to fish population uptake and stress response requires much further study and hypotheses reformulations. We would like to continue this study into the central and western Arctic, and also into southern Ontario and Quebec where large supply rates of contaminants are expected.



LRTAP FLUX STUDY

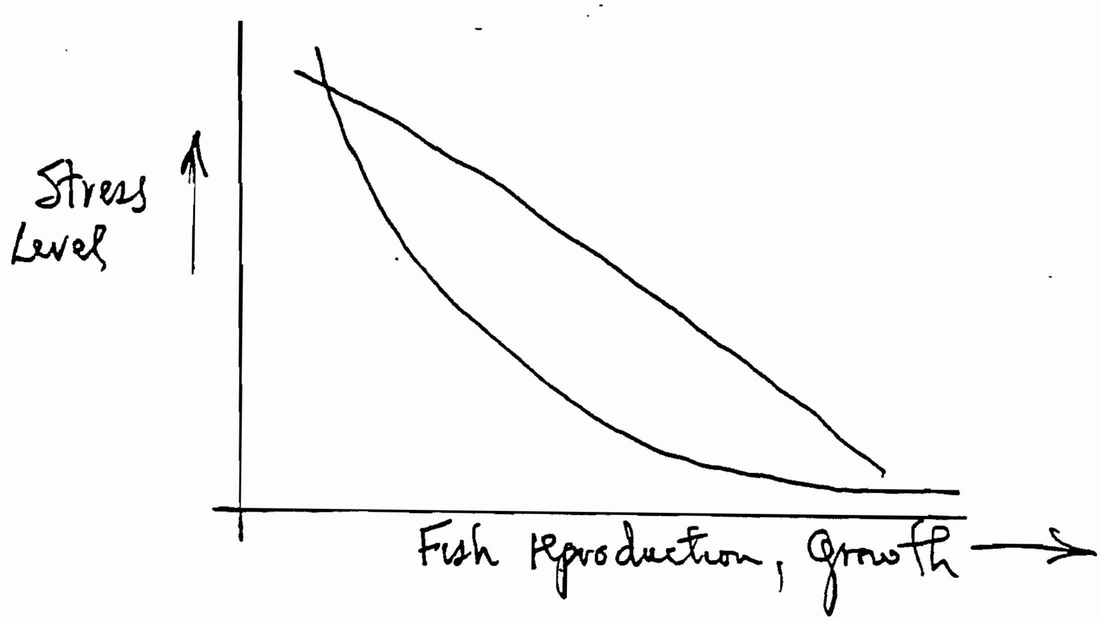


Fig. 1

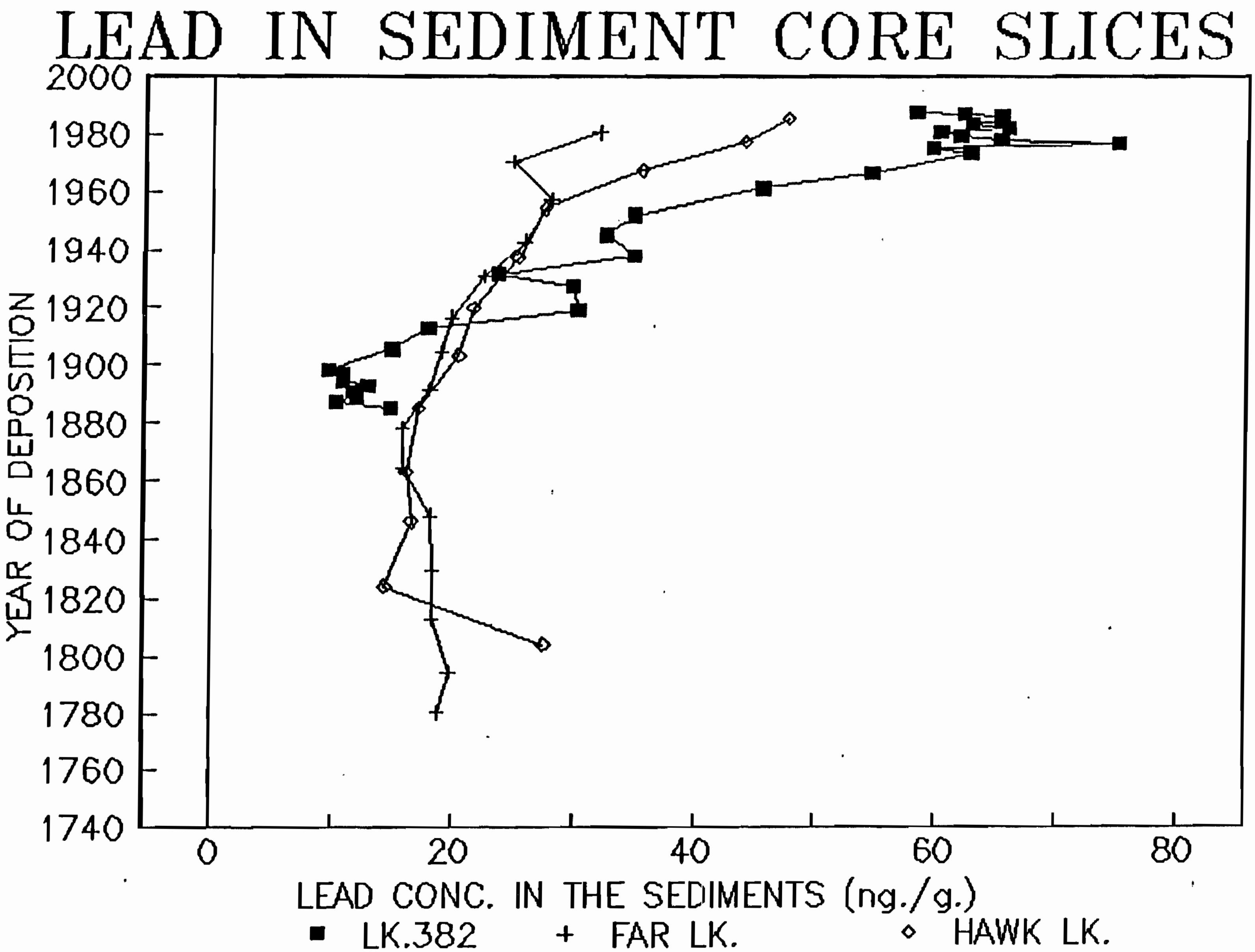

LEAD IN SEDIMENT CORE SLICES
2000
1980
1960
1940
1920
1900
1880
1860
1840
1820
1800
1780
1760
1740
YEAR OF DEPOSITION
0
20
40
60
80
LEAD CONC. IN THE SEDIMENTS (ng./g.)
LK.382
FAR LK.
HAWK LK.

Fig 2a

104

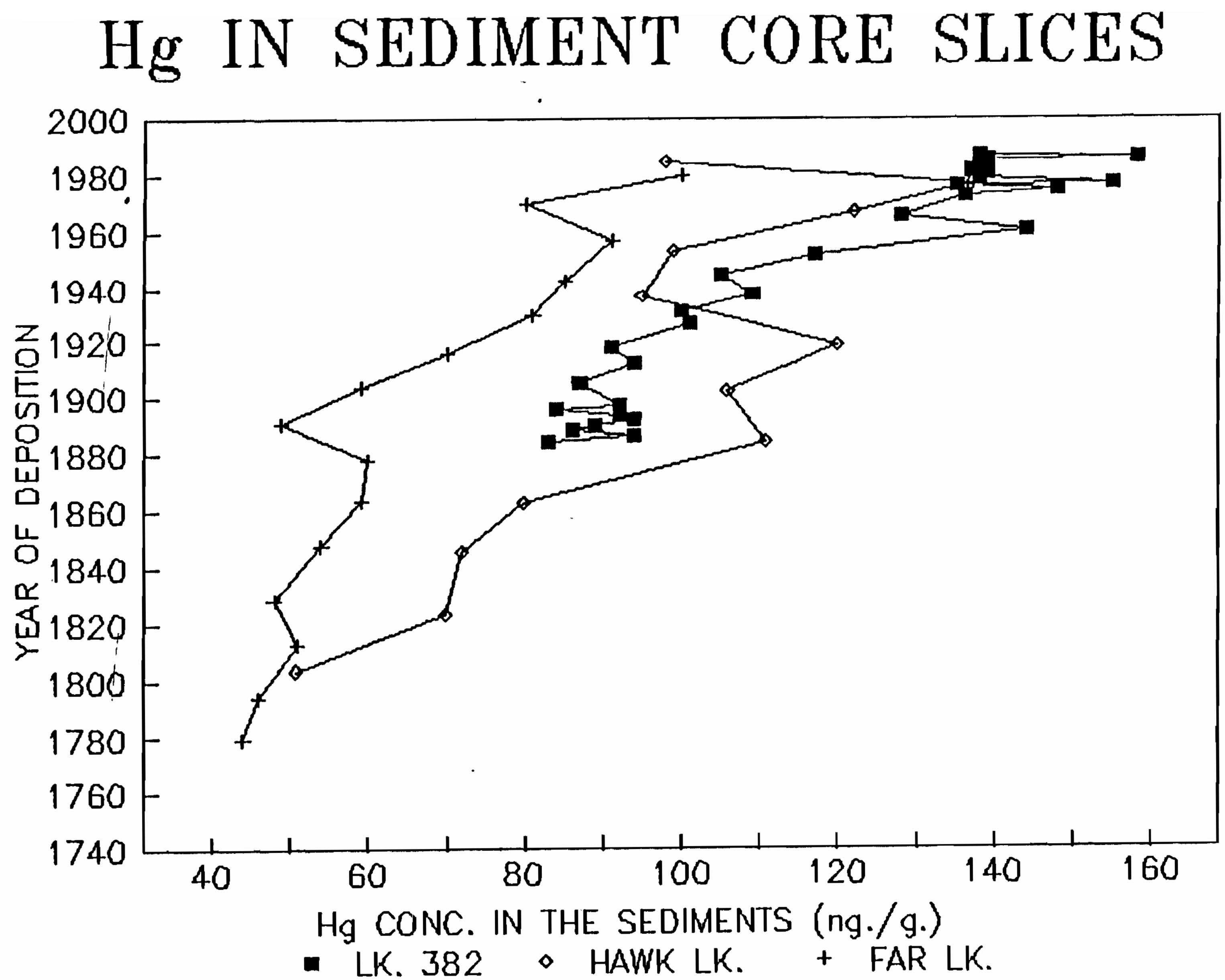
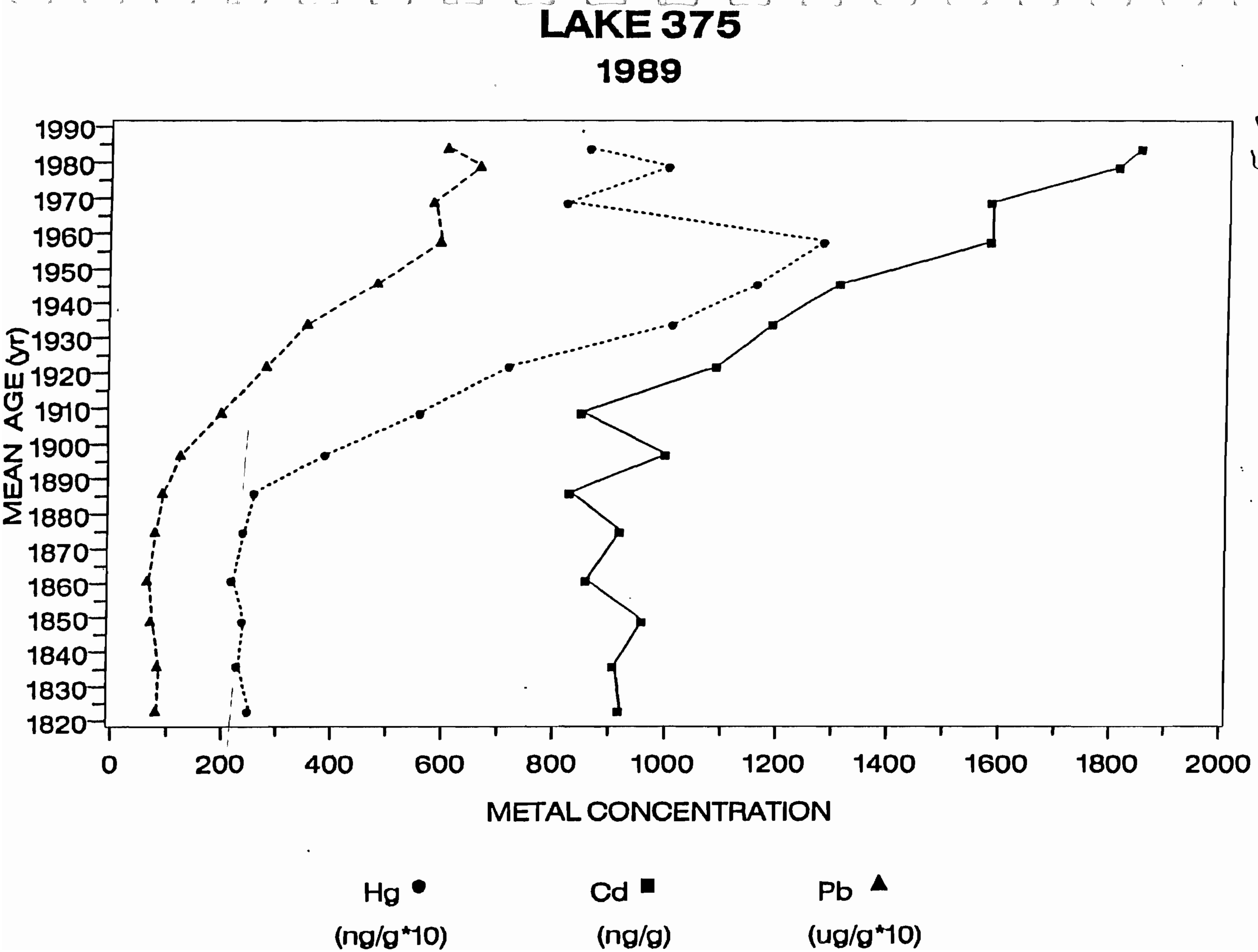

Hg IN SEDIMENT CORE SLICES
YEAR OF DEPOSITION
2000
1980
1960
1940
1920
1900
1880
1860
1840
1820
1800
1780
1760
1740
40
60
80
100
120
140
160
Hg CONC. IN THE SEDIMENTS (ng./g.)
■ LK. 382 ◇ HAWK LK. + FAR LK.

Fig 2b

105


LAKE 375
1989
MEAN AGE (yr)
1990
1980
1970
1960
1950
1940
1930
1920
1910
1900
1890
1880
1870
1860
1850
1840
1830
1820
0
200
400
600
800
1000
1200
1400
1600
1800
2000
METAL CONCENTRATION
Hg
(ng/g*10)
Cd
(ng/g)
Pb
(ug/g*10)
Fig 2c

106

Sum of sediment core PAH minus perylene and retene
Sophia and Hawk Lakes, NWT, and Lakes 382 and 375, ELA

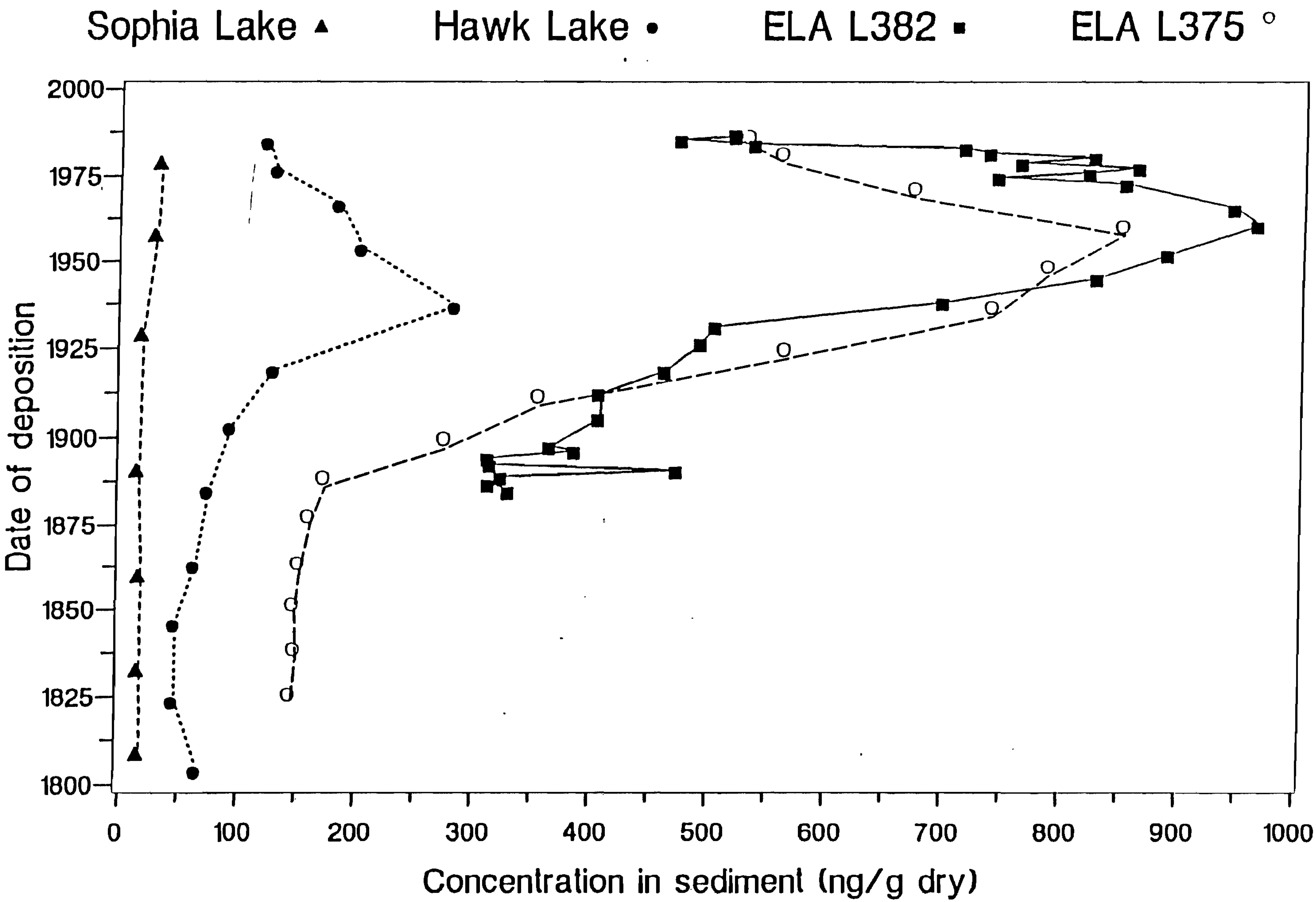


Fig. 3

Total HCH isomers in sediment cores
Sophia and Far Lakes, NWT, and Lakes 382 and 375, ELA

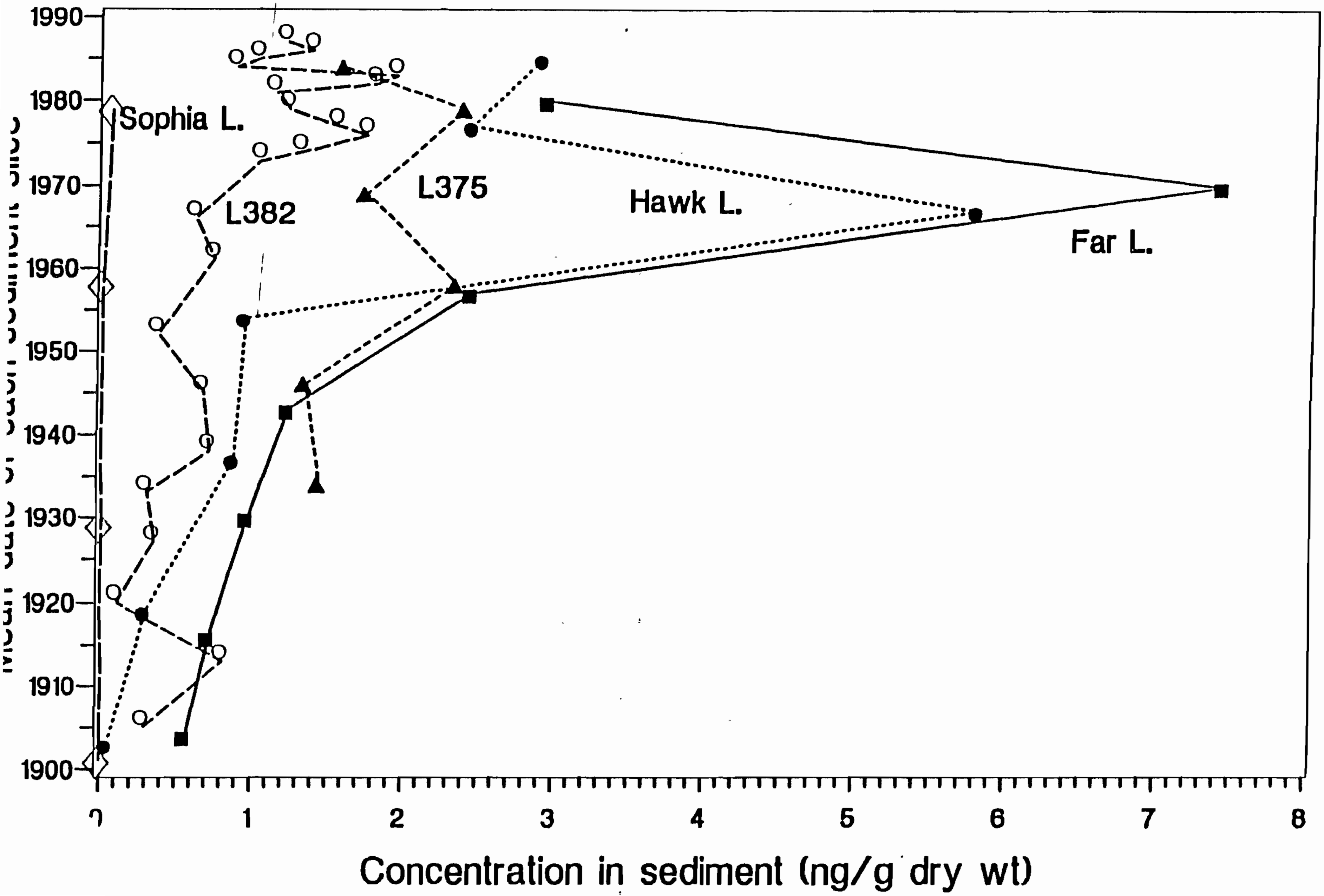


Fig. 4a

108

s-DDT in sediment cores
Sophia, Far and Hawk Lakes, NWT, and Lakes 382 and 375, ELA

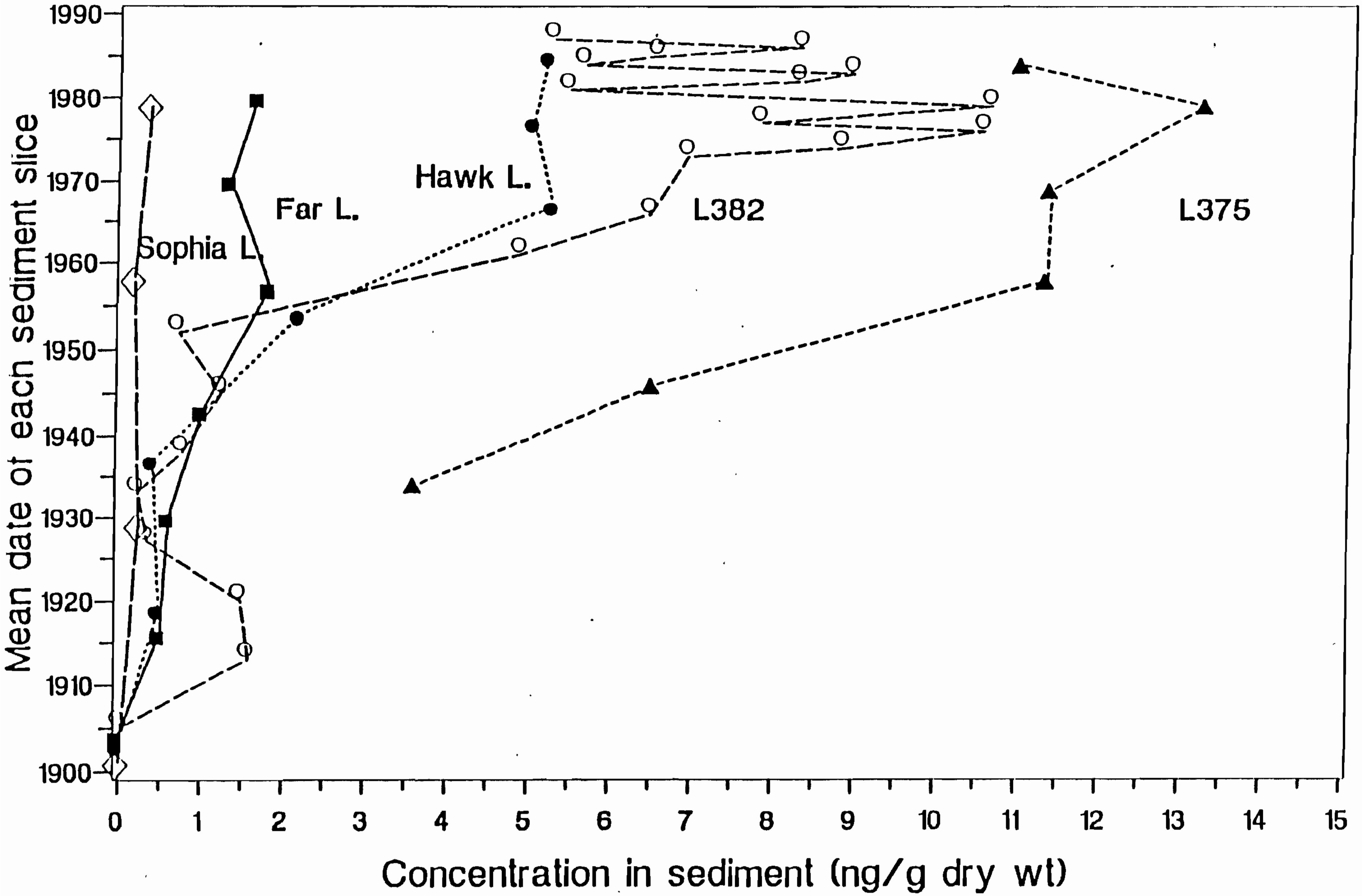
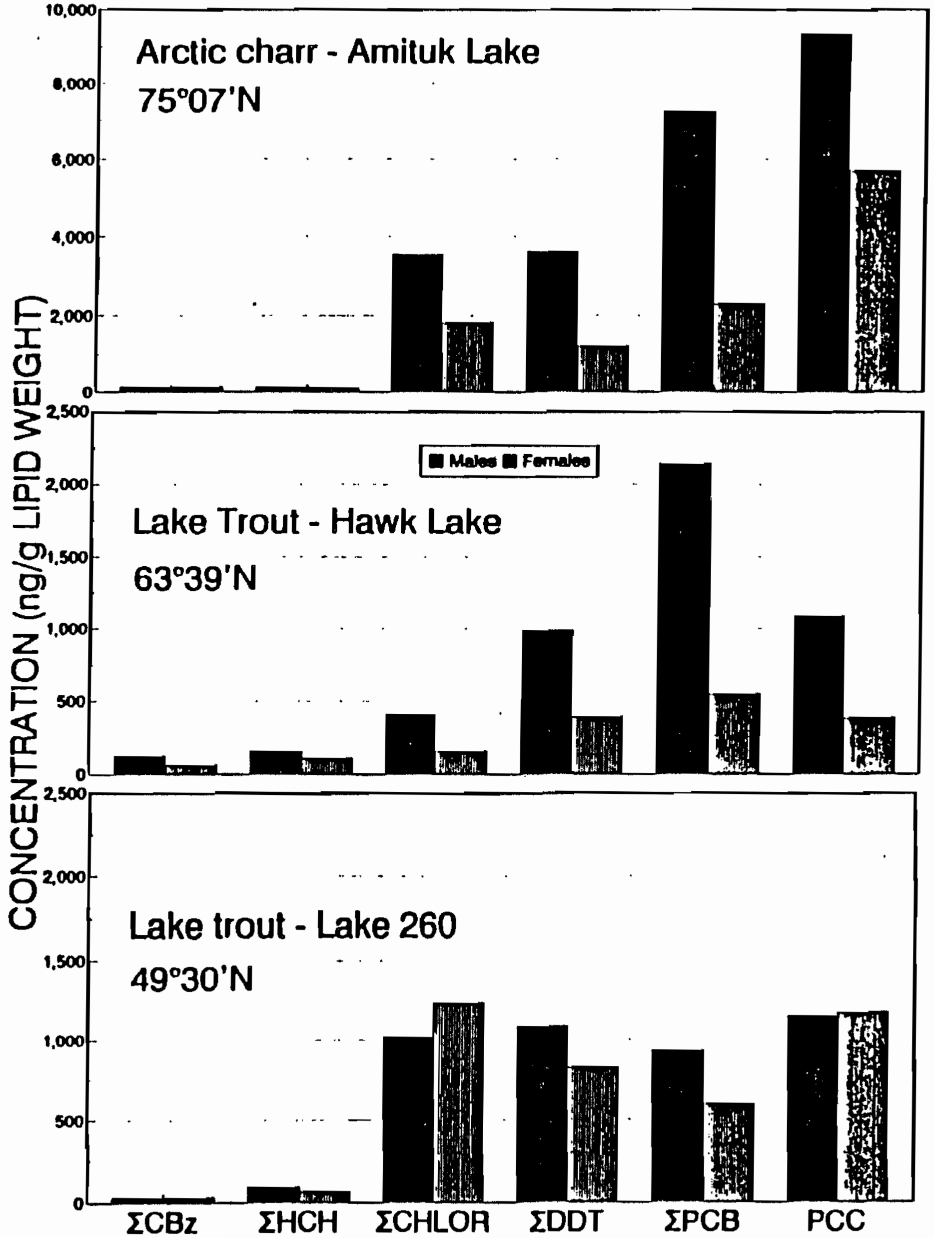


Fig 46



Arctic charr - Amituk Lake
75°07'N
Lake Trout - Hawk Lake
63°39'N
Lake trout - Lake 260
49°30'N
Males
Females
CONCENTRATION (ng/g LIPID WEIGHT)
10,000
8,000
6,000
4,000
2,000
0
2,500
2,000
1,500
1,000
500
ΣCBz
ΣHCH
ΣCHLOR
ΣDDT
ΣPCB
PCC

Fig. 5

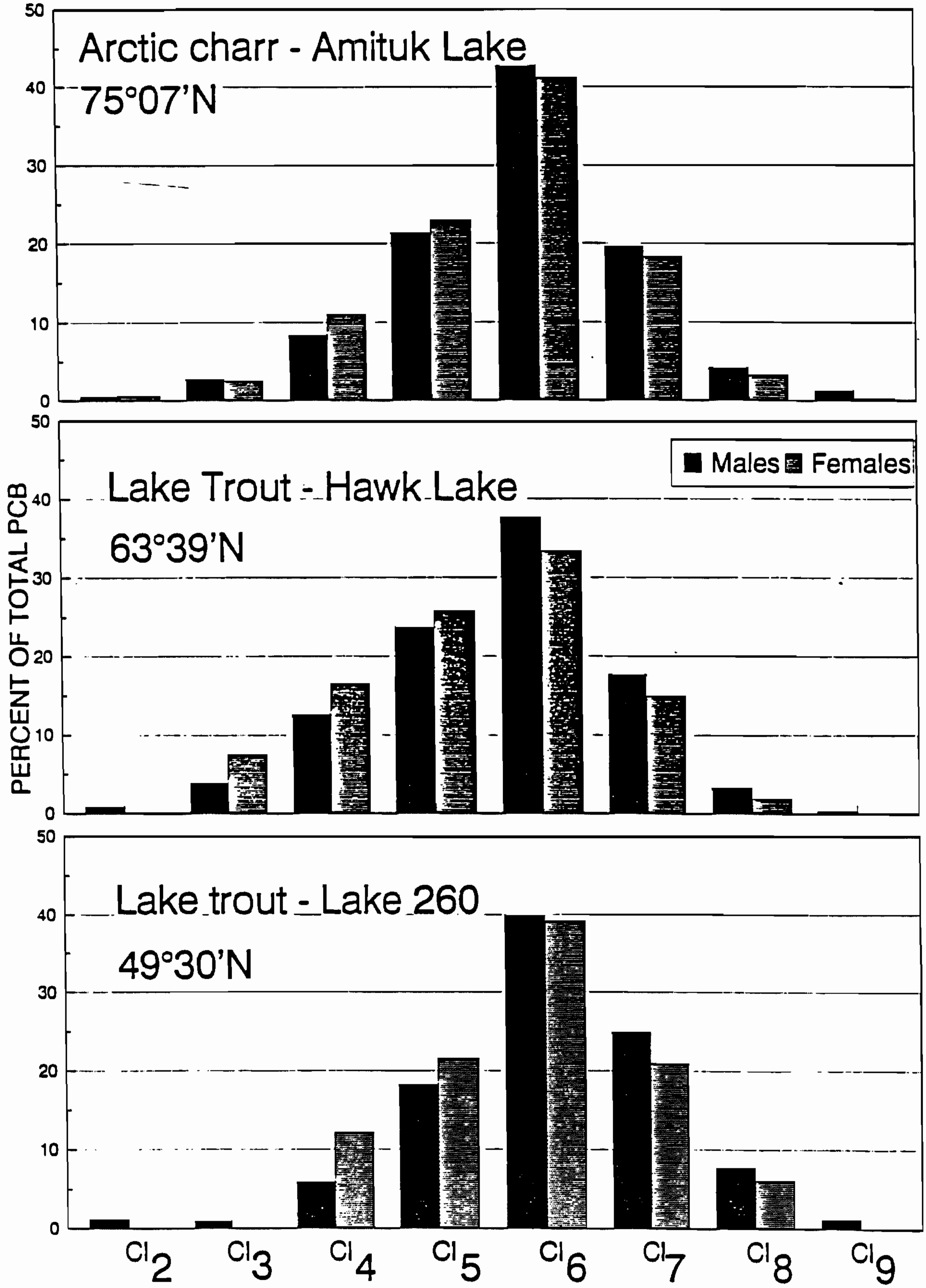

Arctic charr - Amituk Lake
75°07'N
Males
Females
Lake Trout - Hawk Lake
63°39'N
Lake trout - Lake 260
49°30'N
PERCENT OF TOTAL PCB
0
10
20
30
40
50
Cl_2 Cl_3 Cl_4 Cl_5 Cl_6 Cl_7 Cl_8 Cl_9

Fig. 6

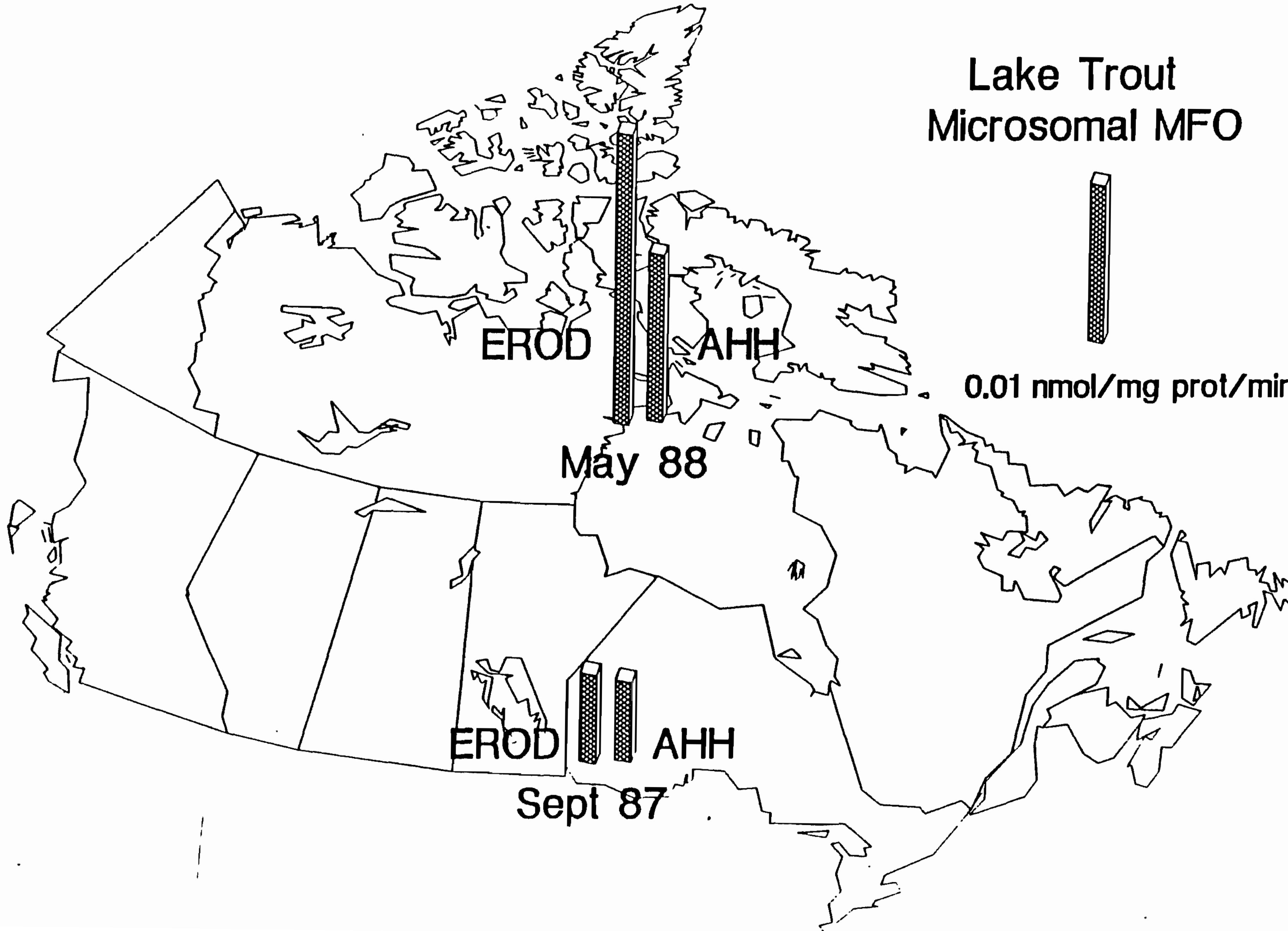
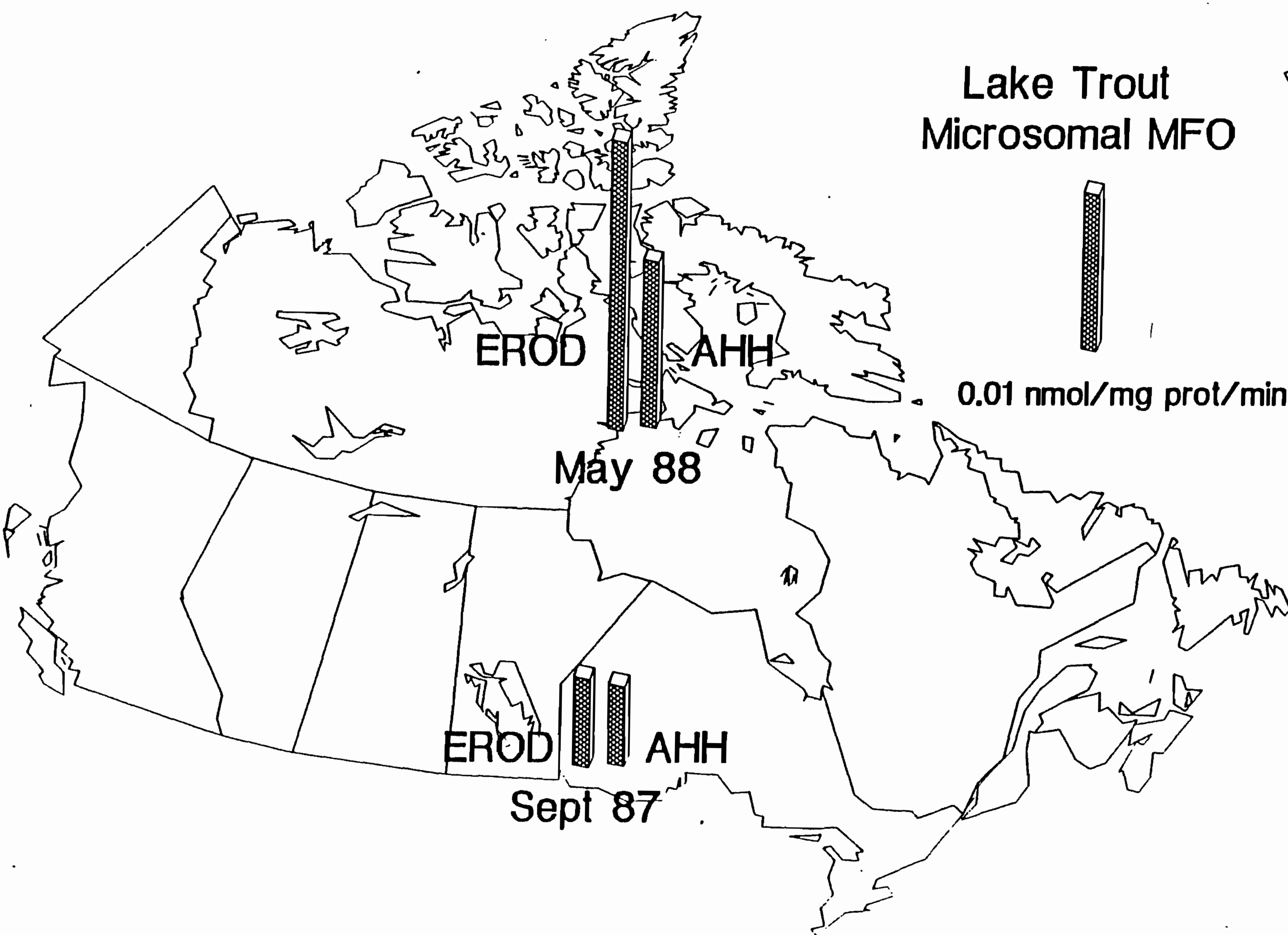

Lake Trout
Microsomal MFO
0.01 nmol/mg prot/min
EROD
AHH
May 88
EROD
AHH
Sept 87

Fig 7a

Fig 7a


Lake Trout
Microsomal MFO
0.01 nmol/mg prot/min
EROD
AHH
May 88
EROD
AHH
Sept 87

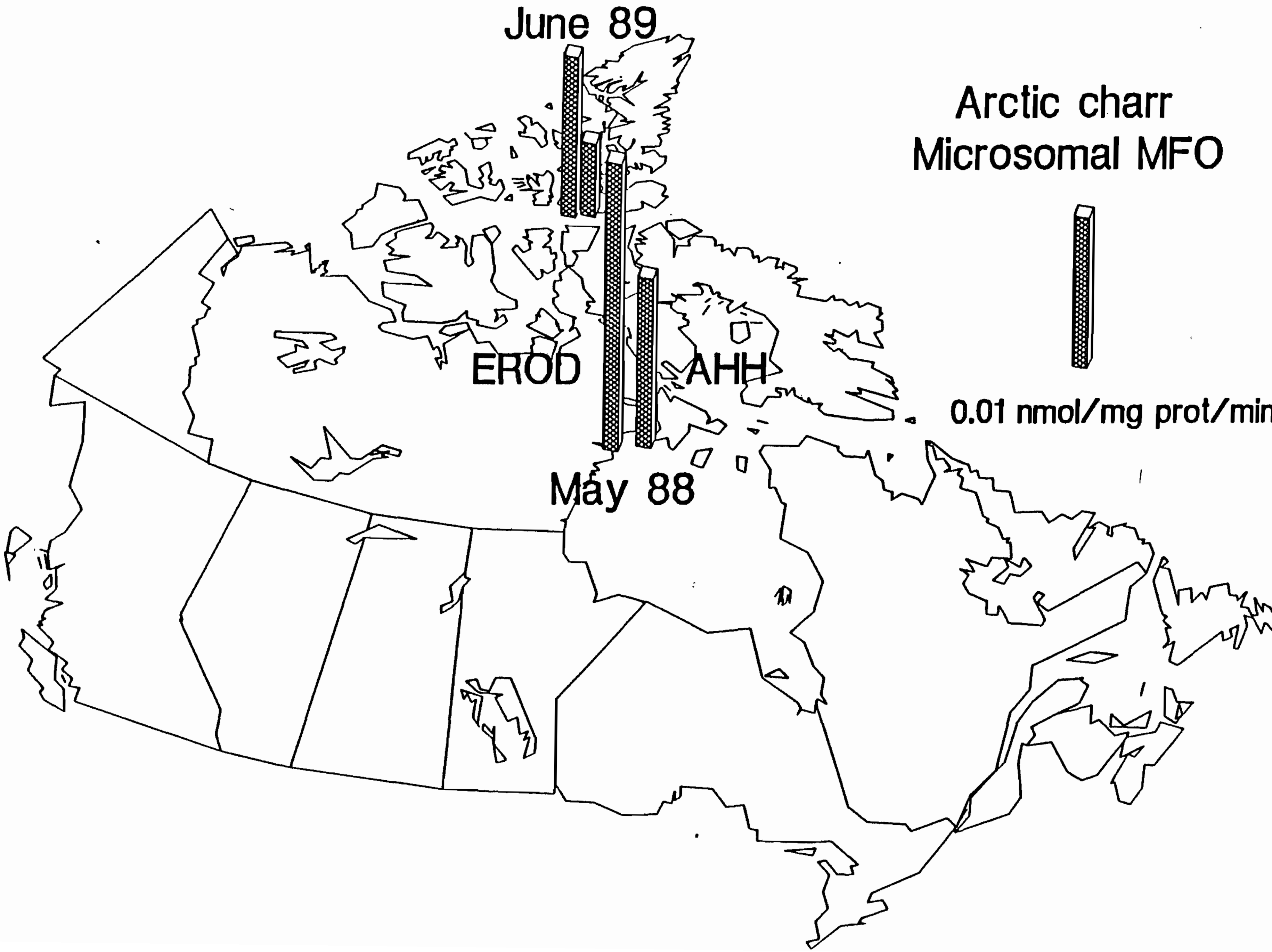

June 89
Arctic charr
Microsomal MFO
EROD
AHH
0.01 nmol/mg prot/min
May 88

Fig 7b

HERBICIDES IN RAINFALL IN NORTHWESTERN ONTARIO, 1989

D.C.G. Muir[1], N.P. Grift[1] and W.M.J. Strachan[2]

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Abstract for presentation at the 18th Workshop on the Chemistry and Biochemistry of Herbicides, Regina. April 24-25, 1990.

Precipitation samples were collected between May and October 1989 using three Strachan-Huneault samplers located at the Experimental Lakes Area in north western Ontario (49°40'N 93°45'W). Our general objective was to determine inputs of a wide spectrum of anthropogenic organic chemicals to the Experimental Lakes Area and, specifically, to calculate the flux of herbicides, widely used in Western Canada and the U.S. upper mid-west to this remote site, approximately 200 km from the nearest agricultural region (the Red River valley).

Samples were collected over periods of 2 weeks (May-June) or 1 month (from late June to late October) using XAD-2 resin column attached to precipitation sampler. The herbicides were eluted from the resin using dichloromethane. Seven herbicides atrazine, trifluralin, dicamba, diclofop, bromoxynil, chlorthal-dimethyl (Dacthal) and triallate were routinely determined in the sample extracts using capillary gas chromatography with electron capture detection and capillary GC with mass selective detection. Diclofop, bromoxynil and dicamba were determined as their methyl derivatives after methylation with diazomethane. Following methylation the sample was cleaned up on a small column of Florisil, eluting neutral and methylated compounds using hexane:ethyl acetate (9:1).

Atrazine was the major herbicide in rainfall, especially in May-June 1989, with concentrations ranging from 42 to 197 ng/L. During period of August to October, atrazine concentrations were lower ranging from 2.9 to 6.3 ng/L. Bromoxynil, Dacthal and dicamba were also present at highest concentrations in June and lowest in the fall months. The phenoxyacid herbicides, 2,4-D and 2,4,5-T, could not be confirmed by GC-MSD although small peaks were observed by GC-ECD. Diclofop, the hydrolysis product of the widely used herbicide diclofop-methyl, was detected in October samples. The efficiency of recovery of XAD for these acid herbicides has not yet been investigated.

Trifluralin and triallate were present at highest concentrations (2 - 6 ng/L) in precipitation in the fall months and were undetectable in samples collected during early June. These herbicides are soil incorporated in the fall or in early spring.

Annual fluxes, based on the 5 month survey, ranged from 100 g/ha for atrazine to 3 g/ha for triallate.

Trifluralin, triallate, bromoxynil, diclofop and dicamba are widely used in various herbicide formulations which are applied to cereal and oilseed crops in Manitoba and North Dakota so their presence in precipitation at this remote site probably reflects relatively short distance (100-300 km). Washout ratios for bromoxynil (a phenol), diclofop and dicamba (acids) are high so efficient removal by precipitation is expected. Trifluralin and triallate have low washout ratios and may therefore be carried longer distances. Atrazine and Dacthal are not widely used within a radius of 300 km of the site. The presence of atrazine must indicate transport from corn growing regions in the U.S. midwest over 500 km south of the Experimental Lakes Area.

Questions and Answers

__KEN MINNS:__ I agree with the concern about the nitrogen. I'm not so clear about this being presented as mitigation. Like, I've had trouble with mitigation all along. It's okay if you've only got one lake to protect or one little stream but mitigation has never been a viable option for the resources that we're supposed to manage. So I would say, yes, we need to understand the role of nitrogen in causing acidification effects on the systems but I don't think we should be looking at it from the point of view of possible mitigation programs.

__BOB HECKY:__ I think you're right in terms of targeting systems for INAUDIBLE. I agree with you. I think there's an aspect of just trying to understand the process because we do have phosphorus mitigation from INAUDIBLE and you have a very strong interaction between these two. In the long period depending on, you know, you may have a residual damage that you may decide you cannot mitigate. INAUDIBLE.

__KEN MINNS:__ Well, I would argue that controlling nitrogen isn't really a question of cost effectiveness. It seems to me that we have an obligation in the same basis we have an obligation to control sulphur. I think I can see arguments where nutrient addition might be used to enhance or speed up the restoration sequence. I'd be more comfortable with it presented that way, I think, than as a mitigation option. What about eutrophication of the lake if you're going around putting a lot of phosphorus in a lake. Would you be concerned about this in the long term, choking the lake with algae by for the sake of trying to get rid of some nitrogen?

__BOB HECKY:__ What we're talking about is increasing the phosphorus by a factor of 4 and we are going to have what we consider mild eutrophication effects on the system especially whether or not the hazard imposed by acidification of the system is greater than that perhaps imposed by the eutrophication. And that's partly what we want to explore with it whether or not it will happen like we realize possibly. It's not absolute. It's something that hasn't been fully explored. But I think it's a very exploratory and anticipatory thing. We don't really have in Canada right now, a nitric acid problem as such but I think there's reason to have concern and it's an emerging problem.

__QUESTION:__ Do you feel that the increased production would annex into the sediment and that presumably would increase the denitrification and the sulphate reduction during the winter?

__JERRY PAYNE:__ In reference to your lake experiment with organics, could you extrapolate or explain a little bit more what you have in mind in terms of this whole lake experiment with organics? Basically the mechanics but the whole thinking that you're going through because obviously it's still complex. The whole concept is so complex, you know.

__BOB HECKY:__ The focus of it now is Great Lakes oriented and it's a long ongoing debate we haven't settled but the way it's moving right now is we would want to make the PCB addition perhaps in two steps to bring the concentrations in the upper sediment to a concentration range such as it exists in the oxygenated areas of the Great Lakes and then to see if that has any consequences for the lake trout reproduction that people are referring to in the Great Lakes right now. The danger, I feel from the LRTAP perspective, is that we can very quickly you might answer that question, that Great Lake concentration, but you might zoom right past where the most critical concentrations are, for some of our lakes are just going through contamination upside now. We won't advance our knowledge of that very much. I think you could design experiments that might answer those questions. Another problem that I see in this Great Lakes perspective being on that experiment is that we'll begin to deal with to try and see if the stress indicators work, if they're going to be working on fairly high concentrations. So my concern is that you'll have such great exposures that you won't be able to answer the critical questions about the blood concentration that these compounds are beginning to have an effect on the populations.

<u>JOE KICENIUK:</u> I think that this is the sort of experiment that many of us have wanted to set up but never figured out how the hell to do it. First of all, you have to duplicate the right mix of PCBs which is not as they're found in nature. It's the more persistent ones that are left behind. The other thing is getting them to the right compartment at the right concentration, and these things not being soluble in water, how does one get them onto the sediment?

<u>BOB HECKY:</u> Well this is an ongoing debate within our group right now. Right now, we're thinking about making up sediment slurries with material and then introduce the sediments already in the material caskets so you shouldn't have to deliver the volume. There are questions On how you go about it. I guess what I'm saying is if we're going to do this experiment first of all it's going to be the amount of PCBs in the environment to be of public concern and here we are contaminating so I think we have to give a lot of answers as to how we're doing it and need to do it. I'm saying there should be a LRTAP perspective brought into that experiment and what we're thinking right now, and we hope to have a Workshop in the fall, is to bring together an international group of experts to look at what type of experiments and how we should go about doing it.

<u>KEN MINNS:</u> I suppose I would go back a step even and wonder is it really possible to construct a valid experiment in that kind of situation. Your lakes that you might choose for your experiment are already contaminated one way or another. It seems to me there are two other criticisms, one is that you're going to lightly pluck a chemical out of the suite that's contaminated the Great Lakes and raising that contaminant level to Great Lakes level may yield nothing of any use with respect to how the Great Lakes has or has not responded. It seems to me the other aspect is the problem of we've had a hard time showing clear cut effects in the Great Lakes where contaminant levels have generally been quite high. Because it seems to me with like the acid experiments and nutrient experiments, you've always operated on a basis of adding a change to the system that's clear cut enough that you can readily discern responses but in organics you're not really doing that. You're not going to add 50X levels and, no, I mean relative to what you've seen in the Great Lakes?

<u>BOB HECKY:</u> Oh, no. It's just relative to our background. There's no doubt that we will make a different system.

<u>JOE KICENIUK:</u> We have one major advantage in LRTAP with regards to organics and that is that we're not dealing with things that could have come out of the end of the pipe so they could be virtually anything. We are dealing with a somewhat more select group of compounds. They have to be volatile enough to get up there into the atmosphere. So it is a little bit more favourable doing contaminants in the LRTAP situation than it is in the Great Lakes. My condolences to the people that have to work on the Great Lakes.

BOB HECKY: I will say I'm trying to lure LRTAP into this. We have some funding and we're proceeding with planning. We're already doing the background on it in some of Canada's lakes but we should be looking and making sure the funds are available. To put that stuff in there and then run out of money after it's in the water, I mean you try to look at the population. Our success, I think, with our experiments in the past is trying to siphon main deposits.

Scotia-Fundy Region and Quebec Region B. Hargrave

LRTAP Studies

(Material for Nfld mtg., to be presented by B. Hargrave)

Two phases of the work have been completed during the last year: the distribution of organochlorines (OCs) in the atmosphere of the Scotian Shelf has been evaluated, and a large volume rainfall sampler has been constructed and its performance assessed.

Large volume atmospheric samples were collected at Sable Is. in winter 1988 and 1989, and in summer 1989. Samples were usually taken in duplicate and were analysed in parallel by scientists from the University of South Carolina (Dr. T.F. Bidleman et al.) and at BIO (R.F. Addison et al.). Agreement between the laboratories has usually been within approx. 25%, which is surprisingly good given the low levels of OC contaminants in the air. Several OCs were present in all samples. These included hexachlorobenzene (HCB: usually higher in winter than in summer samples, probably indicating incomplete collection at higher temperatures) and the hexachlorocyclohexanes (HCH: higher in summer than in winter samples, possibly reflecting spring use as a seed dressing in western Canada). alpha-HCH usually exceeded gamma-HCH by a ratio of 5 - 10 : 1. PCBs showed a slight seasonal change, being higher in summer than in winter, probably indicating increased volatility of the more highly chlorinated congeners at higher temperatures. DDT and chlordane components showed no obvious seasonal variation. Toxaphene, endosulfan and dieldrin were found occasionally in samples. Concentrations of most OCs were relatively low and similar to those reported in the few open ocean samples which have been described in the literature; these probably reflect general northern hemisphere "background" contamination by these compounds. The only exception to this appears to be endosulfan, whose concentrations were relatively high. This <u>may</u> reflect local use in PEI, but this remains to be confirmed. Back trajectory calculations by AES, Downsview, have shown that chlordane was higher in air masses originating from the southern U.S. than in those from northern Canada; this reflects the use pattern of chlordane. These data have been assembled in a draft manuscript which is now in the hands of Dr. Bidleman.

Previous approaches to sampling rainfall (to estimate the flux of OCs via precipitation to the sea) have relied on taking 1 - 5 l samples in glass bottles. Experience has shown that these samples are too small to allow reliable estimation of low levels of OCs, so a device has been constructed which allows collection of > 100 l samples. The sampler consists of a 2 m^2 stainless steel funnel which drains through an XAD adsorbent column (Seastar Instruments) into a measuring cylinder. After sampling, the XAD column which retains OCs is eluted for analysis. Preliminary results show that it is possible to collect over 200 l in a 24 h period. The efficiency of the sampler has to be evaluated before it is put into routine use.

Biomagnification of Organochlorine Pesticides and PCBs in the Arctic Ocean Marine Food Web

B.T. Hargrave, G.H. Harding, W.P. Vass,
P.E. Erickson, B.R. Fowler and V. Scott

Summary. Polychlorinated biphenyls (PCBs), polychlorinated camphenes (PCCs) and isomers of DDT and DDE were the predominant organochlorine hydrocarbons measured in epontic particulate matter, zooplankton, pelagic and benthic amphipods and liver tissue from a glacial eelpout collected at 79°N off Axel Heiberg and Ellef Ringnes Islands and 85°N over the Alpha Ridge in the Arctic Ocean. Chlordane, dieldrin and other cyclodienes and hexachlorocyclohexane isomers were present at lower concentrations.

Levels on a dry weight basis in plankton between <63 µm to 2 mm were similar to those in epontic particulate matter. On a lipid weight basis, concentrations in plankton were from two to five times higher. Organochlorines in amphipods and liver from the eelpout *Lycodes frigidus* exceeded levels in zooplankton by up to an order of magnitude. Large benthic lysianassid amphipods (*Tmetonyx cicada, Anonyx nugax* and *Eurythenes gryllus*) accumulated higher concentrations than small species (*Onisimus* spp. and *Andaniexis* spp.) or the under-ice gammaridean amphipod (*Gammarus wilkitzkii*).

No significant differences in organochlorine concentrations were measured in benthic amphipods collected at different times. Concentrations in lipids of small zooplankton (<63 µm) decreased between May and August. Large zooplankton (>500 µm) collected in August, dominated by adult copepods (*Calanus hyperboreus* and *Calanus glacialis*) and ctenophores (*Oikopleura vanhoeffeni* and *Beroe cucumis*), contained concentrations of a-HCH, chlordane isomers and other cyclodienes that were two to four times higher than levels in May. Biomagnification factors calculated for presumed predator-prey links in the food web varied over two orders of magnitude for different organochlorines. Ratios between epontic particulate matter and plankton (<10) were generally lower than values for trophic links between amphipods, fish and marine mammals (10-100).

ATMOSPHERICALLY-DERIVED HYDROCARBONS (PAHs) IN THE ST. LAWRENCE

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Interim Report for 5th Annual LRTAP Workshop, St. John's, NF, 9-11 October 1990

Preliminary reports from Quebec and data from the Great Lakes and the Maritimes indicate that polycyclic aromatic hydrocarbons (PAHs) are important components of airborne pollutants in Quebec (for example Environment Canada, 1988; Helfrick, J. and Armstrong, D.E., 1986; and Eadie et al., 1982). Many of these compounds, such as benzo(a)pyrene, are known carcinogens (Gelboin and Tso, 1978).

The objective of this project is to evaluate the levels of PAHs in the St. Lawrence, their atmospheric fluxes, and the extent to which these compounds are seqestered in the sediments and/or transferred through the food web. Specific questions being addressed are (1) what are the current levels of PAHs in the sediments and how have they changed over time, (2) what are the atmospheric fluxes of PAHs at different points in the St. Lawrence Estuary, (3) what is the relative importance of various sources of PAHs such as aluminum refineries, forest fires, automobile exhaust, home heating, and ship traffic, (4) what are the levels of PAHs in the water column, and (5) are PAHs entering the food web of the Estuary and if so are they being concentrated in lipid-rich organisms such as copepods?

In the first six months of this new project (begun April, 1990) work has begun in several directions. The first has been a search for the most efficient type of precipitation collector. We have conducted a search of the literature, investigations of commercial products and discussions with a variety of investigators including Bill Strachan (CCIW, Burlington), Bob Duce (Center for Atmospheric Studies, University of Rhode Island), Terry Biddleman (University of South Carolina), and Richard Addison (Bedford Institute). Final plans are now underway for acquisition of a sampler.

Analyses have been begun on suspended particulate material and plankton. Samples were collected by pumping (SPM) and by net tows. After being stored frozen, samples were extracted by refluxing with potassium hydroxide, methanol, water, and hexane. The nonsaponifiable fraction of the extract was purified by column chromatography (silica gel and alumina) and analyzed by capillary gas chromatography with confirmation by GC-MS. Details of the method can be found in Gearing et al. (1978). Some very preliminary numbers are available (Table 1). In these data, unsubstituted compounds predominate, indicating a combustion source rather than petroleum. The values decline from Quebec City seaward, suggesting that local sources are important. Concentrations of individual, unsubstituted PAHs are in the 1-5 ng/l (parts per trillion) range at Quebec City and decline by a factor of 5-10 by

Rimouski. The waters of the Estuary at the mouth of the Saguenay Fjord show no particular elevation in levels of contaminants in suspended matter; it may be that the signal of PAHs from aluminum refineries is a relatively local one. Much more data are needed for confirmation of these trends, especially considering the constant variation in water constituents. These will available as the project continues.

Some PAH concentrations in surface sediments from box cores have also been measured (Table 2). The relative distribution of individual compounds appears to be similar to that in the suspended particulate samples, with combustion products dominant. The levels of PAHs are relatively low, as can be seen from a comparison with the very high levels in Halifax Harbour (Gearing et al., 1990). Some typical sedimentary pyrene concentrations (ng/g) include 4 (Atlantic Abyssal Plain, Laflamme and Hites, 1978), 53 (Pacific Continental Shelf, Prahl and Carpenter, 1983), 100 (Gulf of Maine, Laflamme and Hites, 1978), and 600 (Lake Michigan, Helfrick and Armstrong, 1986). Levels of total PAHs in the Lower Estuary average under 1 ug/g; Chapman et al. (1987) have estimated that sedimentary concentrations of 4 to 10 ug/g can cause significant biological effects.

Many workers have reported a subsurface maximum in PAH concentrations down cores at a depth/time corresponding to around mid-century (Ohta et al., 1983 and references therein). We noted a distinct maximum at 5-10 cm (~1950) in Halifax Harbour. Such a maximum is not a prominent feature of the St. Lawrence cores analysed to date. In one core from off Rimouski in the Lower Estuary, there was not statistically significant change in PAH concentrations over 30 cm (approximately the last 200 years).

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Table 1. Selected PAHs (ng/l) in Suspended Particulate Material from the St. Lawrence

	Quebec City	Upper Estuary (La Malbaie)	Lower Estuary (Rimouski)
Phenanthrene	0.9	0.6	0.04
Fluoranthene	1.8	1.7	trace
Pyrene	2.5	0.8	0.08
Benzo(a)Anthracene	1.1	0.3	0.07
Chrysene	3.7	0.9	0.13
Benzo(a)Pyrene	0.6	0.6	0.07
Perylene	1.4	1.2	0.2

Table 2. Selected PAHs (ng/g) in Surface Sediments from the St. Lawrence

	Lower Saguenay Fjord			Lower Estuary		Gulf	(Halifax Harbour)
Phenanthrene	60	66	6	44	61	25	3400
Fluoranthene	-	-	39	44	127	2	4700
Pyrene	130	138	12	74	116	26	4000
Benzo(a)Anthracene	93	144	12	43	77	56	1600
Chrysene	184	280	19	74	120	25	1800
Benzo(a)Pyrene	75	80	10	37	88	11	1800
Perylene	223	496	63	122	154	21	530

Questions and Answers

<u>**JOE KICENIUK :**</u> How many of these **lysianassids** can you collect in terms of volume or would it be practical to collect? What sort of weight would that represent?

<u>**BARRY HARGRAVE:**</u> I can collect hundreds in an hour. I can collect the minnow trap with two hundred in two hours. A hundred grams.

<u>**JOE KICENIUK:**</u> A hundred grams? So it would actually be practical to collect some of these and use them for effects research on a fish, feed them...

<u>**BARRY HARGRAVE:**</u> I talked with Lyle Lockhart about this and we had tentatively proposed some sort of a joint project. It involves getting live animals though and to keep them alive means you have to bring them through the surface melt water layer and you see when you make a hydrohole through the ice the surface water of the hole is filled with ice melt water so the animal is experiencing an osmotic shock. There's no temperature shock. The water is isothermal but you we need a collector, a sampling system, that protects the animals from osmotic shock when we bring them to the surface and then they need to be kept alive. I have been able to transport them alive from the Arctic, from the ice island to Bedford. Exchange it with deeper water from 2 or 3 meters below. But we've never had the luxury of the time to do that in my work. We've been too busy just collecting the samples but it could be done and the effects work is possible and those would be the animals to use because they are very hardy once you get them. They're very easy to keep once you get them alive. Well what Lyle and I were going to do was we were going to use burbot liver which also contains high concentrations of these organochlorines and we were going to feed the burbot liver to live amphipods. I thought that that was... To look at a food web interaction, we were going to use tissues of one animal and feed it to the other and vice versa and look at effects on mixed function oxidase activity, respiration, reproduction, if I could keep the animals in aquaria long enough. But, yes, you could collect these as a food and feed them to fish.

<u>**JERRY PAYNE:**</u> As a follow-up Barry, you're a biologist and you're doing a lot of chemistry but you obviously must have gone through a thought process of the effects. What do you feel from the literature that's available, say even going from the individual level, because if we follow-up we have difficulty, a lot of difficulty, actually finding individual effects in the Great Lakes, San Francisco Bay and the German Bight even. So there's a lot of information available to a certain extent on organics and biological effects. What do you feel about those concentrations having any effect at any level from zooplankton to polar bears.

<u>**BARRY HARGRAVE:**</u> I don't think that the impact of these compounds is on the food web. I think that the impact is a human impact through the food web. I think that the worry of the problem is that native people in the North whose diet consists 90% of country food which is based on narwhal and seal and fish, those organisms are accumulating from long distance transport, organochlorines, and it's being injected into human food webs through the marine food web and it's being injected through these organisms that are concentrating it. So these are like a node in the food web that feed directly to man, not that man are eating amphipods but they're eating fish that are feeding on amphipods. So as a link next to man as it were I don't think the impact of organochlorines is on the organism, I think it is through the organism that man of Northern communities are experiencing of this contaminated food. Now the levels are close to the recommended daily intake

guidelines by Health and Welfare Canada. About 15% of the Northern population of women contains levels of organochlorines such as PCBs and DDT in their milk which is at or above the level that is recommended as safe for daily intake and there are infants feeding on this. So it's a health concern. I don't see any deformed amphipods in any of the samples or the fish don't have crooked vertebrae. The levels I don't think are affecting the animals as individuals. On a population level, I can't say. It's a very difficult thing to do a population study of animals in such a remote place. The baited trap is attracting animals from an unknown distance probably kilometres. It only works when the ice island isn't drifting. If the island is drifting and this trap is being dragged along the bottom, the animals can't detect the odour flume and follow it to its source before the odour flume is moved. So when the island is drifting which in past years has been quite often when I have been working from it, then I've had very low collection success. But when it's in a fixed location, I can collect as I've indicated hundreds of individuals. But none of those have ever shown me any...like the coloration hasn't changed over the years or they're not deformed in any way. They don't have multiple eyes or lesions on their back or anything like that. The worry is that these organochlorines are concentrated in lipids and these animals undergo or must undergo a seasonal lipid cycle such that when they're starving they draw down their lipid reserves. If they don't metabolize the organochlorines, then that means that the body residue or the body burden then which was dissolved in 10 units of lipid the same amount of organochlorine is dissolved in 2 units of lipid. So it becomes concentrated. There could be an effect.

JERRY PAYNE: But do you believe that the North Sea... The other side of the coin is that there are a lot of problems with the North Sea data. It's extremely important, highly controversial. Have you looked at it intensively enough to say that it's real data or not? You have a basic problem, you got high concentrations in old fish and old fish are also thought to have a lower reproductive efficiency.

BARRY HARGRAVE: I can't comment on the quality of the data. I just read the literature like you do. The levels I'm measuring are an order of magnitude lower than the highest that have been reported in the North Sea. But considering the remoteness of the environment that I'm working, that's shocking. Even if it is an order of magnitude less, it's still very high.

Aromatic Hydrocarbons in Insect Larvae Collected from Newfoundland LRTAP Lake monitoring sites.

By
J.W.Kiceniuk

Artificial substrates (Pat Ryan design) were placed in the outlets of the Newfoundland LRTAP Lake monitoring sites in the spring and removed in the fall. Insect larvae were removed from the substrates,counted, and identified to species by Dr. M. Colbo of Memorial University Biology Department.The larger individual insects were frozen individually at -60°C until they were extracted. Each insect was thawed, weighed, ground up with anhydrous sodium sulphate, and extracted with pentane. The extracts were concentrated to 1ml in a Kuderna Danish apparatus and analyzed by HPLC for classes of aromatic hydrocarbons.The only species common and plentiful to all lakes sampled was Hydropsyche recruata. The results presented are preliminary since all samples had not been analyzed at the time of presentation. From the results available it appears that: a) In H.recruata mono and dicyclic compounds predominate, b) The levels are lowest in individuals from Gros Morne and highest in those from Lake 206, c) Levels are higher in carnivorous species such as Ashnea.

Questions and Answers

<u>JERRY PAYNE:</u> Joe in your first set of overheads, you were putting one over the other, was that pool mixtures or individual? Was there a consistency? Was the variability very much because you add one just little tiny bit and then there's a very large peak?

<u>JOE KICENUIK:</u> Those are individual animals. Well, Lake 206 has a much higher variance than the others. In terms of aromatics Gros Morne and Headwater are about equal. I'm a little bit dubious about the Gros Morne results because they are a very small number of specimens. There's so few insects the productivity of that Lake seems to be so low. I just couldn't get much out of it.

<u>BARRY HARGRAVE:</u> PAHs are not bio-accumulated. They are metabolized. They are not resistant to bio-degradation let's say so unlike organochlorines they don't tend to bioaccumulate. The work that's been done with oil spills, for example, shows that naphthalene and other aromatic hydrocarbons can be rather rapidly degraded by organisms, micro-organisms and fauna. Would it be important if you're going to continue this work to do time series sampling as much as possible from one location to look at how variable over time values are?

<u>JOE KICENIUK:</u> Yes, it would. But one of the advantages, again, of using an insect is that your time span for accumulation is relatively short and insects also don't have quite the capacity to clear these compounds that fish do. So not only are you closer to the source, it is also advantageous in using insects that by using species that have the different feeding strategies that you can look at where material is coming from and I think looking at these preliminary data that those things that are getting detrital or sources of food of animals that are living on the bottom, particularly those that are over wintering, so that they will be feeding on whatever is left there as opposed to ones like the <u>Hydropsyche</u> which are feeding on new productivity, algae that are produced that year. So they are that much cleaner. If that is, in fact, true, then the input is probably from the surface microlayer of the water bound to particulate material and going to the sediment. If these critters were absorbing it directly from water, then you would expect Hydropsyche to have the same sort of accumulations as the predators do. But the food source is probably much more important in the accumulation and that certainly fits what we've looked at with aromatics with the studies on oil. It's not the levels in water, unless you're dealing in salt water where animals are drinking and then they sort of become one and the same.

DNA-Adduct Levels as a Biochemical Indicator for LRTAP Mediated PAH

Atmospheric transport of organic pollutants is a significant component of LRTAP, and has been well documented even in remote areas in the arctic. Bioaccumulation of organochlorines in fish of Atlantic Canada due to LRTAP has been documented (Peterson and Ray, 1987). Although similar data are not available for PAH, some reports have indicated the occurrence of PAH in the St. Lawrence estuary (Picard-Berube et al., 1983) and Hudson Bay (Stich and Dunn, 1980).

Because PAH are very quickly metabolized to alcohols and epoxides which are generally difficult to detect and determine, the actual concentration of PAH in aquatic organisms is therefore also difficult to determine. PAH can react with DNA, RNA and proteins to form a variety of adducts. Aromatic DNA-adducts have been observed in beluga whales from the St. Lawrence and in fish from several contaminated areas. We are investigating the effect of PAH, a LRTAP component, on fish in remote areas of Newfoundland and Labrador by using the ^{32}P-postlabelling technique.

^{32}P-postlabelling is a recently developed technique for detecting aromatic DNA-adducts (Randerath et al., 1981; Gupta et al., 1982), which are believed to be the crucial initial steps in the initiation of carcinogenesis (Fig. 1). Metabolic pathway for a model carcinogenic PAH is shown in Fig. 2.

A particular advantage of the technique is that the adducts do not have to be well characterized and that it is applicable to unknown adducts induced by mixtures of environmental carcinogens and/or mutagens (Randerath et al., 1986). It is also extremely sensitive (Reddy and Randerath, 1986) and can detect one modified residue at the level of 10^{9-10} nucleotides (Table 1). The technique can also be used for retrospective analysis for evidence of previous exposure to carcinogens and/or mutagens (Dunn and Stich,1986; Phillips et al., 1986, 1988). Dunn et al. (1987) have also successfully applied the technique to determine aromatic DNA-adducts in fish from polluted areas. The method involves digestion of exposed DNA to deoxyribonucleoside-3' monophosphates using micrococcal endonuclease and spleen exonuclease. The digest is treated with Nuclease P1 to remove normal nucleotides and then ^{32}P-postlabelled by treatment with T_4 polynucleotide kinase and (γ-^{32}P)ATP which yields (5'-^{32}P)deoxyribonucleoside-3'-5' diphosphates. Any unused (γ-^{32}P)ATP is converted to $^{32}P_i$ by digestion with Apyrase. Separation and purification of the labelled adducts are done by PEI cellulose anion exchange TLC and determined by screen enhanced autoradiography. Quantitation is done by excision of the spots followed by scintillation counting. Actual amounts of nucleotides per reaction are quantitated by high performance liquid chromatography (Dunn and San, 1988).

We have collected fish from several remote areas of Newfoundland and Labrador: (Fig. 3)

1. Experimental lakes area in Newfoundland,
2. Harding Pond in Gros Morne National Park in Newfoundland, and
3. Several lakes in remote areas of Labrador.

The fish collected were salmon parr, trout and char where available.

The ^{32}P-postlabelling technique will be used to analyze several tissues of fish collected from these remote areas of Newfoundland and Labrador, for DNA-adducts which may prove to be a useful biochemical indicator for PAH exposure due to LRTAP.

Table 1. Sensitivity of analytical methods.

DNA adducts 1 adduct per diploid genome	Adduct:base ca $1:10^{10}$	DNA used
Immunoassay, e.g. competitive USERIA	$1.4:10^{7}$	25 μg
HPLC-fluorescence detection	$1\ :10^{7}$	100 μg
Synchronous fluorescence spectrophotometry	$1\ :10^{7}$	-
^{32}P-Postlabelling	$1\ :10^{8}-1:10^{10}$	1 μg

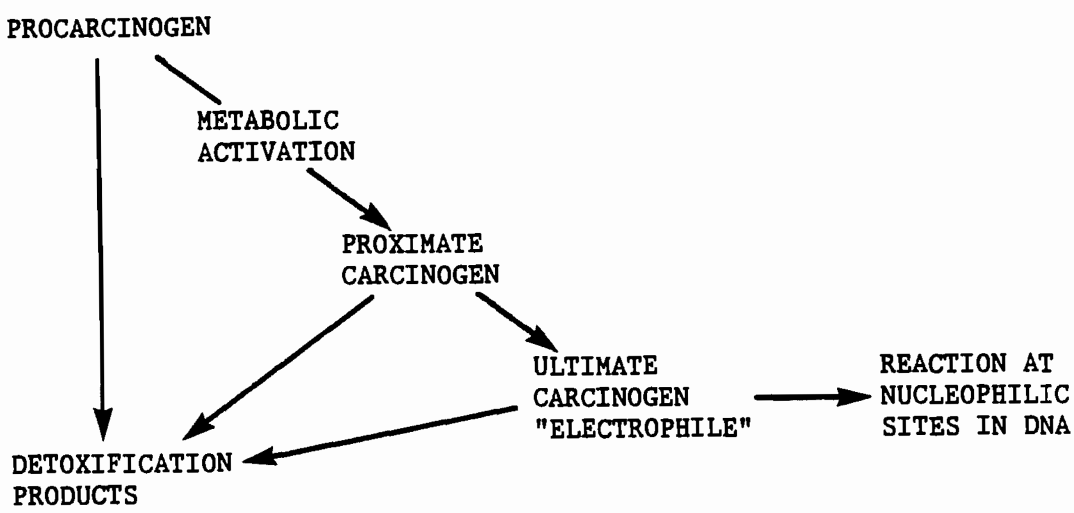

Fig. 1. Metabolic Activation and Detoxification of Chemical Carcinogens.

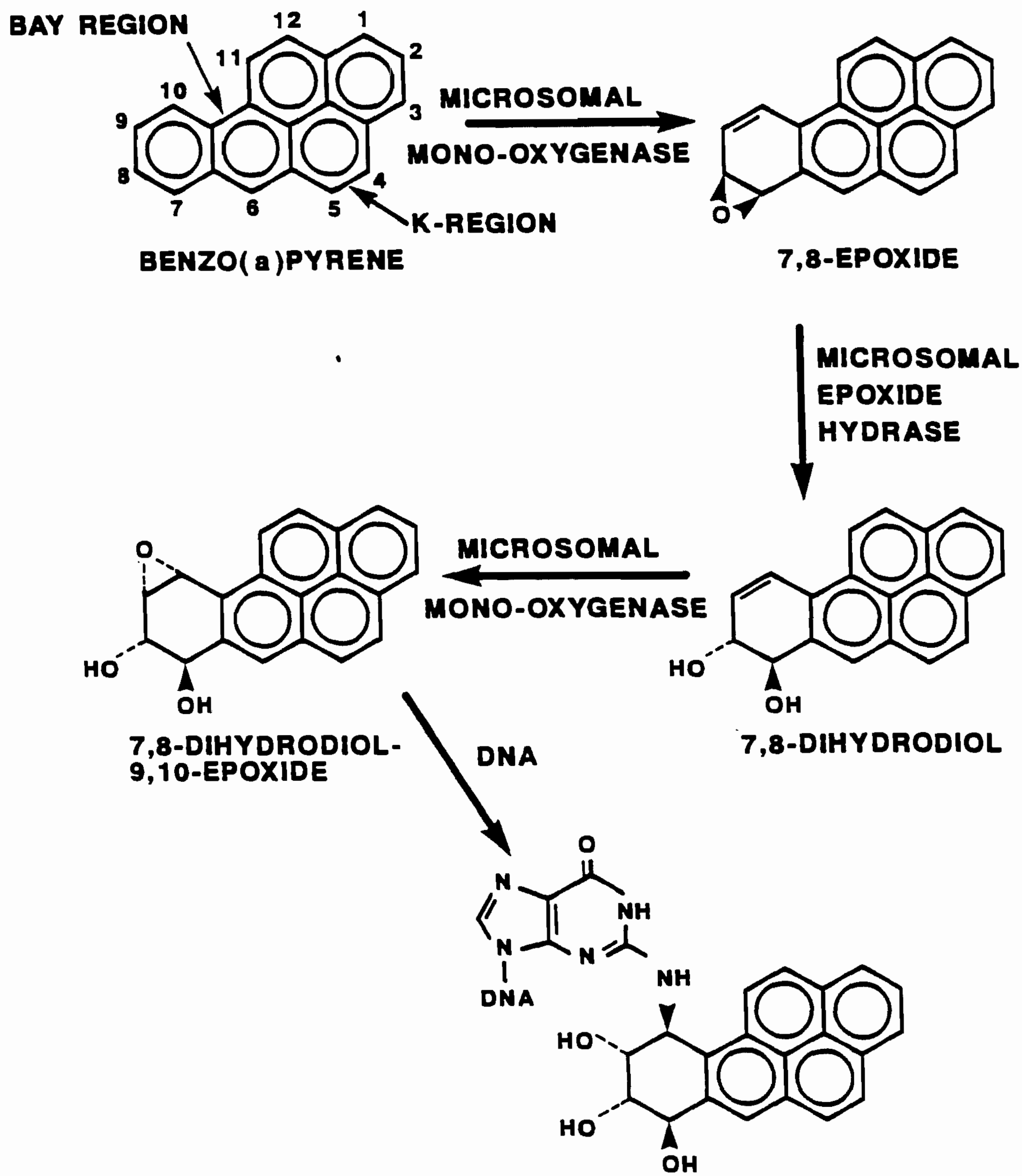

Fig. 2. Metabolic Pathway For Benzo(a)pyrene.

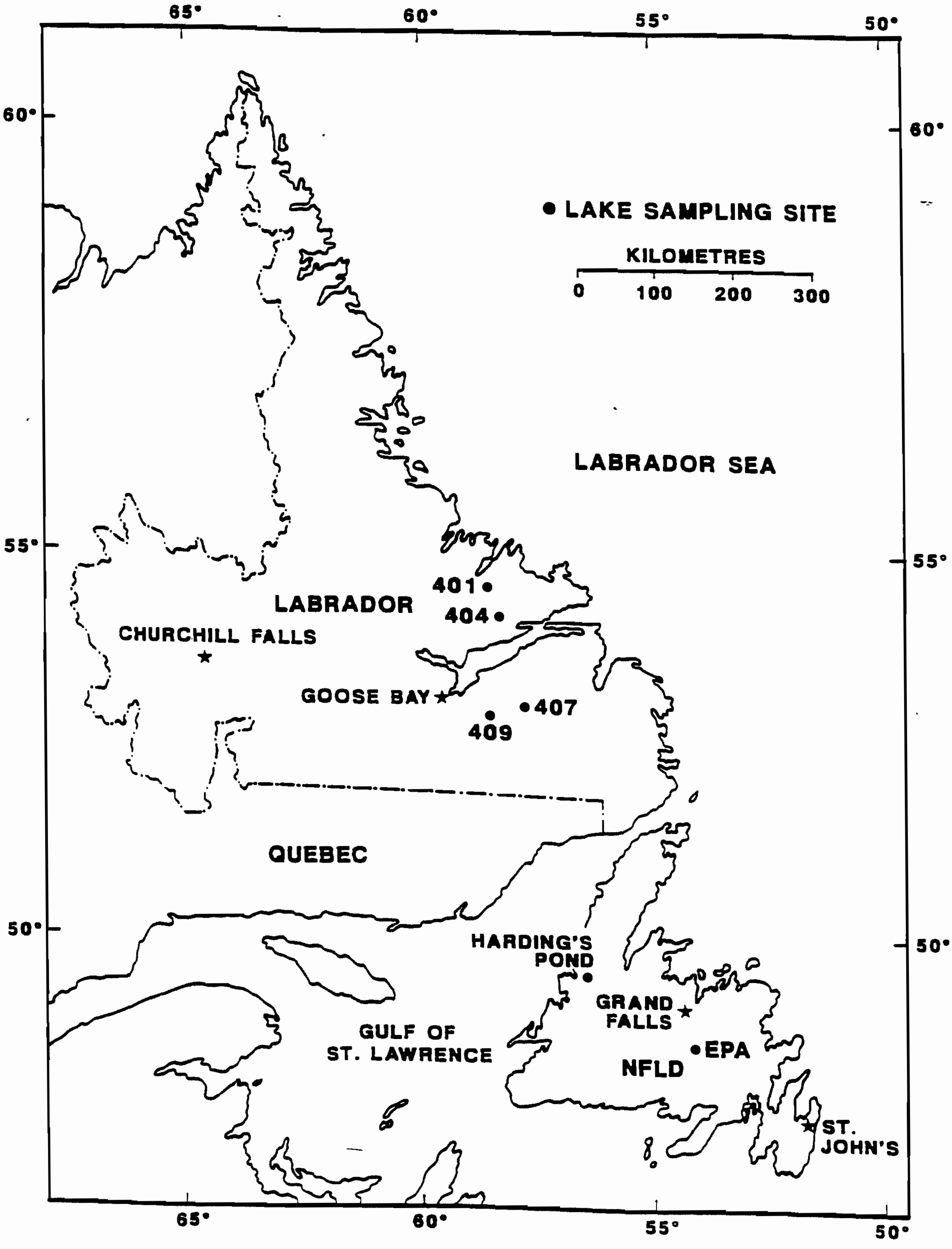

Fig. 3. Lake Sampling Locations.

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Questions and Answers

<u>IOLA PRICE:</u> I'm not exactly clear. So the idea is that the PAHs induce changes in the DNA and you're measuring that.

<u>SANKAR RAY:</u> That's right. As I said before it is very difficult to measure PAH levels as it is in the tissue because of metabolic products. So you don't have any idea what kind of concentration it actually had or what effect it had; so this will hopefully leave a fingerprint behind for the exposure and the exposure level.

4.4. METALLIC CONTAMINANT STUDIES

Central and Arctic Region S. Brown

CADMIUM WHOLE LAKE EXPERIMENT AT THE EXPERIMENTAL LAKES AREA, NORTHWESTERN ONTARIO, AND ASSOCIATED STUDIES ON CADMIUM

Freshwater Institute, Central and Arctic Region, DFO

Prepared for the 5th Annual LRTAP Workshop, St. John's, Newfoundland, 9-11 October 1990 by S.B. Brown, D.F. Malley, C.L. Baron, G.J. Brunskill, M.J. Capel, S.M. Chalanchuk, P.S.S. Chang, E.R. DeBruyn, R.E. Evans, W.L. Fairchild, D.L. Findlay, S.E. Harrison, R.H. Hesslein, M.H. Holoka, R.V. Hunt, J.F. Klaverkamp, S.G. Lawrence, D.A. Majewski, H.S. Majewski, K.H. Mills, R.E. McNicol, V. Palace, C.J. Ranson, E. Scherer, M. Stephenson, A.R. Stewart and L.J. Wesson.

SYNPOSIS

Over 4 years, a total of 3.8 kg of Cd has been added to Lake 382. This has raised the concentration of Cd in the epilimnion from 1.6 ng/L to 50-180 ng/L. The sediments retain at least 73% of the added Cd. There is no evidence of effects on primary production but the phytoplankton community may be showing decreased diversity. Cadmium has accumulated in phytoplankton, zooplankton, benthic insects, mussels, macrophytes and fish with organisms containing up to 30 times background levels. Mussels have elevated metallothionein levels. They have not yet reached equilibrium with the added Cd.

Cd has accumulated in Lake 382 fish and the findings suggest that equilibrium between Cd and large fish (white sucker and lake trout) has not been obtained. There is little evidence of increased metallothionein levels in tissues. Presently, the low environmental Cd has not yet induced clear evidence of detrimental effects on fish as judged by biochemical, histopathological and population measurements. However, kidney Cd levels have increased to half the level where histopathological effects are first observed in other species. The reduced gonadosomatic index, egg size and number of vitellogenic oocytes observed in 1988 were not seen in 1989. If the reproductive effect was an initial response to Cd, then compensation or acclimation has occurred. Lowered energy reserves found in fish during the latter part of 1987 and at the beginning of 1988 may have caused the lower fecundity. Depressed growth rates in juvenile year classes of white sucker may represent an early effect of Cd but further studies are required for verification.

Long-term laboratory studies indicate that biochemical and histological effects occur when Cd concentrations reach approximately 8000-10000 ng/g in vital organs (liver and kidney) of lake trout. Biochemical responses were evident in more sensitive rainbow trout when tissue Cd levels were 2000-4000 ng/g. Lake whitefish could detect and avoid water containing Cd as low as 200 ng/L, the Canadian Water Quality Guideline.

INTRODUCTION

As for other contaminants, the Cd is being studied at the Experimental Lakes Area (ELA), northwestern Ontario by experimentally adding it to a whole lake. The main objective of this experiment is to describe the geochemical and biological pathways of low levels of Cd from between water, sediments and organisms and to determine the progression of stress caused by Cd from the molecular to the ecological levels of organization. The experiment permits us to test the adequacy of the Canadian Water Quality Guideline of 200 ng/L in protecting the biota of soft waters. It also permits us to observe the importance of the sediments as a sink for Cd; to identify some responses which may serve as early-warning indicators of impending ecological damage and to assess the predictive value of results from small-scale, laboratory, microcosm or mesocosm experiments against the response of individuals and populations exposed in the lake. At least 30 researchers from three organizations are collaborating in this experiment.

The experimental addition of Cd to ELA Lake 382, has been described in previous DFO LRTAP Workshop reports (Malley and Brown, 1989; Malley et al. 1990) and by Malley et al. (1990).

METHODS

Starting in June 1987 the epilimnion of Lake 382 was annually loaded with Cd and 109Cd during the ice-free season to reach an epilimnetic target concentrations of 100 to 160 ng/L. The radioactive Cd was added to trace Cd fate and to determine Cd concentrations in abiotic and biotic compartments. In the first three years, 975, 643 and 778 g of Cd and 96, 64 and 77 mCi of 109Cd, respectively, have been added to Lake 382. During 1990, again both forms of Cd have been added and the target epilimnetic Cd level is 160 ng/L. In 1990, depth profiles of Cd concentrations in the water were determined at 6 times in the season.

RESULTS

Water Chemistry

Total unfiltered Cd concentration during the first three years of Cd addition averaged 74, 48 and 85 ng/L (entire ice-free season means). Water Cd is approximately 150 ng/L in 1990.

Sediments

In March 1989, 23 sediment cores were taken along three transects radiating from the deepest portion of the Lake 382. To date 10 cores have been analyzed. Preliminary results show the Cd activity in Lake 382 sediments are approximately mass-balanced. An estimated 73% of the total Cd input in 1987 and 1988 was associated with sediments in March 1989. Cd activity in deep sediments was evenly distributed between cores. Cd activity in shallow sediments depends upon their organic content. In deep sediments, Cd profiles were variable. Some were "undisturbed", like 210Pb. Others were mixed, but not to the same extent as 210Pb.

Phytoplankton and Primary Production

Species diversity of phytoplankton in the epilimnion of Lake 382 ranged from 0.80 to 0.90 from 1977 to 1988. In 1989, it was slightly lower at 0.78.

This may still be within the range of natural variability or could be an early effect of the Cd. The decline in biomass (g/m^3) of phytoplankton in the epilimnion observed in the spring and summer of 1989 continued in 1990 and again fall biomass was similar to a number of previous years. The possibility that there has been a change in species composition of the community compared with that of reference lakes is being explored.

Lake 382 by nature is highly variable relative to reference lakes. In 1987 and 1988 there was approximately a 43% increase in annual mean chlorophyll a concentration as compared to the years 1983 through 1986. The increase in primary production in 1988 was followed by a decrease in 1989. Reference basins showed similar trends but the changes in Lake 382 were greater in magnitude. Presently, no effect can be attributed to Cd without further monitoring.

Macrophytes

It was concluded after monitoring 109Cd concentration in macrophytes for three years that accumulation was highest in annuals producing a large amount of biomass (*Nuphar*, *Potamogeton* and *Myriophyllum*) and lowest in slow-growing submerged perennials (*Lobelia*). Accumulation was very high in the roots of the emergent *Carex*, but the Cd apparently was not transported to the leaves of the sedge to a large extent.

Zooplankton

Plankton from lake water were filtered from each lake stratum (as determined by temperature profile). Samples were processed into two fractions of >54 µm and 20-54 µm. Each previous year, the Cd concentration of the >54 µm fraction was consistently higher in the metalimnion than in the other lake strata until the fall, when the Cd levels were higher in the epilimnion. This indicates migration of organisms between the metalimnion and the epilimnion because little 109Cd reaches the lower strata until fall turnover. The Cd level of the plankton in the hypolimnion was low during most of the sampling season, but showed a slight rise in the fall prior to turnover. Normalized percentages of total water Cd associated with each size fraction were approximately 5% for the >54 µm fraction and up to 25% for the 20-54 µm fraction. In July 1990, when epilimnetic Cd levels reached approximately 150 ng Cd/L, the usual large biomass of >54 µm fraction was not found in the metalimnion. Instead, it was found in the hypolimnion where the Cd concentration was lower. This may be an indication of an avoidance reaction by the >54 µm zooplankton fraction.

In 1989, the abundances in the total water column of rotifers, cladocerans, calanoid and cyclopoid copepods were higher than in pre-Cd years (1985 and 1986) and in the first years of Cd addition (1987-1988). However, the cladoceran, *Daphnia catawba*, less abundant than *D. galeata mendotae*, and occupying the metalimnion and hypolimnion, was less abundant in 1988 than in 1985 to 1987; in 1989 it was rare and found almost entirely in the hypolimnion. In 1989, the proportions of *D. galeata mendotae* and of cladoceran eggs in the epilimnion compared with the whole water column were intermediate between the values seen before (1985-1986) and after the Cd addition (1987-1988).

Benthos

By August 1990, the concentration ratio between whole body Cd of mussels and water Cd was approximately 15000. Mussels in the west bay contained Cd at concentrations nearly 20 times that of background levels before Cd addition to the lake. Studies were begun on this species on possible physiological responses to Cd contamination. Individuals exposed for a total of 10 days to 10000 ng/L Cd showed significantly lower glutathione levels in the digestive gland after 6 days than was observed in control animals, but both control and exposed animals showed some variability in levels and non-linear changes with time in four tissues. By September 1989, mussels in Lake 382 had metallothionein above levels found in Lake 377 (reference lake) mussels in mantle, gill, foot, kidney (P=0.06) and visceral mass. The largest increases were in the gill and mantle - about 3 times higher than in the reference lake.

During the open water season in 1990, benthic aquatic insects (especially the burrowing mayfly, Hexagenia) were collected from Lake 382. Organisms and sediment will be analyzed by atomic absorption analysis for Cd residues. Subsamples of sediment were taken to characterize the sediment in which the organisms live with respect to sand/silt/clay, organic C and organic N. Cadmium species in surficial sediments were determined in collaboration with Leah Bendell-Young (University of Ottawa). Insect emergence was collected using submerged funnel traps and shoreline emergence cages in Lake 382. Emergence will be measured in three sediment zones; shoreline, epilimnetic (2 m) and hypolimnetic (7 m). Analysis of residues will be similar to that of the benthic samples. Estimates of the contaminant load in emerging insects will be made for both 1990 and 1991. Loading of residues will be categorized with respect to sediment type and location of emergence in the lake. These loading estimates can then be related to established models of the relationship between lake productivity and dipteran emergence in ELA lakes.

Fish

1. Fish Studies From Lake 382 and Reference Systems.

Parameters examined in fish from Lake 382 and reference lakes are organized in terms of primary, secondary, tertiary and quaternary responses. The purpose is to integrate changes seen in biochemical and histopathological indices with effects observed at the population level and with studies conducted by investigators examining other aspects of the ecosystem. Overall, this type of study will help to provide much needed information linking effects in organisms to chemical causes. Thus, potential effects of Cd in fish are examined in fish species from different trophic levels and integrated over four levels of biological organization:

a. Tissue uptake and distribution of Cd (PRIMARY RESPONSE) provides levels of Cd in the vital organs which can then be related to physiological and pathological effects. The relationships derived from comparison between Cd burden and effects can then be used to predict consequences of similar Cd levels in other systems regardless of differences in water quality.

b. Biochemical and histological responses (SECONDARY RESPONSE).

i) Carbohydrate metabolism (energy).
ii) Ionoregulation (maintenance of homeostasis).
iii) Metallothionein, acid-soluble thiols and ascorbate.
iv) Growth indices.
v) Reproductive indices.

c. Whole animal effects (TERTIARY RESPONSE).

i) Behavioral responses.

d. Population effects (QUATERNARY RESPONSE).

i) Population responses - population growth rates, survival, recruitment and abundance.
ii) Community - population ratios, etc.

1 a. Tissue Uptake and Distribution:

In 1989, Cd concentrations in whole fathead minnow and pearl dace from Lake 382 were 8-15 times background levels and similar to previous years. Cadmium concentrations in whole large fish were higher in 1989 than in 1988 and by October 1989 were 22-30 times background values. The continuing Cd accumulation in white sucker and lake trout contrasts with the near constant Cd concentrations in the minnows. The longer lived white sucker and trout may require more time to reach equilibrium than the minnows. The difference could be related to the higher metabolic rate of minnows and their shorter lifespan. The ratio of Cd concentrations in whole fish:Cd concentration in water were 2580, 2170, 890 and 680 for fathead minnow, pearl dace, white sucker and lake trout, respectively.

In 1989, trout and white sucker kidney Cd levels increased 5-10 fold over background despite a similar Cd loading rate and water concentration to previous years. The large fish from lake 382 now have 4000-5000 ng Cd/g wet weight in kidney tissue. This represents concentration factors of greater than 40,000 over ambient water Cd levels. Histopathological lesions in rats begin when the level of Cd in the kidney exceeds 10000 ng/g. Information for fish is limited but brook trout survival in a long-term laboratory exposure was reduced 50% when Cd concentration in kidney was 8000 ng/g.

1 b. Biochemical and Histological Responses:

In October 1987 and May/June 1988, all parameters were similar to those found in fish from reference lakes with the exception of liver glycogen which was initially 3-10 times higher. Following periods when body energy reserves have been mobilized (i.e. starvation), processes which release glucose are inhibited to maintain normal plasma glucose levels. When re-feeding occurs, excess glucose is first converted to liver glycogen. Liver glycogen declined between July and September 1987 in trout from Lake 382, as did muscle protein. The decreasing energy reserves during this period may reflect changes in food supply or feeding behavior. Biochemical parameters whose basal levels are diet-dependent (ascorbic acid & acid-soluble thiols) were also lower than levels found in fish from reference lakes. In 1989, biochemical analyses related to energy metabolism showed no remarkable differences between Lake 382 and reference lakes. Analysis of parameters related to energy metabolism in fish collected in 1990 are underway. Plasma measurements assessing osmoregulatory function and carbohydrate metabolism were similar between fish from Lake 382 and those from reference lakes for each year examined (1987-1989).

Metallothionein concentrations in liver and kidney of fish from Lake 382 varied seasonally but fell within the ranges found in fish from reference lakes.

Plasma thyroid hormones (T3 & T4) and thyroid epithelial cell height (TECH) were measured and compared to growth rates and gonad development in lake trout from Lake 382 and from reference Lake 468. In 1989, plasma T3 exceeded T4 in fish from each lake. Indices of thyroid function showed pronounced changes during the open-water season only in fish from Lake 468. Fish in Lake 468 grew rapidly and T3 and TECH were inversely related to gonad development. Fish from Lake 382 had low plasma T3 and TECH which varied little during the open-water season. Elevated T3 and TECH were associated with active somatic growth and subsequent normal gonad development in Lake 468, whereas low T3 and TECH were associated with slow growth in Lake 382 fish. The difference in thyroid function between Lake 382 trout and those from reference lakes was evident early in 1987 prior to Cd additions and may be more relatable to differences in quality and quantity of food supply than to Cd. Growth rates in Lake 382 trout are very slow and evidence indicates that this was the case prior to Cd additions. The relationships between poor gonad development in trout from Lake 382 in 1988 and plasma levels of reproductive steroid hormones (estrogen, testosterone & 11-ketotestosterone) are currently being determined. Evaluations of endocrine functions in fish captured in 1990 are ongoing.

Information was gathered on variability ranges for ELA lake trout and white sucker egg parameters (differential counts, egg sizes profiles and gonado-somatic index, GSI) by sampling reference lakes along with Lake 382. The 1988 data showed a marked reduction in female lake trout GSI prior to spawning. A similar although less extensive effect was observed in nearby reference Lake 305. Also in 1988, vitellogenic oocytes were smaller than those found in fish from reference Lakes 468 and 305). Differential counts showed more recruitment eggs and fewer vitellogenic oocytes in September 1988 than in other years. Because variability in ovarian development has been attributed to the quantity and quality of food supply, alterations observed in 1988 appear related to reduced fish energy reserves (see above). In 1989, all egg and fecundity measurements recovered and were similar to those found in 1987.

1 c. Whole Animal and Population Effects:

Analysis of gut contents from Lake 382 lake trout so far indicates that these fish rely more heavily on invertebrates than do trout in Lake 468 and other reference lakes. This coupled with their low growth rate suggests that trout in Lake 382 may be more susceptible to Cd-induced changes in invertebrate prey than populations from other lakes.

Growth rates of fish from Lake 382 and reference lakes indicate possible depressed early growth in Lake 382 white suckers.

2. Laboratory Studies with Cadmium

In an experiment in which lake trout were exposed to ambient Cd levels of 500 and 5000 ng/L for 250 to 274 d in the laboratory, their ability to capture prey species was impaired. Tissue Cd, biochemical and histological analyses of these fish are not yet complete. However, preliminary findings show increased levels of acid-soluble thiols in kidney and altered liver morphology. Moreover, lake trout exposed to 5000 ng/L had lower thyroid function as determined by reduced thyroid epithelial cell height and plasma T3 measurements.

In a second experiment, lake trout were fed food enriched with Cd. Dietary Cd levels ranged logarithmically from 500 ng/g (concentration currently in prey species for Lake 382 trout) to 500000 ng/g. By 42 d, Cd had accumulated in liver and kidney tissues in a dose-dependent fashion. Liver and kidney Cd levels reached 8000-10000 ng/g in fish receiving the highest Cd dose. This is approximately twice the concentration found in lake trout from Lake 382. In groups fed more than 5000 ng Cd/g, Cd accumulation altered liver morphology and reduced liver glycogen. Degenerated interrenal cells and elevated plasma glucose were observed in fish fed the 50000 and 500000 ng/g doses. After 105 d, interrenal cells from all treatment groups were further enlarged compared with the controls and the 42 d treatment groups. The hypertrophied interrenal cells and nuclei suggest that the fish have mounted an adaptive stress response. In contrast, plasma electrolytes and osmolality showed no significant alterations due to dietary Cd. Other biochemical and histological analyses are presently ongoing.

Exposure of rainbow trout fed vitamin C- (ascorbate) and vitamin E-deficient diets to ambient Cd levels of 2000 and 4000 ng/L for 180 d resulted in significant accumulation of Cd in liver. Tissue Cd levels were comparable to those presently found in lake trout from Lake 382. Tissue to water concentration factors were approximately 1000. Fish fed diets deficient in ascorbate showed enhanced Cd accumulation in the liver. Liver ascorbate levels were reduced by Cd exposure while kidney levels of acid-soluble thiols were increased in a dose-dependant manner.

Preference-avoidance testing of previously unexposed lake whitefish to Cd was completed. A total of 27 response parameters were computed on the behavioral responses of these fish to Cd ranging from 200 to 256000 ng/L. Responses to Cd were dichotomous among individuals; while most fish showed "avoidance", a significant number of fish displayed "preference" when measured simply as time spent on the treated side of the trough. However, when the magnitude of the response and not direction was considered, a bimodal dose-response relationship was evident. The fish reacted to water containing Cd at <1000 ng/L and >8000 ng/L but showed little reaction to concentrations between those. The fish responded to the lowest Cd concentration tested (200 ng/L), suggesting that their response threshold is still lower.

PUBLICATIONS AND PRESENTATIONS ON CADMIUM WITH RELEVANCE TO LRTAP

(N.B. The reference list also includes publications and presentations on cadmium from Central and Arctic Region prior to 1989 where these are not included in previous LRTAP Workshop Proceedings.)

Primary Publications:

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Klaverkamp, J.F. and D.A. Duncan. 1987. Acclimation to cadmium toxicity by white suckers: Cadmium binding capacity and metal distribution in gill and liver cytosol. Environ. Toxicol. Chem. 6: 275-289.

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Klaverkamp, J.F., M.D. Dutton, H.S. Majewski, R.V. Hunt and L. J. Wesson. 1990. Evaluating the effectiveness of metal pollution controls in a smelter by using metallothionein and Other Biochemical Responses in Fish. In: Ecotoxicology of Metals: New Concepts and Applications. CRC Press, Inc. (In Press)

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Dutton, M.D., H.S. Majewski, and J.F. Klaverkamp. Biochemical stress indicators in fish from lakes near a metal smelter. International Association for Great Lakes Research. Hamilton, Ontario, 17-20 May 1988.

Harrison, S.E., R. Hunt and J.F. Klaverkamp. Zinc, copper, cadmium, mercury and selenium accumulation in fish and sediments from lakes near a base metal smelter. Annual Meeting of the Soc. Environ. Toxicol. and Chem. Pensecola, Florida. 9-13 November 1988.

Harrison, S.E. and J.F. Klaverkamp. Cadmium accumulation and distribution in fish exposed by water and dietary routes of uptake. Presented at the 8th Annual Meeting of the Soc. Environ. Toxicol. and Chem. Pensacola, Florida, 9-13 November 1987.

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Questions and Answers

<u>GLORIA SANGALANG:</u> I assume you mean the total cadmium?

<u>SCOTT BROWN:</u> Yes, these are total cadmium measurements.

<u>GLORIA SANGALANG:</u> Have you considered doing a speciation of these?

<u>SCOTT BROWN:</u> Yes, we're working on it. We haven't got it completed yet.

<u>GLORIA SANGALANG</u> Because you could be working with organic cadmium and maybe the high levels would not be as toxic.

<u>SCOTT BROWN:</u> Yes, yes. We have the tissues and things collected for within the tissues. The water is largely, within the water, accordingly to Morris' work is about 70% is free ion and 30% is attached to particulates in the lake.

<u>PETER DAVENPORT:</u> I was wondering what sort of levels were accumulating in the lake sediment?

<u>SCOTT BROWN:</u> Yes, well I have some of Malcolm's work there. I just can't remember a number off the top of my head but there's lots here. I have actually some pictures of these cores if you'd like to look at them. I didn't show them. We have collected a pile of data. I was just going over the highlights on the biota where we saw effects but if you want to see me after, I can give you exact numbers.

<u>PETER DAVENPORT:</u> Yes, and I have sort of a supplementary. I was wondering what sort of levels or do you know what sort of levels are naturally occurring in organic lake sediments in Canada? You mentioned the sources of cadmium but, of course, you've overlooked the fact that it does vary quite widely in nature.
Geologically it has quite a strong hold on cadmium.

<u>PETER DAVENPORT:</u> That geologically , it's quite a strong controller of cadmium.

<u>SCOTT BROWN:</u> Yes. I have personally haven't looked at that but in this Lake the sediments were quite low to begin with and I recognize that. I don't have those numbers at my disposal right now.

<u>PETER DAVENPORT:</u> I'm sort of interested because I am interested in geochemical mapping. I am with the Department of Mines so initially it was for prospecting but, of course, it has wider applications. I assume these sort of data would be useful to you?

4.5. PALAEOECOLOGY STUDIES

Central and Arctic Region - R. Hecky

Paleoecological Studies at the Freshwater Institute, Winnipeg

Prepared by R.H. Hesslein

The objectives of the Central and Arctic's small paleoecology program is to validate and calibrate pH reconstruction techniques by doing the following:

1. Reconstruct pH from microfossils in sediments of experimentally acidified lakes using accepted pH/diatom relationships.
2. Check results of above against known record.
3. Determine the utility of pigment analyses in the reconstruction of lake pH's.
4. Complete the pH calibration of surface sediments of 50 lakes at ELA by having chrysophytes analyzed.
5. Evaluate gravity coring vs freeze coring for stratigraphic disturbance in organic-rich sediments.

Winnipeg LRTAP paleoecological allocation was mostly expended in support of the post-doctoral fellowship for Dr. Peter Leavitt, a paleoecologist and specialist in pigment records in sediments. Dr. Leavitt performed a number of tasks, some of which are still in progress.

Dr. Leavitt's first challenge was to resolve differences of opinion and define a coring method which would allow the very high (yearly) resolution of changes in the ELA lakes. This task as aided by the completion of work on cores taken at ELA by J. Crusius and R. Anderson at Lamont-Doherty Geological Observatory in New York. They (Crusius and Anderson, 1991, under review) determined that gravity cores contained unreliable sediment histories from the comparison of lead-210 and caesium-137 in carefully taken gravity cores and freeze cores. They also showed that in the freeze cores the established record atmospheric deposition of Pb-210 and Cs-137 was very well preserved. Leavitt then determined that in sediments from some lakes in ELA individual yearly laminae could be clearly distinguished in the set of freeze cores which he collected.

Dr. Leavitt has sectioned the cores into annual laminae and distributed the samples to investigators for a number of analyses. The pigment analyses is being done by Leavitt himself. The radiometric dating is being done by Dr. G. Brunskill in Winnipeg. Algal microfossil reconstructions are being done by Dr. J. Smol's group at Queens University. Invertebrate microfossil reconstructions are being done by Dr. B. Hahn at the University of Manitoba. Stable isotope analyses is being done by Dr. R. Hesslein's group in Winnipeg. All of the analyses are expected to be in a report by March 1991.

D. Findlay in Winnipeg has a manuscript partially completed describing the correlation of algal microfossils in surface sediments in ELA lakes with the pH of the lake waters. This calibration will provide the basis for the correlation of downcore algal microfossil reconstruction of pH from the cores of Leavitt's being analyzed. This manuscript will be submitted for publication by March 1991.

Questions and Answers

KEN MINNS: Does that mean that you didn't do any down core reconstruction on lakes that hadn't been acidified?

BOB HECKY: The answer is that we've emphasized the acidified lakes but we have a general coring program reconstructing the histories of many of the lakes in our area. And that's why we're confident. We have some very interesting stratigraphic changes but they're not pH related.

IOLA PRICE: I have a question. Can you elaborate a little bit more on the freezing versus regular gravity coring. Is this something that we should be looking at to try to apply a consistent methodology across the LRTAP Program in Canada and get that applied elsewhere in Departments' work?

BOB HECKY: I think if palaeoliminology is going to be a continuing and important part of the Program then I think we do want to move the standardized methodologies and in particular in these very soft organic rich sediments there are problems in some of the coring techniques that have been applied and if especially that recent record is of greatest interest that is precisely the stratigraphy is being lost with some techniques. So the answer is yes I think we should be moving to standardized methodologies and in some cases it's going to be a very different kind of methodology than has been used in the past. Is that answering your question?

IOLA PRICE: Yes. Then I guess my supplementary would be then how do you propose then, in fact, to get that methodology accepted across to them?

BOB HECKY: I think by the weight of evidence is that it's a short answer that the work that we're doing has satisfied us that the freeze coring technique will capture that recent sedimentary history in organic rich sediments. I think the evidence suggests that the KB coring with fairly large diameter cores can recover it but some of the techniques using gravity cores which use a freefall approach and have a one way valve which tends to retard water movement through the core as it is entering the sediment, does create a compression wave which can blow away or compress the very upper sediments. Now I'm new in this game and I'm not familiar with the kinds of techniques that have been used in Eastern Canada but I'm told there's a variety of techniques that have been used and I think that we should move to the standardization of them in my recommendation. In lakes with known stratigraphies from our own region I think it's fairly well validated that we have reason to be confident in the freeze coring approach and some reason to be very questionable about some of the other techniques that have been used. But there hasn't been a side by side comparison of all the techniques that may have been used in previous or continuing studies on that. So maybe there's a need to make that kind of study.

SUE MILBURN: Perhaps it's a bit of devil's advocate question but why would we do a lot more of this palaeo work under the LRTAP Program? Is there more stuff that we think we can get out of it or is this maybe something that's more applicable to the organics and some of the other contaminants? I think in terms of the acid rain problem we probably go as much as we're going to get out of this. Maybe I'm wrong.

BOB HECKY: You're not a devil's advocate with me. I don't feel well positioned to represent the program that's been funded in the past within LRTAP. Is there anyone else here that would like to speak to that? I think that what I was suggesting is that especially on the technique side that there is still a need perhaps to satisfy ourselves about appropriate techniques in different kinds of sediments and that goes into the organic series as well as anywhere else.

<u>IOLA PRICE:</u> That's the question I'm asking the palaeo group this afternoon to address because I've been looking at it, too, and wondering have we gone as far as we can go and in times of tight resources should we, in fact, be shifting to some other area that will give us more bang for our buck.

<u>BOB HECKY:</u> Well I don't feel in a good position to represent that because in our region we haven't done a great deal of that kind of work. We've been working more on validation of technique rather than trying to reconstruct this. John.

<u>JOHN SMITH:</u> Have you actually worked out any transfer functions between diatom assemblages and pH or is this something... I didn't quite follow that when you...

<u>BOB HECKY:</u> We have sampled 50 lakes with a range of pHs and established the diatom species within those lakes. There are published transfer functions and there's a general classification of diatom species into general levels of acid preference. If you do that regionally within any specific locality, you'll probably get a slightly different or sometimes quite a different transfer function from the more general ones. But they are basically working from statistical, correlational approach to interpretation. So there are a number of functions is the answer and we....

<u>JOHN SMITH:</u> I just wondered how successful you had been in actually reconstructing past changes in pH?

<u>BOB HECKY:</u> All I can say is that Dave Finley's analysis is still underway. He's telling me that we're not getting the kinds of fit that you might like to see. Now that doesn't mean that you won't establish a general trend. And the trend may be correct. But whether it's predicting exactly or within the kind of resolution you might like to see, that might be a problem. I don't think we're going to destroy the trend analysis. It's just a question of the resolution that's available and how well you can hope to do an action creating the pH that existed at a certain time in the past.

<u>BOB WILSON:</u> I think one potential problem might be there that you're looking at only a 10 year history where if you're trying to reconstruct things over the last several thousand years, the lakes have had a lot more time to complete the response. So it's likely that there will be some species that you're not going to pick up in the record but that doesn't mean that they won't become more prominent given more time for the populations to develop.

<u>BOB HECKY:</u> That's a valid concern and it may be part of the problem that we might have. The advantage that we do have is that we have a fairly fine scale resolution but I share your concern that our experiments are necessarily short term relative to the time scale and the problem that we're concerned about and that we may actually terminate them while populations are adjusting and we might not get quite the same response. But it is a known record and that is what we've never...work against and that's the importance of it. The other response to that is that the phytoplankton response is generally fairly quick but they're not necessarily the long term responses that lakes in the natural environment might exhibit.

<u>BOB WILSON:</u> I guess that one other point there is that sometimes the benthic

response will be delayed considerably because of buffering so to the extent that some of fossil reconstructions rely on benthic organisms as well or benthic diatoms. You may have a delay in seeing that response?

BOB HECKY: Yes, that's a valid concern about.. We have a very good record of phytoplankton population in the record. We do not necessarily have an equally good record of the benthic populations. You're quite right that, within the diatom reconstruction, it's often the benthic species that are the ones that are being used in the reconstruction.

Palaeoecological Research in Nova Scotia
John Smith

I work at the Bedford Institute of Oceanography in the Atlantic Environmental Radioactivity Unit (AERU) in the Marine Chemistry Division where we focus on applications of radionuclides as tracers for marine environmental processes. We weren't funded this last year so I have no data to report. However, we were funded in previous years, the results of which have been reported at previous Workshops, and I thought I might review this past work. We have had two main projects. One focused on the use of radionuclides to reconstruct the input functions for long range transport of pollutants into Nova Scotian lakes. This work relied on lead-210 and other tracers to reconstruct sedimentation rate histories and to determine sediment input functions for substances such as PAHs. Our second project involved an unsolicited proposal for the development of transfer functions correlating lake pH with the composition of diatom assemblages in dated sediment cores. The goal of this project was to reconstruct the past history of pH changes for various lakes in Nova Scotia and New Brunswick. The first of these projects ran into scientific difficulties and the second encountered bureaucratic obstacles (it was discontinued owing to the end of the UP program).

With regard to the first project, we collected cores from three lakes from Kejimikujik National Park in 1988. Gravity coring techniques were employed to collect cores from the ice during the winter. We used a Lehigh core, a 10 cm internal diameter, PVC pipe, essentially a plumber's pipe. In Kejimikujik, we lowered this gravity core, having a weighted head, slowly into the sediments. There was no free fall of the core barrel and the surface layer was retained largely intact. Compression of the sediments in the core barrel was not a major concern owing to the relatively large diameter of the core barrel.

The principle radioactive tracer used to date the sediments was Pb-210, with which most of you are probably now familiar. This is a natural radionuclide produced in the atmosphere by radio active decay from Rn-222, which itself is an inert gas. Lead-210 is deposited in the water column with precipitation and dry fallout and is rapidly adsorbed onto particles and accumulates in the sediments. It has a half life of 22.3 years. Once it accumulates into the sediments, it decays by that half life and the decrease in the lead-210 concentration with depth can be used to determine the sedimentation rate. This is a typical lead-210 distribution from Mountain Lake in Kejimikujik and it behaves as one would predict. There is an exponential decrease in the lead-210 concentration with depth, approaching a constant background due to radium-226 within the sediments. In principle, these profiles are relatively simple to interpret. Lead-210 has a half life of approximately 20 years so it's activity will decrease by a factor of 2 every 20 years. In this case, it decreases by a factor of 2 over the first 4 cms. Therefore, 4 cms of material has been deposited in 20 years. The sedimentation rate is approximately a quarter of a cm per year.

The problem that we encountered was one of sediment mixing. In the Saguenay Fiord in Quebec, we can date sediments to plus or minus one or two years over the past 100 years because we have laminated sediments, ie. no bioturbation. This is due to a high flux of organic material from pulp and paper mills which utilize the available oxygen and produce an inhospitable environment for bioturbating macrofauna, resulting in the excellent preservation of sediment structure. However, in more oxygenated sediments, organisms can produce substantial mixing owing to their feeding and habitat construction activities.

Sediment mixing can be identified using other types of radioactive tracers, having input functions which differ from that of Pb-210.
Plutonium and cesium-137 are both nuclear weapons fallout products. They began to be produced in the early 1950s. The input function to the environment was maximized in the early 1960s and has diminished since then. In principle, the distribution of these radionuclides in the sediments should be somewhat similar to the input function, but, in any case, plutonium and cesium should be largely absent from sediments deposited prior to 1950 if they have not undergone sediment mixing. Cs-137 is somewhat mobile in high porosity, lake sediments and, as a result, does not provide an unambiguous time-stratigraphic marker in aquatic sediments. However, Pu-239,240 is much less mobile in lake sediments and, when used in conjunction with Cs-137, can provide validation of the Pb-210 geochronology. In the case of the three Kejimikujik lakes (Mountain, Beaverskin and Luxton), the plutonium and the cesium were found at depths as deep as the excess lead-210, ie., they penetrate to the bottom of the excess lead-210 column. One must conclude from these data that the distributions of all three radionuclides are almost entirely controlled by mixing as opposed to sedimentation. The sedimentation rate in these systems could, in principle, have been close to zero, but mixing by organisms may have produced the profiles of the three tracers observed in the present figure. In the six cores analyzed from three different lakes, downward transport of surface sediments by mixing was indicated in each case by plutonium and cesium tracers. We have encountered this same problem in sediments from lakes in New Brunswick.

We have measured PAH distributions in these sediments and, of course, these also show evidence of downward mixing. In the absence of the tracer evidence one could easily conclude that the PAH input function was increasing exponentially with time, because that is the shape that diffusive mixing forces onto many types of concentration gradients. Other contaminants (Pb, Hg, etc.) will exhibit a profile similar to that of the radionuclides and PAH's under the influence of sediment mixing. In the absence of evidence from fallout radionuclide tracers, investigators have frequently relied on the Pb-210 data to provide a geochronology and have simply ascribed dates to the different sediment strata, despite the fact that the entire sediment column may have undergone substantial mixing. There's a rather extensive, and I believe, erroneous literature on applications of Pb-210 dating to the reconstruction of contaminant input functions and pH changes in lakes in which the geochronology has not been validated using an independent methodology.

In any case, we have not yet found a well preserved, sedimentary system in a Nova Scotia lake that would permit us to undertake useful contaminant and pH reconstruction experiments. Clearly, the identification of a suitable sediment regime and the initial radionuclide work are probably the single, most critical step in programs of this nature.

Questions and Answers

<u>IAN DAVIES:</u> Is there any way you can use diffusion coefficient... Perhaps you already explained this. I just didn't understand it but can you use diffusion coefficients? Can you back calculate from knowing the rates of diffusions in sediments what the profiles should have looked like essentially like a computer enhancement of...

<u>JOHN SMITH:</u> This what I've shown is an extreme case in which you have complete mixing down to the base of the excess lead 210 zone if you like. There are a lot of less extreme cases in which you have just a deviation of the profile from an exponential curve. You may have a kind of surface mixed zone. There are a lot potential situations that can arise and many of these are conducive to modelling. If you can model it, then, yes, you can go back and recover some of the historical information. Of course, you introduce a fair amount of noise into the system but nevertheless you can go back and reconstruct pollutant inputs and possibly do a pH reconstruction. This is the extreme case in which sedimentation is totally dominated by mixing. In many cases, they'll be half and half or sedimentation may dominate mixing as opposed to the other way around. But yes you can model some of these systems and get useful information out of them.

Newfoundland Region S. Ray

Proposed Paleoecological Study in Newfoundland Region

DFO has been involved in extensive research on LRTAP since the early 1980's, but data are not available for the Labrador region. Databases for the colder regions of Canada, particularly Arctic and sub-Arctic areas, are practically non-existent. Consequently, there is a tremendous knowledge gap regarding (LRTAP) the effects of the contaminants on present fishery resources in the region and their viability in future. However the historical data and the present trend of LRTAP can be easily obtained by paleoecological study of sediments from lakes situated in remote regions of Newfoundland and Labrador.

The prime reasons for paleoecological studies are listed below:

1. It provides the regional acidification history, e.g. when did it start and/or is it still continuing.

2. Quality of organic contaminants, like PAH, organochlorines, etc.

3. Quality of metal contaminants e.g. Pb, Cd, Hg, etc.

4. Flux rate of contaminants i.e. input/unit area.

Various parameters studied (in conjunction with each other) will provide unambiguous answers regarding history of acidification and the nature and extent of damage to fishery resources. Future study on biological effect can be undertaken only when the nature of the pollutant is known and will be a natural extension of the proposed study.

Similar projects have been carried out during LRTAP IV in eastern Canada, but not in sub-Arctic regions. The proposed work will bridge the knowledge gap and provide a comprehensive picture.

I have proposed a 4 year collaborative project with D. Scruton of Habitat Research and Assessment Section, Science Branch to determine not only the history of acidification, if any, but also the extent and nature of contaminants deposited in the region by LRTAP.

Diatom stratigraphy of core samples has proved its suitability in determining pH profile and has been extensively used in the Atlantic region. However, paleolimnological indices are unique to each area and have to be calibrated independently for Labrador. Plant pigments and chrysophytes are also to be studied in the same cores for comparison.

PAH and chlorinated hydrocarbons are also to be determined for exact nature of organic contaminants. However, deposition of PAH may result not only due to civilization effects, but also forest fires and may give inconclusive results if used unaided by synthetic organic contaminants like chlorinated hydrocarbons in use only since the late 1940's.

Sample sites for candidate paleo-coring will be carefully selected in 4 distinct geographic zones of Labrador in conjunction with previous national inventory surveys conducted under earlier LRTAP surveys. This background dataset on lake water chemistry, fish population biology, and bathymetry will yield valuable insights necessary for optimizing the best sites for paleoecological reconstruction and for establishing background LRTAP mediated contaminant levels.

The proposed work schedule is as follows:

Yr 1 - sample collection and preparation for contractual analysis
Yr 2 - develop criteria for calibration indices for diatoms and chrysophytes; diatom, chrysophytes, and pigment stratigraphy; pH reconstruction
Yr 3 - analysis of chemical contaminants
Yr 4 - manuscript preparation

I hope that the proposed study will fill a major void in the available data base and allow the management objective to initiate counter measures to protect valuable recreational and commercial fishery resources in the region.

Questions and Answers

__JOHN SMITH:__ One thing you have to be concerned with. We've done some sediments in Labrador in Lake Melville and what you find when you get further North that the lead 210 signals become increasingly smaller. There are several hypothesis as to why this is the case. It looks like a question of radon excelation from the earth's crust which is the process that produces lead 210 in the atmosphere. It seems this diminishes as you get further North with ice cover, fewer soils and so forth. In any case, the lead 210 signal becomes a lot weaker and you may run into problems in Labrador in terms of the strength of the signal. I don't know how much that will interfere with your project but it's something to bear in mind.

4.6. BIOMONITORING PROGRAM

<u>Quebec Region</u> A. Kemp Biomonitoring Program

Québec Region
1990-91

In the Québec Region, two sites are currently being studied under the National Biomonitoring Programm. The first, located in La Mauricie National Park, encompasses four lakes: Éclair, Francina, Hamel and Théode (Fig. 1). The second, which is on the North Shore, has five salmon rivers, namely Godbout, de la Trinité, aux Rochers, Matamek and Jupitagon (Fig. 2). In 1990-91, we carried out the activities provided for in the program, specifically sampling of benthos and fish in the lakes in the fall and benthos sampling in the rivers in June, August and October.

We have received the identification results for the benthos samples taken in 1987 and 1988, while those collected in 1989 and 1990 are currently being analyzed by a contractor. No statistical analysis has been conducted yet on these findings. Last June, we sent Ian Davies our collection of benthic organisms as our contribution to the National Taxonomic Verification Exercise and to check the quality of our identifications.

We have obtained the results of the study on the emergence of adult insects, conducted from May to November 1989 for the purpose of completing and validating species identifications of organisms found in benthic communities in La Mauricie National Park lakes. The four emergence traps in three lakes worked very well. From six to ten thousand insects, among 169 different taxa, were captured in each lakes. However, owing to limited knowledge of taxonomy of some groups, including both adults and larvae, particularly the Chironomidae, it will apparently be difficult to use these specimens to aid in identifying larvae collected under the biomonitoring Program.

Bioassays were conducted again this year in North Shore rivers. These bioassays consist in exposing pre-smolt parr of atlantic salmon to the decline in pH levels in the spring. The experiment begins with the fish being placed in the water about 30 days before the date on which the acid peak is expected to occur, that is around April 1. It ends some 45 days after this peak, around June 15. The parrs for experiment were provided by fish farm located at l'Anse-Pleureuse which represent the control site.

Every weak, mortality is recorded and biological samples are taken, including a) plasma for measuring hematocrit, total plasma proteins, osmolality, sodium, and chloride; b) gills for histological studies; and c) gills for the aluminum assay. In addition, the physico-chemical quality of the water in each of the rivers under study is analyzed. Nineteen parameters are measured, the primary ones being pH, alkalinity, conductivity, total dissolved aluminum, inorganic aluminum and dissolved organic carbon.

Last year, at the LRTAP workshop (MPO, 1989), we presented the results obtained in 1988 for the de la Trinité and aux Rochers rivers and those obtained in 1989 for the Matamek and Jupitagon rivers. For the de la Trinité and aux Rochers rivers, the results showed that the parr were exposed to an acute acid shock that lasted about ten days. The minimum pH observed was 4.7 in aux Rochers river. The acid shock caused stress in the fish as revealed by the plasma parameters. However, mortality was nil and, at the end of experiment, when the pH level was back to normal, the plasma parameters had returned to normal levels as well. In 1989, in the Matamek and Jupitagon rivers, the situation was somewhat different. As regards the physical chemistry of the water, no well-defined acid peak occurred as with the first two rivers studied, but the pH remained below 6.0 throughout the experiment. Futhermore, the total dissolved aluminum and the inorganic aluminum concentrations measured were much higher in 1989 than in 1988. The inorganic aluminum concentrations attaining in 1989 values greater than 100 $\mu g\ l^{-1}$, compared with concentrations generally below 50 $\mu g\ l^{-1}$ in 1988.

The stress level, as indicated by the plasma parameters, was higher in 1989 than in 1988. The plasma sodium and chloride and hematocrit values for the surviving fish were similar to those observed by Lacroix and Townsend in 1987 for dying juvenile salmon. However, the major difference between the two years centred on the mortality rate. At Jupitagon river, the mortality rate was low, approximately 5% over three weeks, whereas at Matamek, a very high rate (90%) was recorded, 14 days after the minimum pH level observed.

However, the mortality recorded, in particular for the Matamek River, may have been due at least in part to other stress factors, such as the strong current. At the time of the spring run-off the cages in this river were submitted to a strong current because no well-protected site. Hence, with a view to pinpointing the causes of this mortality, we conducted further bioassays in the Matamek and Jupitagon rivers, but we used a different site in the Matamek River so that the parr would be less exposed to the current. In addition, we planned to use the Moisie River as a control river. Although the Moisie was not one of the five rivers sampled under the Biomonitoring Program, it would allow us to check the impact of the experimental manipulations since it was not subject to acid shock given its sustained pH of over 6.0. Unfortunately, the ice break-up on the Moisie River was particularly violent this year and we lost our cages, so we have no biological data for this river after ice break-up. In spite of this, the results obtained this year are very interesting.

The pH levels recorded for the Jupitagon River this year show that the acid shock as such lasted 12 days, with an acid peak of pH 5.1 (Fig 3). Twenty-five days after this peak the pH level had risen to 6.0, which seems to be the chronic pH for this river. These observations are fairly consistent with those in 1989, although the minimum recorded this year in the Jupitagon River was slightly lower than that observed in 1989, that is 5.1 as opposed to 5.4 (Fig. 3). The pH results for the Matamek River do not exhibit a classic pattern. Aside from one relatively high value of 5.8, which is difficult to explain, the pH varied between 5.0 and 5.25 (Fig. 3). This pH level appears to be the chronic pH for this river. These observations are also fairly consistent with those in 1989 (Fig. 3). The pH levels recorded for the Moisie River (Fig. 3) clearly indicate that it would be an excellent choice as a control river.

Inorganic aluminum concentrations varied from one river to another, with the Matamek River showing the highest levels throughout the experiment (Fig. 4). This river also exhibited the widest fluctuations in inorganic aluminum concentrations, with a range from 30 to 105 $\mu g\ l^{-1}$. Aside a six-day period when the pH was at its lowest level, the inorganic aluminum concentration was always greater than 45 $\mu g\ l^{-1}$. Toward the end of the experiment, we noted a marked increase in the inorganic aluminum level. In the Jupitagon River, on the other hand, the inorganic aluminum concentration fluctuated little, always remaining below 35 µg l^{-1}. This year's results differ from those obtained in 1989, in both rivers (Fig. 4). The concentrations recorded in 1989 were higher and showed greater variability. Upon verification, it appears that the differences are not due to the analysis techniques used, but represent year-to-year variability. In contrast the total dissolved aluminum show little variation between year in both rivers and the concentration varied between 250 and 400 µg l^{-1}4 (Fig. 5). Data for conductivity are presented in figure 6.

In summary, the Matamek River is a river with a low chronic pH level (5.0 to 5.2) with a high inorganic aluminum concentration (over 50 µg l^{-1}). The Jupitagon River, on the other hand, has an intermediate chronic pH (6.0); its pH level drops by one unit during acid shock; and its inorganic aluminum concentrations are low (lesser than 40 µg l^{-1}).

The highest mortality rate recorded this year in the Matamek River was 40% and occurred 20 days after the lowest pH was observed. After this, the mortality rate remained high, at a level of over 20% (Fig. 7). The mortality rate in the Jupitagon River is always below 5% (Fig. 7).

The stress that caused this mortality is reflected in the plasma parameters. Six days after the acid peak, the different stress indicators; plasma osmolality and total proteins, hematocrit and gill aluminum; clearly showed that the fish were suffering stress, in both rivers (Fig. 8, 9, 10 and 11). However, full recovery was noted after 30 days in Jupitagon River, concurrent with a decline in acidity. In the Matamek River, where the pH held steady at close to 5.1 and inorganic aluminum concentration remained higher than 50 µg l^{-1}, the stress indicators remained at critical levels until the end of experiment (Fig. 8, 9, 10 and 11). The stress suffered by the Jupitagon River parr was not as severe at any time as that to which Matamek River parr were subject.

The difference in mortality and the stress level between the two rivers is explain by pointing to the differences in their pH levels and variability and their inorganic aluminum concentrations. This year, parr were not exposed to violent current, thus it seems that the current stress may be discard as a possible effect. The high mortality rate observed in the Matamek River is probably due to the combined effects of the pH and the aluminum. In fact, from the results of bioassays made in 1988 in de la Trinité and aux Rochers rivers and the results obtained for the Jupitagon River and from a survey of the literature on this topic (Lacroix and Townsend, 1987), it appears that a pH of 5.0 alone would not be sufficient to cause the mortality observed. However, the high aluminum concentrations found in the gills of the Matamek River parr (Fig. 11) show that the elevated inorganic aluminum levels in the water (Fig. 4) have an impact on their gills. Analysis of the histological sections is still under way and will make it possible to assess the damage to gills of these fish.

We plan to conduct further bioassays next year spring in order to examine in greater detail the impact of manipulations on the stress indicators. To this end, the Moisie River work will be continued, and control fish on fish farm will be subjected to different handling stress levels just before the plasma samples are taken. In addition, the results show that the inorganic aluminum concentrations may vary considerably from year to year. Hence, it seems important to document these variations and their potential impact on the survival of salmon. The Matamek River work will be continued because existing conditions in this river appear to be critical for the salmon. Consideration could be given to implementing projects to examine what is actually happening to natural population in the Matamek River.

Aside from carrying out the above activities, the Québec Region has been monitoring the physico-chemical quality of salmon rivers on the North Shore since 1981. Through this monitoring effort, it has been determined that these rivers are extremely sensitive to acid precipitation. In 1987, the International Council for the Exploration of the Sea (ICES) prepared a document describing salmon habitats in Canada that were vulnerable to acidification and those that were already beyond help. The area of the habitat in the province of Québec was, however, greatly underestimated, at 3 km^2. Since the data were incomplete and the chemical status of many of the rivers was not known, sampling of the 51 salmon rivers on the North Shore was undertaken in 1989-1990. The Québec Department of Recreation, Fish and Game for its part, evaluated the area of all accessible North Shore salmon habitats by photo interpretation.

The finding show that salmon rivers cover an area of 275.3 km^2, of which 223.8 km^2 (over 80%) is considered vulnerable to acidification according to the ICES' vulnerability criterion, which is 50 µeq/l $CaCO_3$ weighted by flow. From these results, it is also appear that habitats suitable for salmon that are not vulnerable to acidification are found in only a small number of rivers, particularly the Moisie River, which alone accounts for 85% of non-vulnerable habitat (Table 1).

These results clearly point to the limited buffering capacity of the habitat in North Shore salmon rivers and the significant potential impact on salmon of anthropogenic acidification.

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Lacroix, G. L. and D. R. Townsend. 1987. Responses of juvenile atlantic salmon (Salmo salar) to episodic increases in acidity of Nova Scotia rivers. Can. J. Fish. Aquat. Sci. 44: 1475-1484.

Table 1. Proportion of total salmon habitat and mean alkalinity (weighted by flow) of salmon rivers on the North Shore.

name	% total habitat	Alkalinity (μeq/l $CaCO_3$)	name	% total habitat	Alkalinity (μeq/l $CaCO_3$)
Mingan	3.31	-	Watshishou	1.23	34.63
Musquaro	2.46	-7.23	Au Saumon	0.15	35.12
Bouleau	0.05	-3.42	Au Tonnerre	-	36.99
Kegaska	1.55	0.34	Nabisipi	2.11	38.66
Petite Watshishou	0.33	2.24	St-Paul	4.89	38.78
Musquanousse	2.87	3.21	Jupitagon	0.55	38.89
Corneille	0.05	4.81	Aux Anglais	0.001	39.04
Coacoachou	0.15	7.34	Godbout	1.62	39.89
Washicoutai	0.00	7.86	Romaine	9.05	40.32
Matamek	0.03	9.19	De la Trinité	1.00	40.66
Pigou	0.01	11.65	Aguanus	0.40	40.70
Checatica	0.001	12.59	Natashquan	31.29	41.62
Gros Mecatina	0.41	12.88	Du Calumet	0.01	42.49
Belles Amours	0.00	14.05	Mistassini	0.02	42.68
Veco	0.34	14.74	Petite Trinité	0.004	46.47
Sheldrake	-	15.97	St-Jean	3.52	46.61
Aux Rochers	1.86	17.02	Coxipi	0.51	49.05
Piashti	0.10	18.43	Netagamiou	0.09	50.72
Olomane	7.00	19.87	Napetipi	0.02	52.56
Etamaniou	2.12	24.23	Petit Mecatina	1.38	55.50
St-Augustin N.-O.	1.86	26.41	Magpie	0.000	61.03
Kecarpoui	0.004	29.14	Brador	0.02	68.77
St-Augustin	10.49	29.75	Escoumin	0.07	91.67
Vieux Fort	0.40	31.34	Moisie	6.50	96.27
Franquelin	0.003	33.82	Laval	0.19	100.39

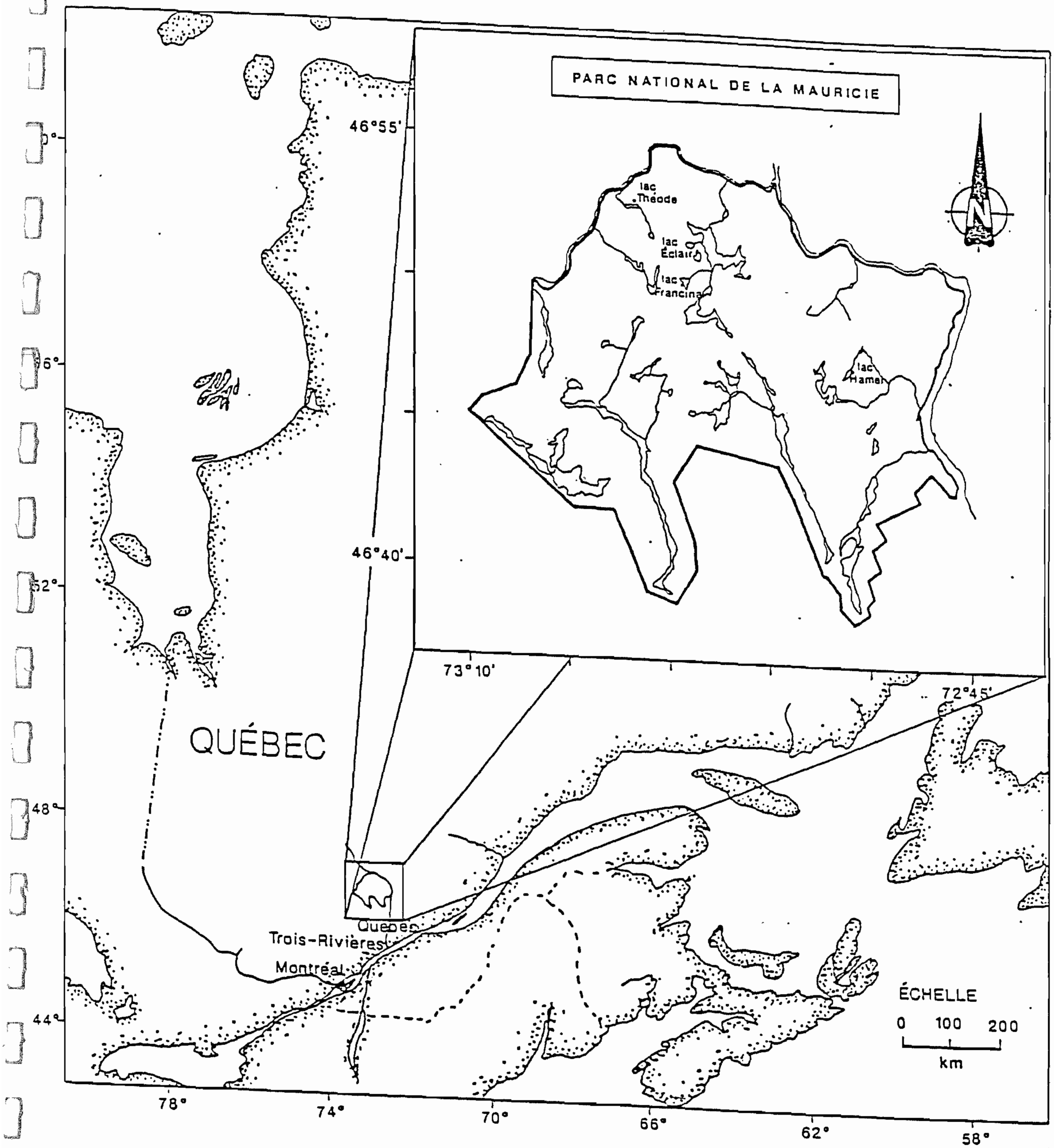


Figure 1. Map of province of Québec showing location of La Mauricie National Parc and the study lakes for the Biomonitoring Program.

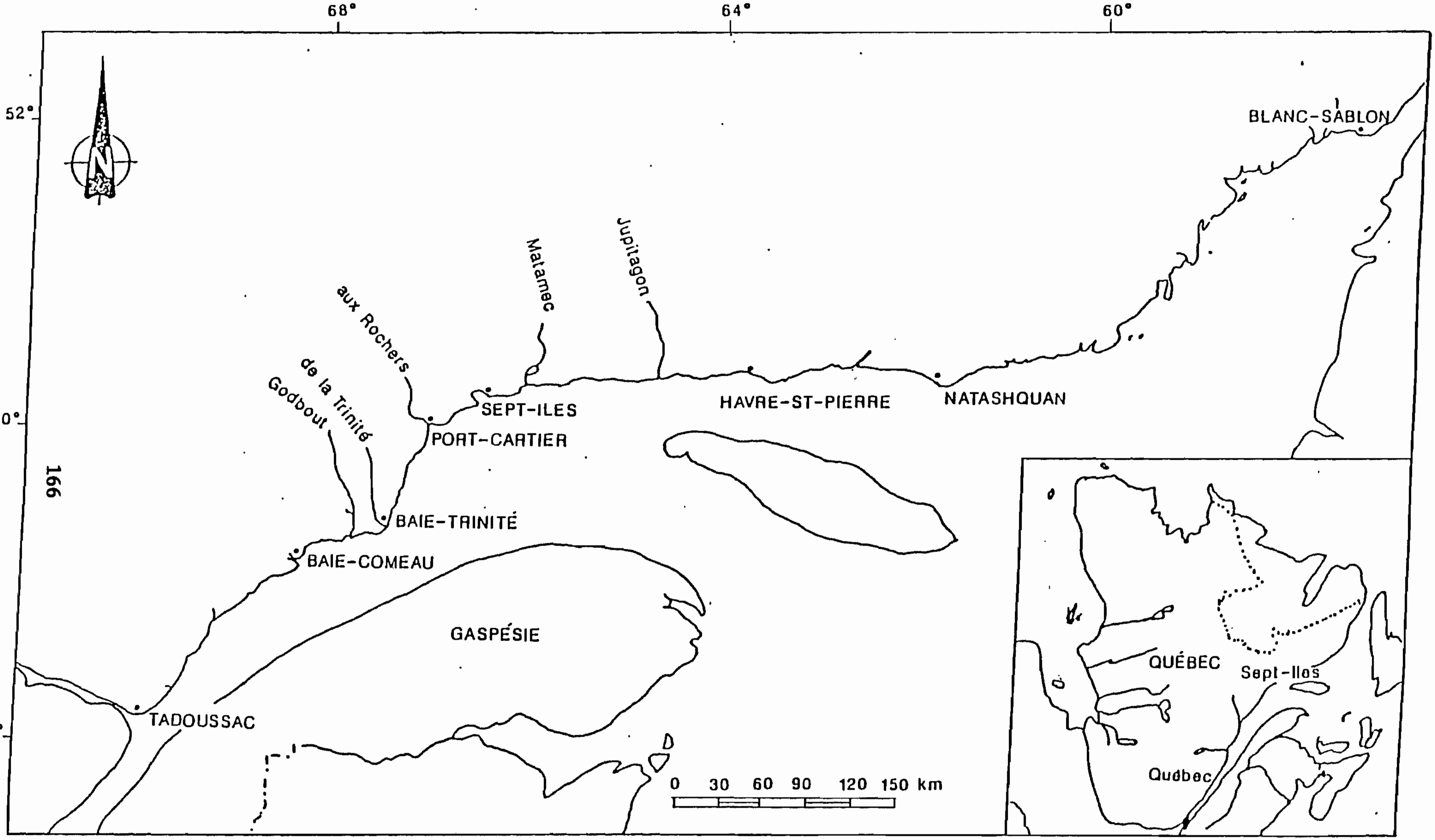
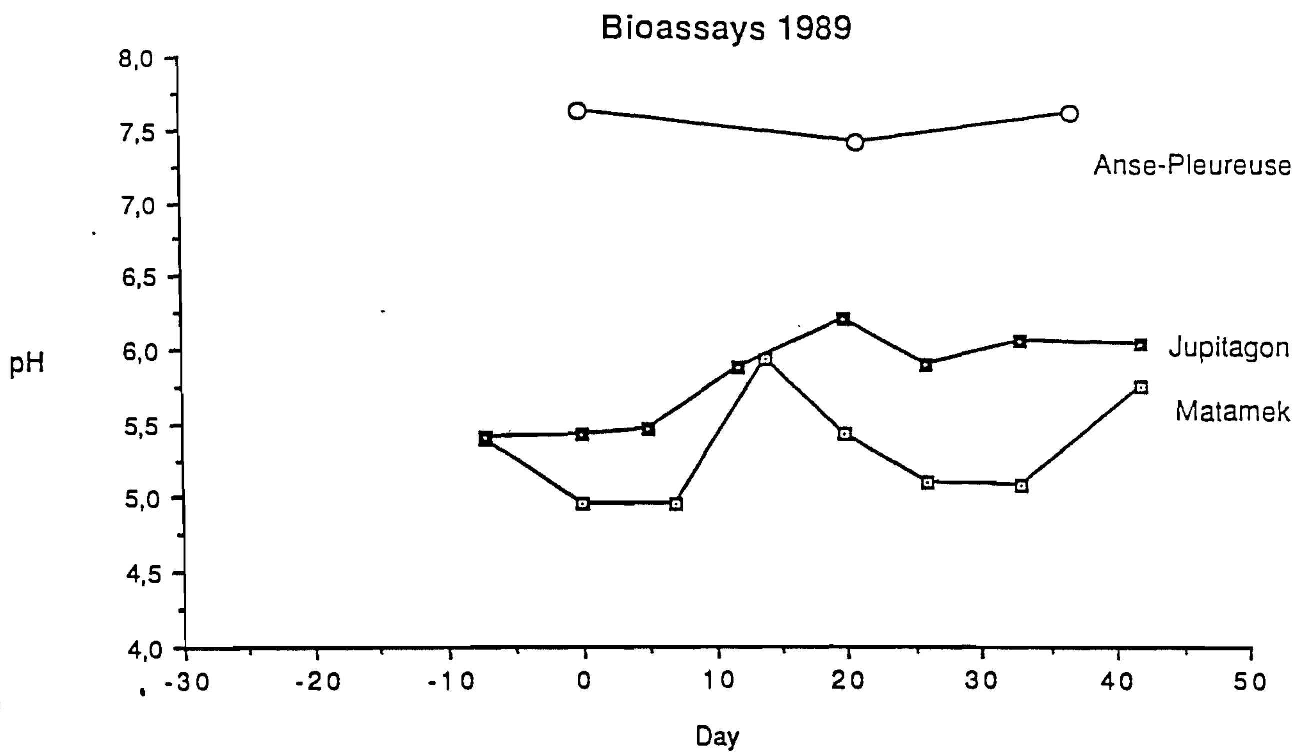


Figure 2. Location of study strems for the Biomonitoring Program.



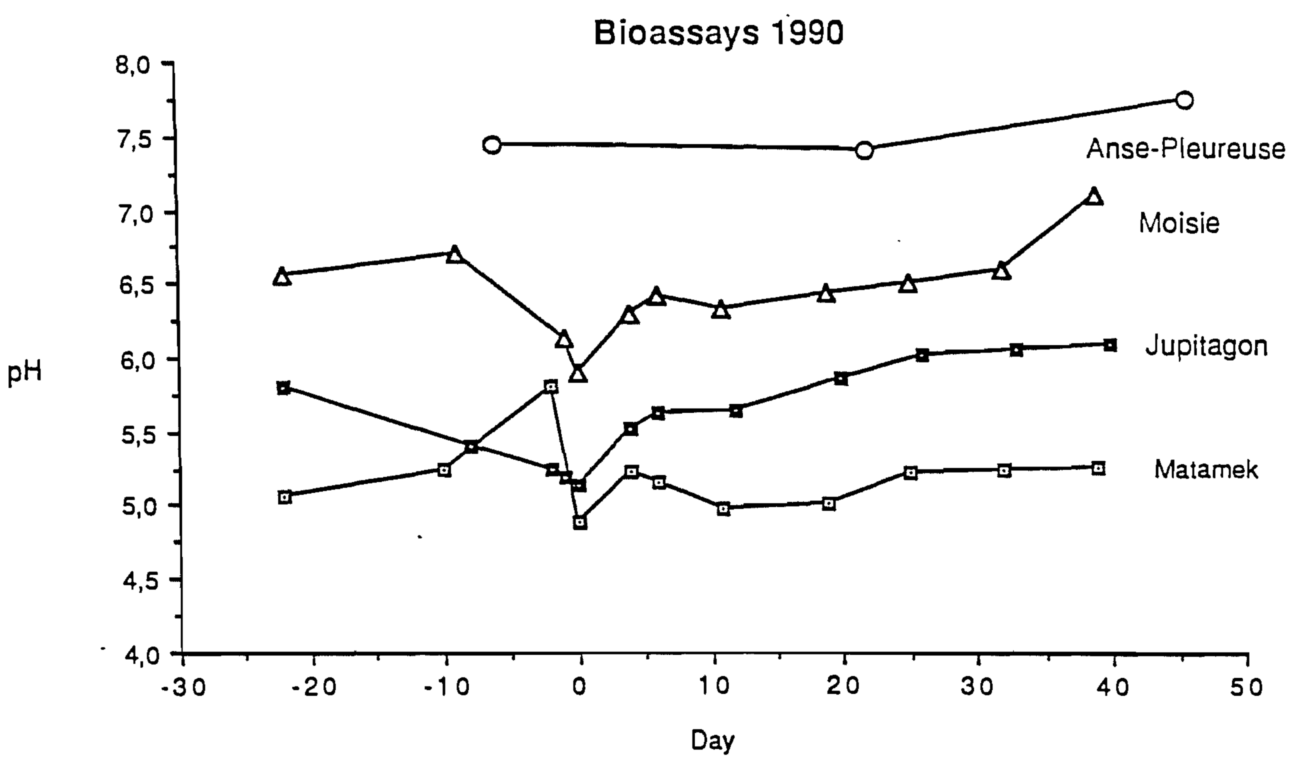


Figure 3. Evolution of pH during bioassays in 1989 and 1990.

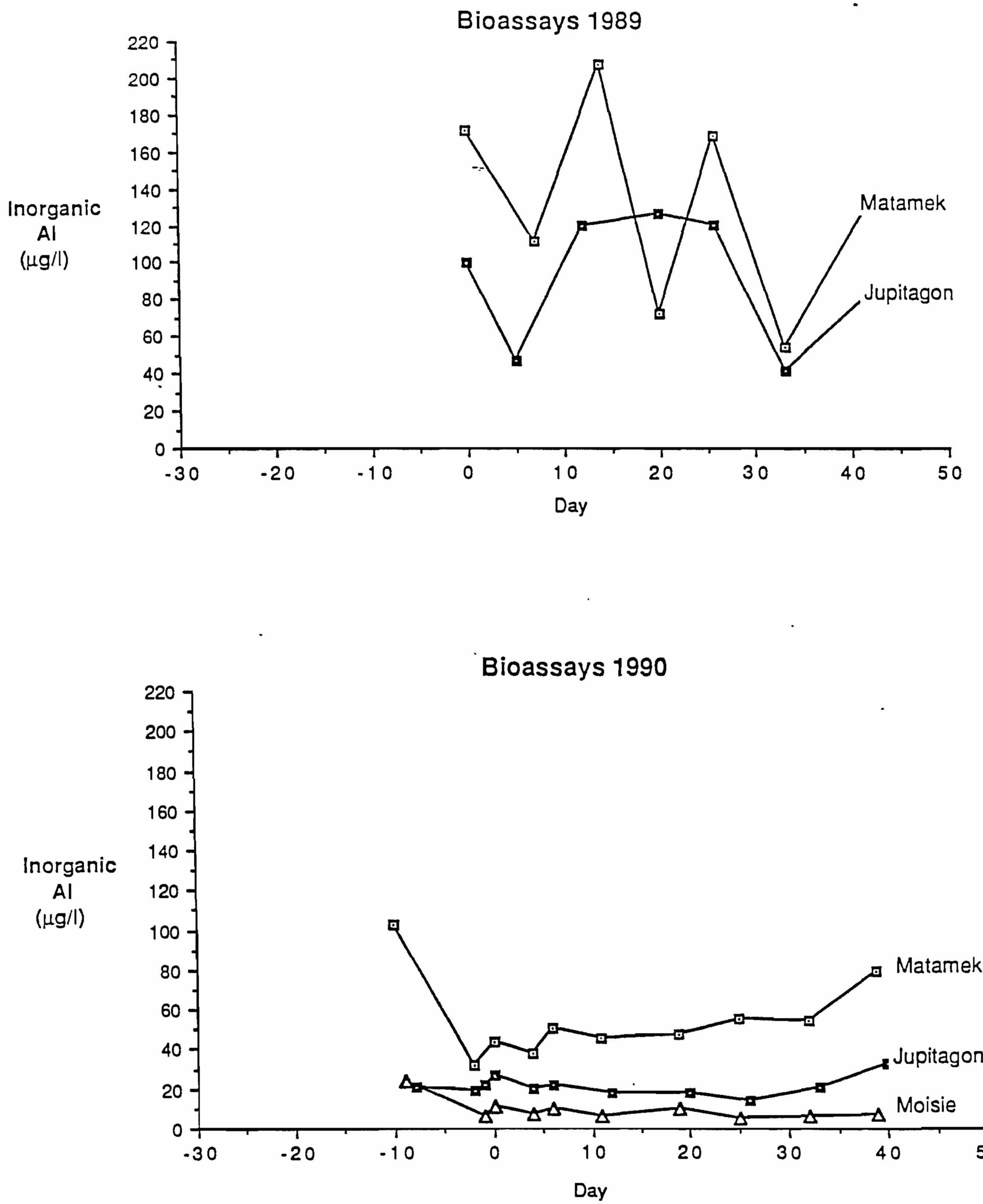
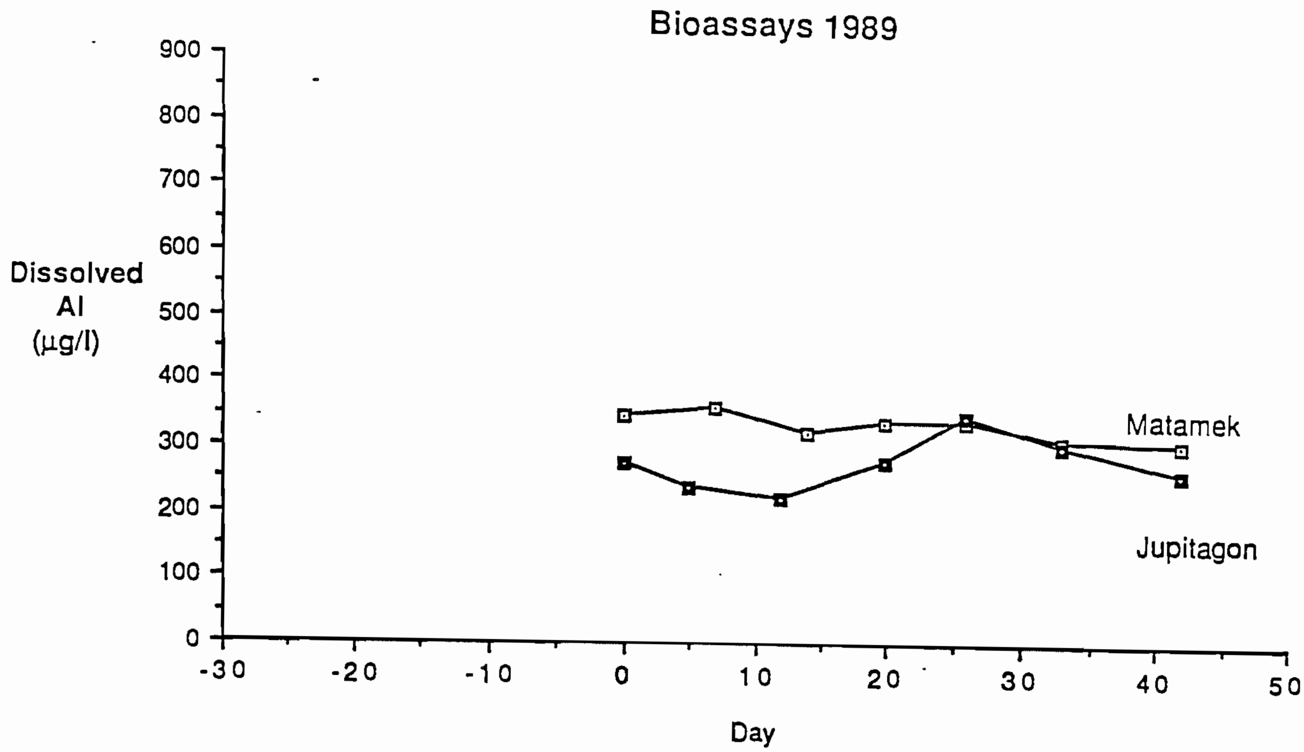


Figure 4. Evolution of inorganic aluminum during bioassays in 1989 and 1990.



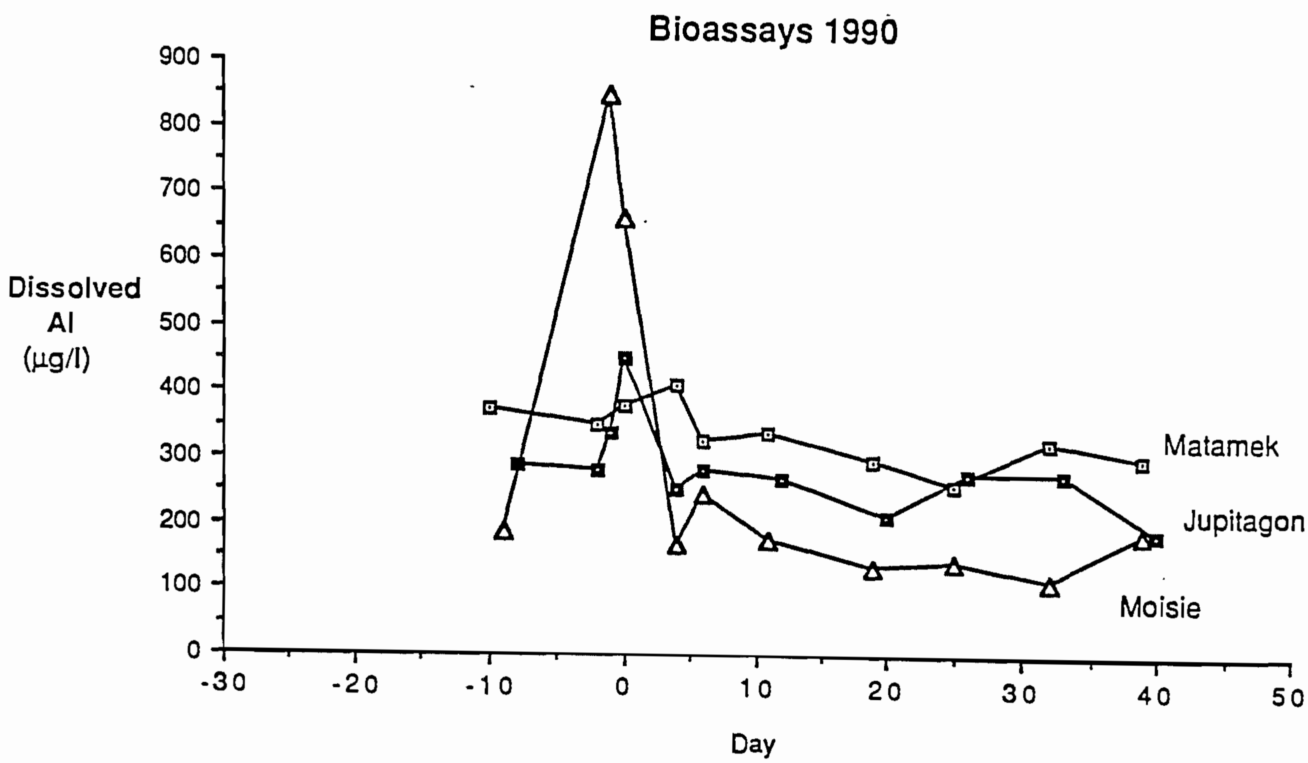
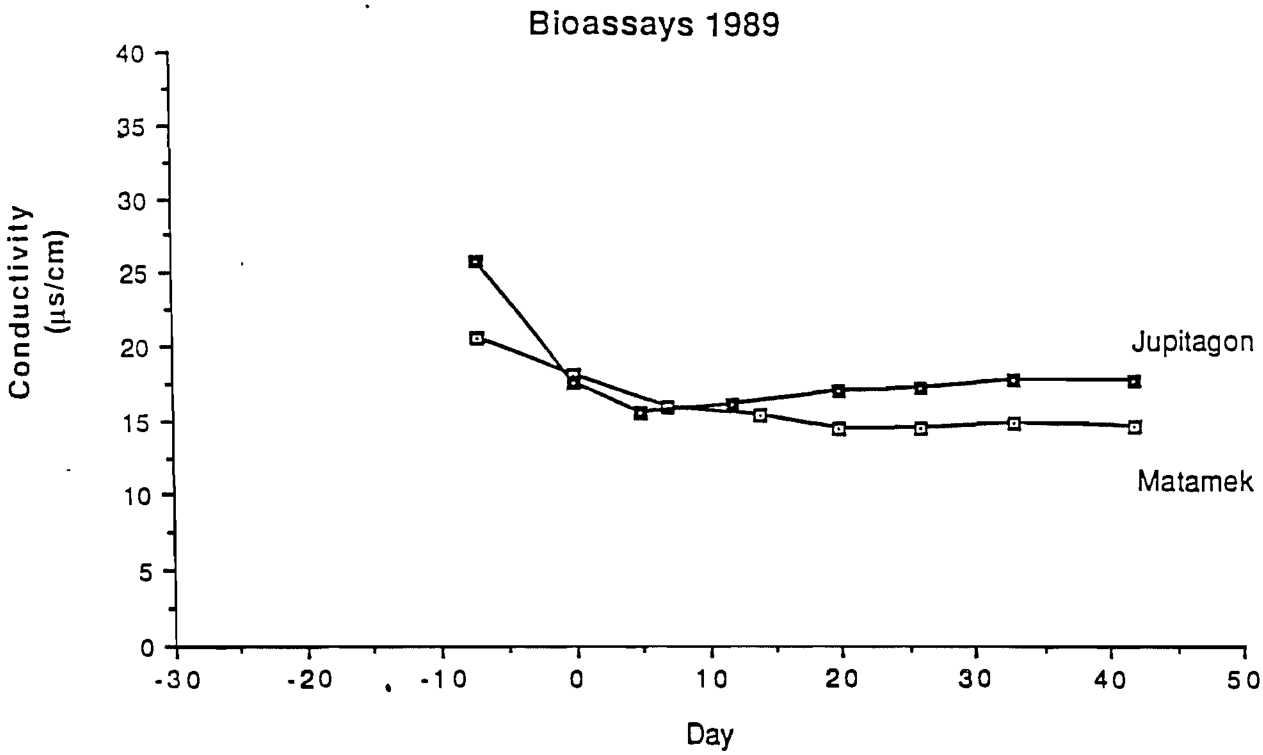


Figure 5. Evolution of total dissolved aluminum during bioassays in 1989 and 1990.



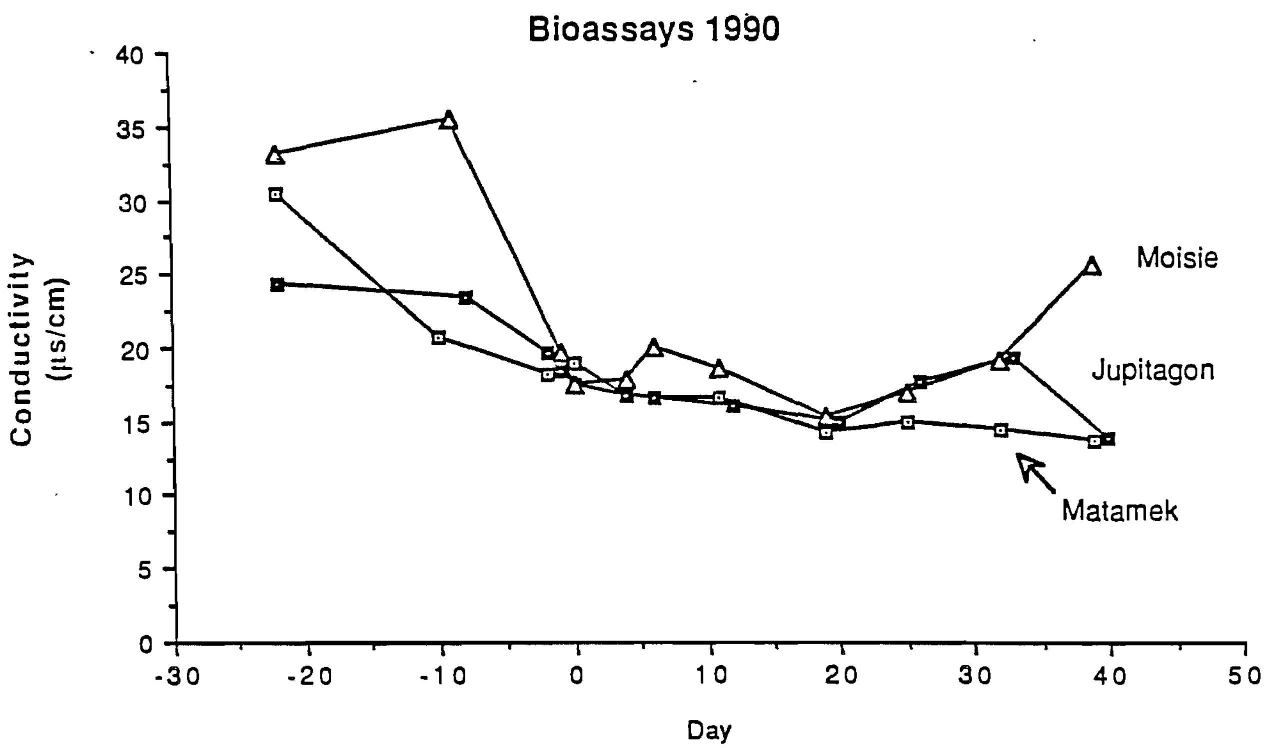
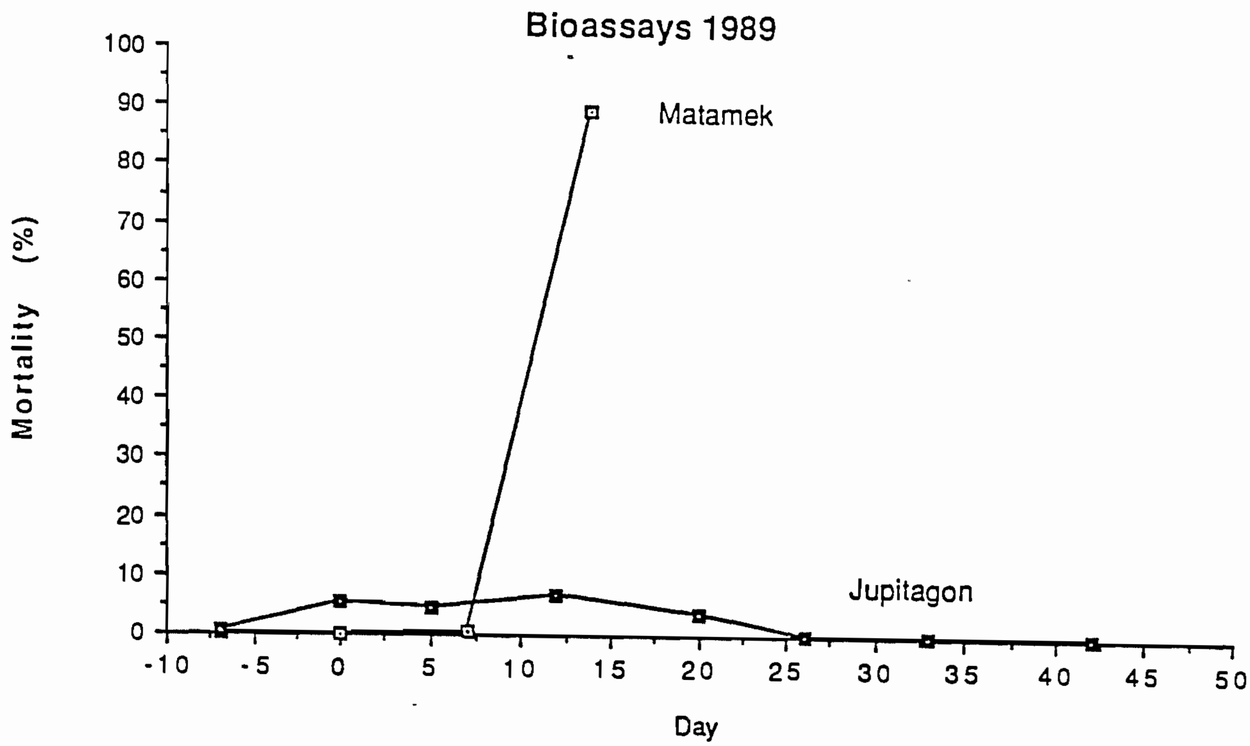


Figure 6. Evolution of conductivity during bioassays in 1989 and 1990.



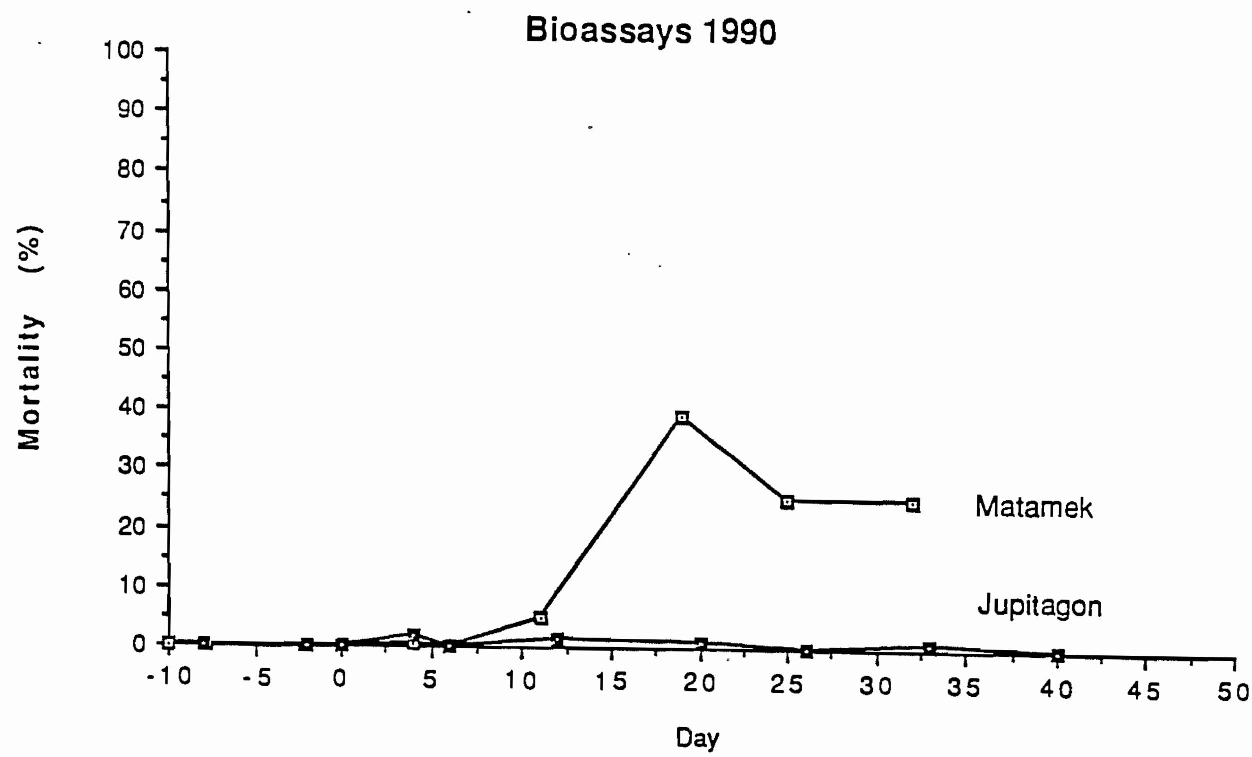
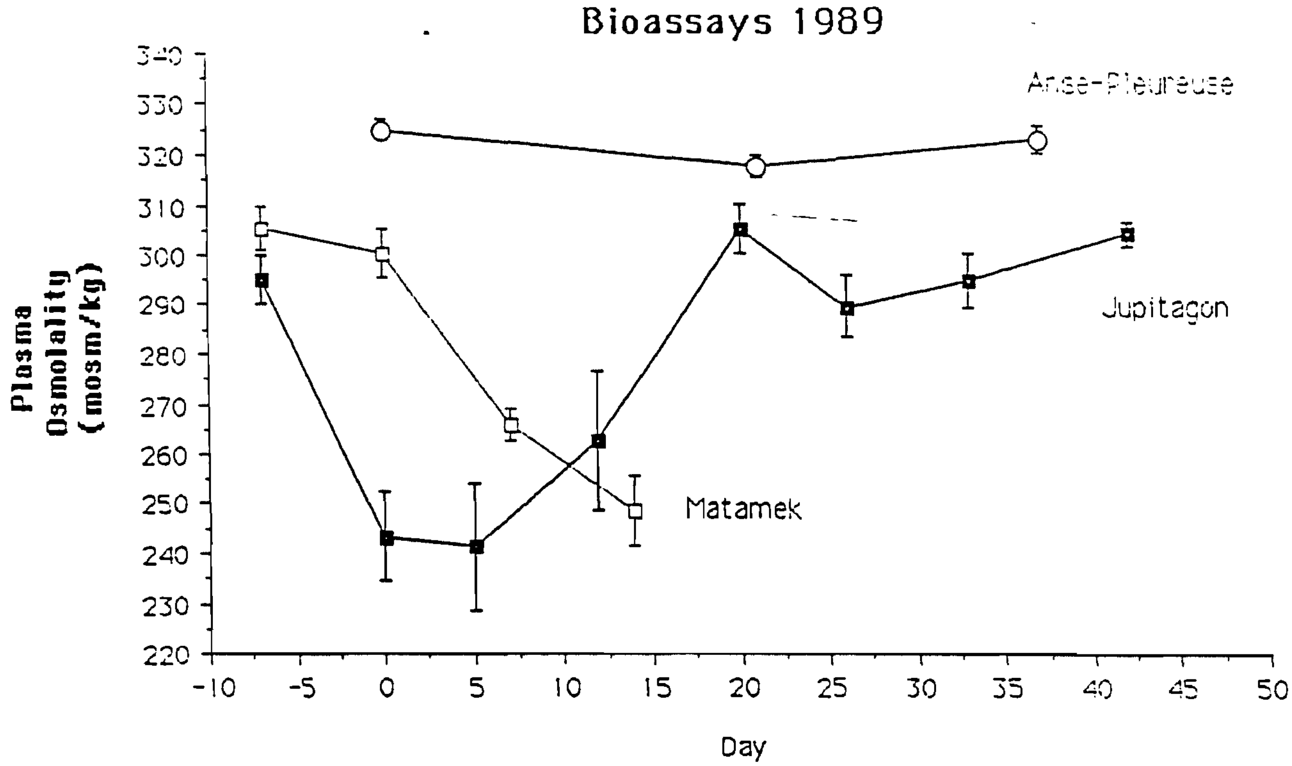


Figure 7. Evolution of mortality during bioassays in 1989 and 1990.



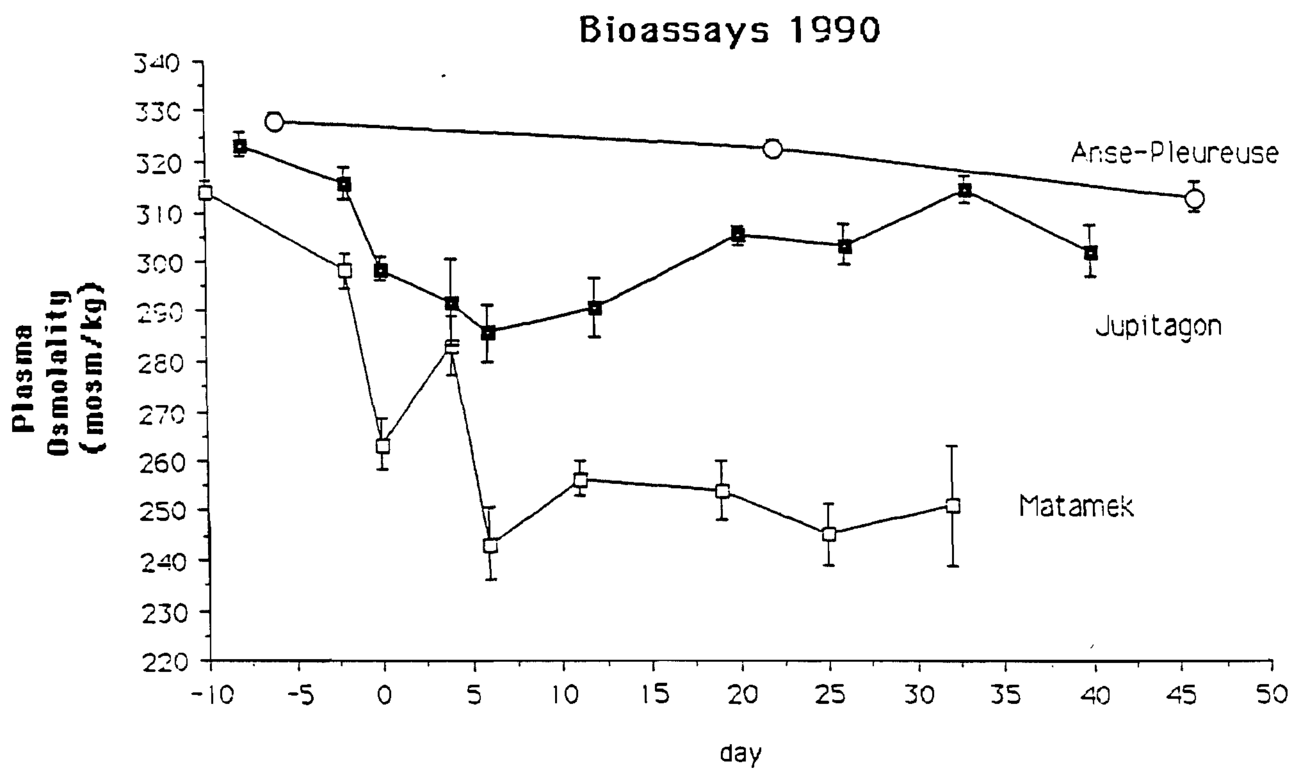
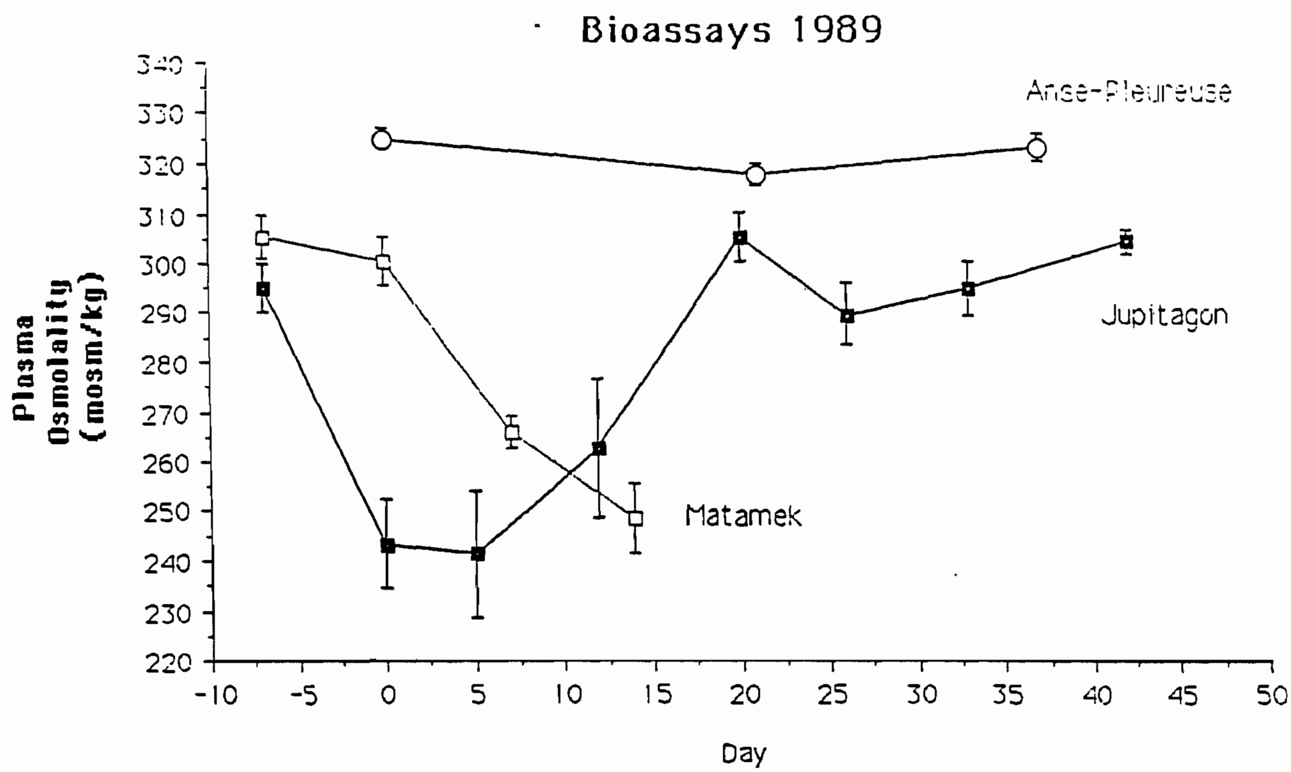


Figure 8. Evolution of plasma osmolality of parrs during bioassays in 1989 and 1990. Vertical bar represents standard-error ($8 \leq n \leq 11$).



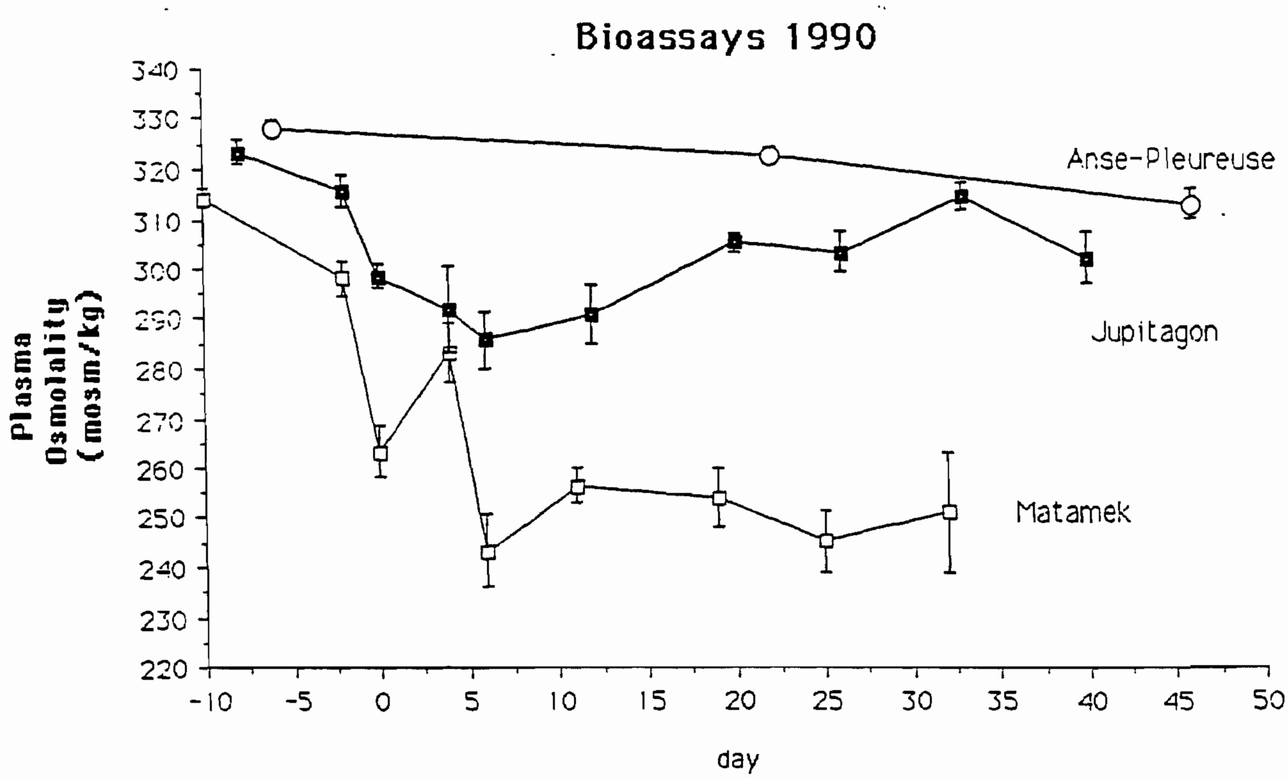


Figure 8. Evolution of plasma osmolality of parrs during bioassays in 1989 and 1990. Vertical bar represents standard-error ($8 \leq n \leq 11$).

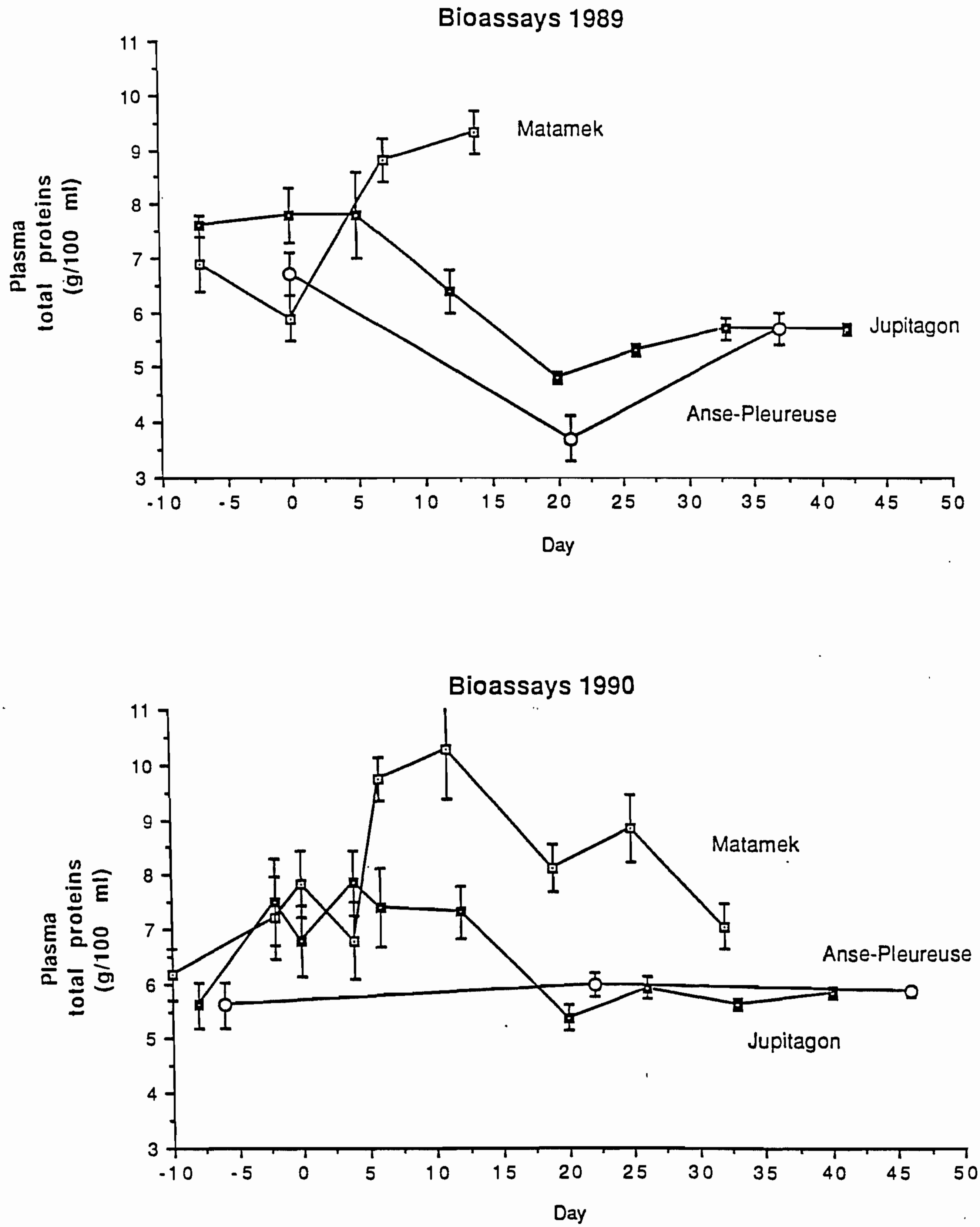


Figure 9. Evolution of plasma total proteins during bioassays in 1989 and 1990. Vertical bar represents standard-error ($8 \leq n \leq 11$).

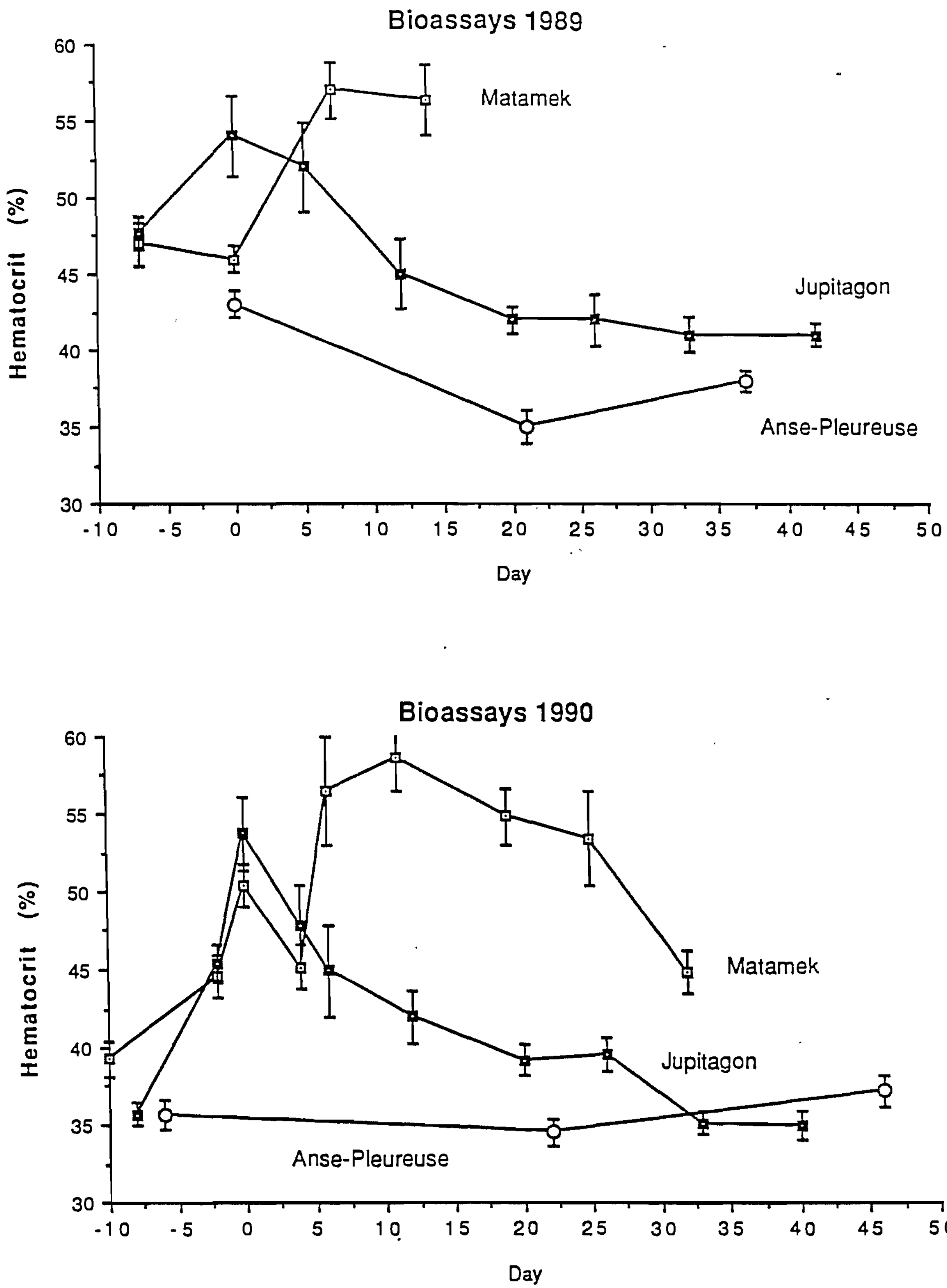
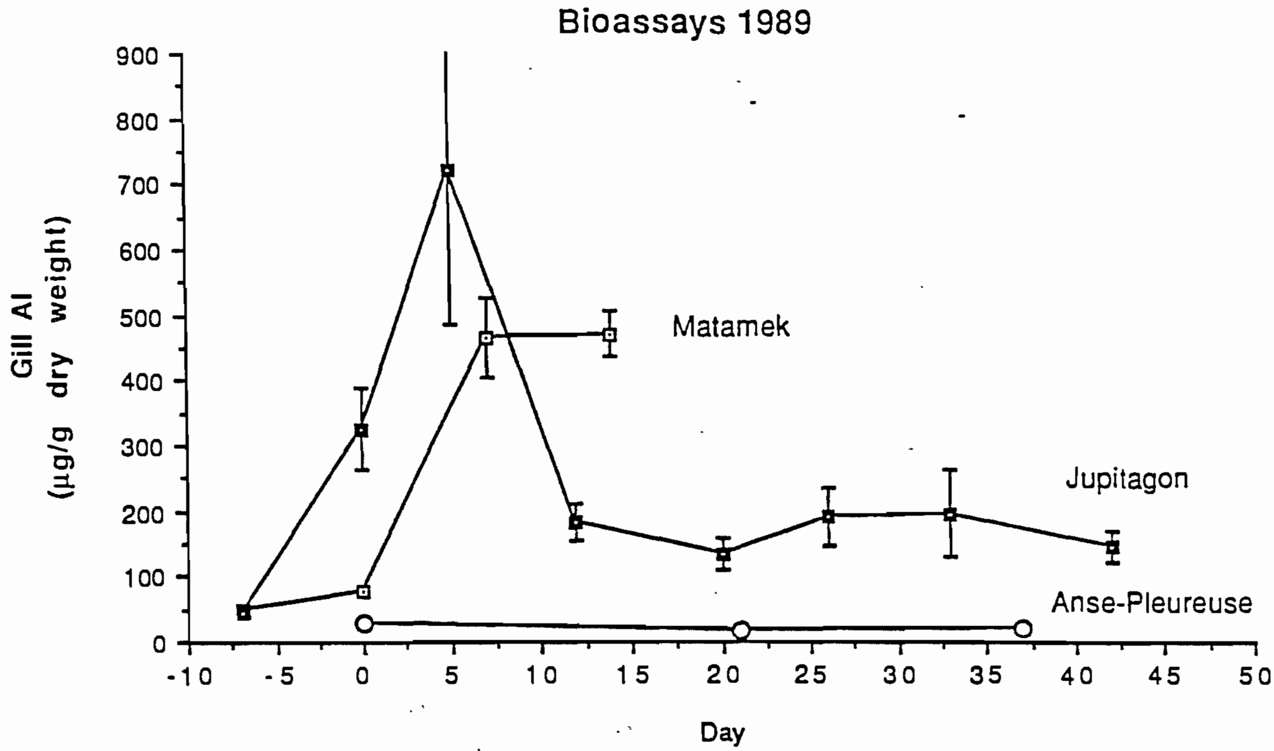


Figure 10. Evolution of hematocrit during bioassays in 1989 and 1990. Vertical bar represents standard-error ($8 \leq n \leq 11$).



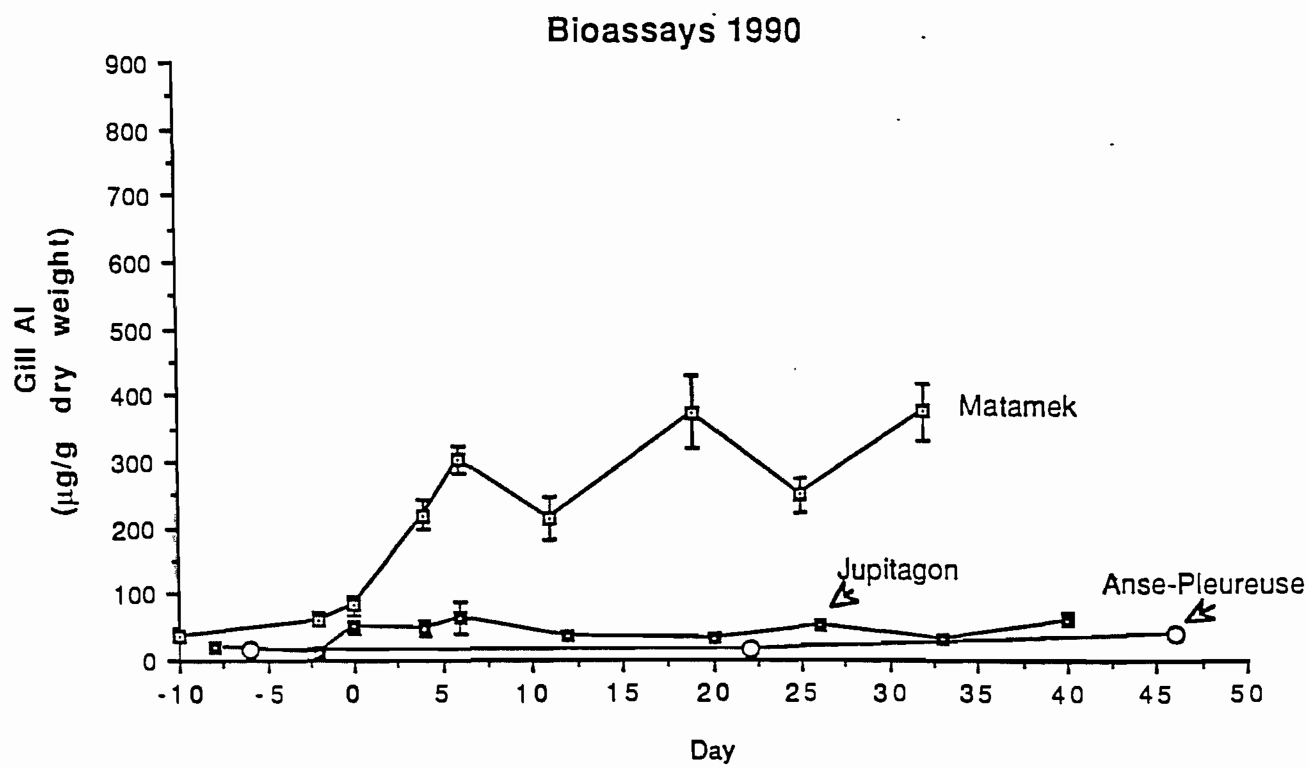


Figure 11. Evolution of gill aluminum during bioassays in 1989 and 1990. Vertical bar represents standard-error ($8 \leq n \leq 11$).

BIOLOGICAL EFFECTS MONITORING IN SCOTIA-FUNDY: 1990 REGIONAL REPORT

JUVENILE SALMONID POPULATION MONITORING

W.J. White and P.J. Zamora

A survey of the distribution of Atlantic salmon and brook trout in acidified rivers along the Atlantic coast of Nova Scotia, which was started in 1982, was continued in 1990. Rivers in the pH range 4.7 to 5.4 are electrofished annually. All of the rivers included in the survey have supported salmon in the past.

Juvenile salmon appear to be absent from three of the eleven rivers included in the survey. The pH in the rivers in which salmon are not found is less than 5.0. Brook trout are not found in three rivers, but since two of these supported the more acid sensitive salmon, the absence of trout in these rivers is not attributed to low pH.

Juvenile salmon have not been found since 1988 in Middle River Chester, a river where they were found in most previous years. It is too early to conclude that the biomonitoring program has documented an extinction event in this river. Monitoring will be continued in this river.

FISH POPULATION STUDIES IN THE KEJIMKUJIK LAKES

W.J. White and S.E. Barbour

The third year of this study has just been completed. The method is working well. Catches have been found to be very variable and it is felt that representatives of almost all species present have been recorded. Lake whitefish are present in Cobrielle Lake from immigration from adjoining Mountain Lake, but none have been captured by us to date.

Blood samples have been taken from white perch and yellow perch this summer in a pilot study of indicators of acid stress in these species. Differences exist between the species haematocrit levels but further study is required to establish relationships to the environment.

We are tagging speckled trout for Parks Canada as a co-operative venture. Mark - recapture estimates may be possible at some future date. A ban has been placed on sports fishing in Cobrielle Lake and some other park lakes where research and long term programs are being carried out in order to reduce visitor disturbance.

INVERTEBRATE COMMUNITY STRUCTURE IN NOVA SCOTIA SOUTH SHORE RIVERS AND THE KEJIMKUJIK LAKES

N.H.F. Watson and E.A. Hamilton

Field sampling at all river and lake sites has been carried out according to the biomonitoring protocols. Five rivers, the Roseway, Medway, LaHave, Gold, and Canaan were sampled at approximately 10 week intervals in spring, mid-summer, and early fall. Three Kejimkujik Park lakes, Cobrielle, Big Dam East, and Big Dam West were sampled twice, once in spring and once in early fall. During these periods exercises to compare operator efficiency with various gear were carried out.

We have carried out a preliminary assessment of results from invertebrate sampling from the three Kejimkujik lakes using data from autumn 1987 sampling. Most taxa are found in all three lakes but there initially appear to be individual differences in species assemblages, most obviously related to water clarity and colour, rather than to mean pH or physical interconnection.

The two clear water lakes, Cobrielle and Big Dam East, have a slightly greater number of taxa and share more taxa with each other than with Big Dam West Lake. It remains to be seen if these differences stand up after more sampling and analysis has been completed.

Laboratory analysis continued both in-house and by contract. A set of type specimens has been identified representing 150+ forms found in samples examined to date. These are to be sent off for confirmation in the near future. One interesting aspect of this is the apparent differences between some of our common species and those observed by Peterson in an earlier survey of the area. If the differences do turn out to be real, as we think they are, it may indicate that apparently dramatic changes may occur in the abundance of some species in a short time.

We have developed and are testing a database in dBaseIV software which seems to meet our needs for a flexible approach to working with a data set where individuals may need to be enumerated at varying levels of taxonomic specificity. Data from samples are being loaded and test calculations are underway.

We have been collaborating with Dr. Raj Misra in his efforts to produce a general statistical treatment to deal with multivariate data sets and time series. He has tested his methodology with a subset of our data from the Canaan River running from Fall 1987 to fall 1989 and is satisfied with the results.

CAGED FISH BIOASSAYS

Stephen E. Barbour

Introduction

The Long Range Transport of Atmospheric Pollution Biological Effects Monitoring (LRTAP-BEM) program caged fish study is designed to demonstrate the lethality of the chronic acidification of the waters of southwestern Nova Scotia to fish and to monitor impacts on fish over the long-term. The study was initiated in the Scotia-Fundy Region in 1988 and continued in 1989. The study animal was the Atlantic salmon, *Salmo salar* L., which is the major economic anadromous species in the region and is limited in its juvenile stages by the availability of suitable freshwater habitat. This species is under threat from acidification in southwestern Nova Scotia rivers. The period of study was planned to be November-December in each year as this is the period of greatest pH depression in the study areas. Five rivers were proposed for biomonitoring - Roseway, Lahave, Gold, East (Chester), and Ingram. These selections were modified in 1989 with the resulting list becoming the Carlton, Clyde, Roseway, Canaan, East, Ingram and Avon rivers (Figure 1). The East River is the site of the LRTAP experimental liming program. The Carlton and Avon rivers are used as natural control rivers.

The objective in the first two years was to finalize the study design, to design, build and prove a cage prototype, deploy the cages and implement the actual study. In 1989 a blood sampling program was initiated to detect stress in fish caged in sub-lethal conditions.

Methods

Three rivers were monitored in 1988; the East, Canaan (tributary to the East), and Gold. In 1989 the Gold River was replaced by the Ingram River and the Avon River was added as a high pH control. The twelve fish cages were deployed in pairs with the limed cages always downstream of unlimed cages. This provided the study with a simple statistical design with replicates and controls to demonstrate that water quality is the dominant factor in the bioassay.

The fish cages (Figure 2) were designed to recreate the preferred physical habitat of juvenile Atlantic salmon in order to reduce any stress, other than water quality, on the test animals. Data from Morantz *et. al.* 1987 were used to specify water velocity (no greater than 20 cm/sec.), depth (minimum 20 cm.), and cover (solid, in winter salmon parr prefer to hide) within the test chamber. In practice, the forward test chamber was omitted because of excessive turbulence, while the environment in the aft chamber was easily controlled because of the damping effects of the structures in the centre of the cage. In 1989 the forward chamber was fitted with longitudinal baffles in order to straighten the flow and allow measurement of the water current. Four cobble stones (~10 X 10 X 8 cm.) were placed in each aft chamber in order to break up laminar flow and allow selection of velocities by the fish.

The structures in the centre of each cage were designed to damp water flow through the cage and to contain gravel of a chosen composition in order to add experimental control to the study design. The cages were deployed as pairs, with the central container filled with river substrate gravel in the ambient cage, and with limestone gravel (commercial marble chips) in the limed cage. The idea was to create a control microenvironment which would further demonstrate that pH was impacting the study animals.

Twenty-five salmon fry (30 in 1989), in a size range 5 - 15 cm. fork length, were placed in the aft test chamber of each cage. The fish were randomly selected from Lahave River stock from hatchery pools at Mersey River Fish Culture Station.

In 1988, the cages were deployed in the Canaan and East Rivers during the first week of November and in the Gold River in mid-November. The study was terminated on January 4, 1989. In 1989, the study was started in late October and terminated in late December in order to avoid the excessive ice conditions which often occur in January.

The cages were tended daily except for the occasional occurrence of severe weather. The routine at each site began with the in situ measurement of pH (with a Metrohm model E588 glass electrode pH meter) in the aft chamber of the first cage. A water sample was taken and then the condition of the fish was noted. The cage located furthest downstream was always tended first, with the worker moving upstream to the next cage until all four were done. The movement of the worker from downstream to upstream avoided contamination of water samples by debris stirred up by the wading of the worker. A water sample of river water was taken upstream of the cages.

In 1989, daily pH measurements for each cage were made in the laboratory on the same day water was sampled. This avoided freezing of the electrode which occurred in 1988 and spoiled some of our measurements.

After the initial round of sampling, a second round tended to the removal and measurement of mortalities, the cleaning of the gravel in the chambers, and the reading of the water temperature from a thermograph installed in one of the cages. Death of fish was ascertained from the absence of opercular movement, lack of response to a pinch of the tail, and lack of movement when dipped out by the attendant. Moribund fish were left in the cage and were always found to be dead by the following day, at which time they were tallied.

A pilot study of stress indicators in fish blood was initiated in 1989. Ten fish were sacrificed from each study group. Blood was collected in a tuberculin syringe by puncturing the dorsal aorta from just behind the anal fin. The blood was gently extruded from the syringe into as many micro-haematocrit tubes as it would fill. The tubes were centrifuged for 5 minutes at 3000 rpm and data collected using a haematocrit reader. Plasma was obtained by breaking the tubes near the phase change and extruding the plasma phase into a micro test tube. Sodium values were obtained by atomic absorption spectrophotometry on appropriately diluted samples.

Results

In 1988 the study was conducted over a period of 57 days in the Canaan and East rivers and 49 days in the Gold River. The temperature ranged between 8°C. early in the study to 2°C. in the Canaan and East rivers. The Gold River ranged from 6°C. to nearly 0°C. The temperatures near 0°C. caused great difficulty due to freezing, which caused minor damage to the cages and impeded access to the fish. The cold air temperatures resulted in aberrant pH readings, probably because the meter became too cold and at certain times the electrode froze. A comparison of the field data to laboratory pH data from the stored water samples resulted in the choice of the latter for presentation in this report.

In 1989 the study was conducted over a period of 57 days in the Canaan, East and Ingram rivers and 59 days in the Avon River. The temperature ranged between 10°C. early in the study to 2°C. in the East River. The Canaan Ingram and Avon rivers ranged from 9°C. to nearly 0°C.

Figure 3 compares data for the ambient and limed cages in the Canaan river in 1989. The values from the limed cages often differ from those from the ambient cages. The limed values were usually the same or slightly higher than the pH values in the ambient cages. The occasional large differences are all of higher pH. Before Julian day 315 (November 11) the limed cage pH values were obviously higher than in the ambient cages. This was a period of drier weather with low river flows. The residence time of the water around the limestone gravel was probably greatly increased, allowing a greater effect on the water chemistry.

Comparisons of the pH curves in the ambient cages among four of the rivers in 1989 are presented in Figure 4 and simple statistics for all rivers in both years in Table 1. The values in the Canaan River were always below 5.1 while in the Ingram River they were always above 4.7 and were usually above 5.0. The Avon River showed major changes in pH. Early and late in the project the pH was near 5.5 or better but during the middle part of the project the pH was closer to 5.3. In the East River the pH was always greater than 6.2.

The mortality of salmon fry in the bioassay is summarized in Tables 2 and 3. There was no mortality in any of the cages in the Gold, Avon or East rivers and negligible mortality in the Ingram River (a single fish). The pH in these rivers did not fall below 4.78. This provides ample evidence that the fish cage design was adequate for the successful maintenance of the experimental animals.

There was significant mortality in the cages of the Canaan River, where the pH was less than 4.8 in 1988 and less than 4.9 in 1989. There was a significant (Chi squared, $p < .01$) difference between the mortality of fish in the limed and ambient cages. The slight (Table 2) difference between the mortalities in the two ambient cages was not statistically significant ($p > .25$).

A probability plot of the time to death of lumped mortality data for the ambient fish cages in both years is given in Figure 5. The plots are strongly curved, which demonstrates that the data are not normally distributed. Data transformations did not improve the fit to normality. This suggests that the mortality was a result of the cumulative effect of a chronic stressing factor, which eventually reached a threshold after which the fish succumbed.

The time to fifty percent mortality of the test population (LT50) in the ambient cages was 50 days in 1988 and 53 days in 1989 (Figure 5). This is slightly to the right of the intersection of the probability curve with the midpoint of the y-axis because surviving fish were included in the calculation of the LT50.

The surviving fishes in both the ambient and limed cages in the Canaan River were superficially examined for state of health. They were generally lethargic and weak. They were pale brown dorsally with obvious parr marks, a colour pattern normally associated with sub-dominant (stressed?) salmon parr. In contrast, fish from the cages in the Gold River and East River were active and strong (difficult to catch with dip nets), and darker coloured with more subtle parr marks. All fish were thin since they had not been fed since their removal from the fish culture station.

Caged fish haematocrit and plasma sodium levels varied among rivers (Figure 6). The rank order of haematocrit levels was highest in the Canaan River, then the Avon, the Ingram, and lowest in the East River. The rank order of plasma sodium was reversed. Variation was greatest in the two intermediate rivers.

Discussion

The pH curves for all the rivers in both years followed the usual episodic seasonal pattern for southwestern Nova Scotia (Watt 1981) of a rapid decline with the onset of autumn rains, followed by a gradual increase as freezing began and the proportion of groundwater in the river flow rose.

The pH of the water in the limed cages was consistently higher than in the ambient cages. The increase tended to be about .05 pH units and yet this was enough to significantly alter the time to mortality of Atlantic salmon fry in the Canaan River. There could be no effect demonstrated in the Gold, Ingram, Avon or East rivers since there was no, or little, mortality in any of the cages. Mortality did occur in the limed cages in the Canaan River and, from the appearance of the fish, it was clear that they were stressed. There is no doubt, however, that the cage limestone had had an effect on survival, and limestone substrate may prove a useful tool in helping salmon endure the annual episodes of low pH.

It should be noted that there were peaks of pH recorded in the limed cages and these may possibly have had a mitigating effect on the pH stress. Also, in 1988, the daily cleaning of the gravel may have dosed the fish with calcium fines that were the mitigating factor.

In the pilot study on blood chemistry the rank order of haematocrit values was strongly negatively correlated to the ambient pH. Stressed salmon smolts in acid conditions commonly exhibit increased haematocrit (normal is near 50 and stressed is near 80) (Farmer *et. al.* 1989). Plasma sodium levels were correlated positively with pH, which indicates ion loss in acidic conditions. The variation in both blood values was high in the Ingram and Avon rivers, indicating stress in some individuals in these fish groups where there was virtually no mortality. Variation was low in the East River groups (where the pH was highest), further illustrating that the fish cages were not a source of stress.

Mortality of fish from acidification is thought to occur as a result of a breakdown of the ionoregulatory system in the gills (Wood and McDonald 1982). The fish essentially leak ions to the environment and are unable to pump ions into their systems. This problem is enhanced by low calcium concentrations in the water. The effect of the limed fish cages may have been to increase the available calcium in the water, allowing partial mitigation of the acid stress. The rate of ion leakage may have been slowed, but not stopped, thereby postponing the time of death for the fish being held in otherwise lethal pH conditions.

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Table 1: Statistical description of the pH conditions in the 1988 and 1989 LRTAP - BEM caged fish bioassays.

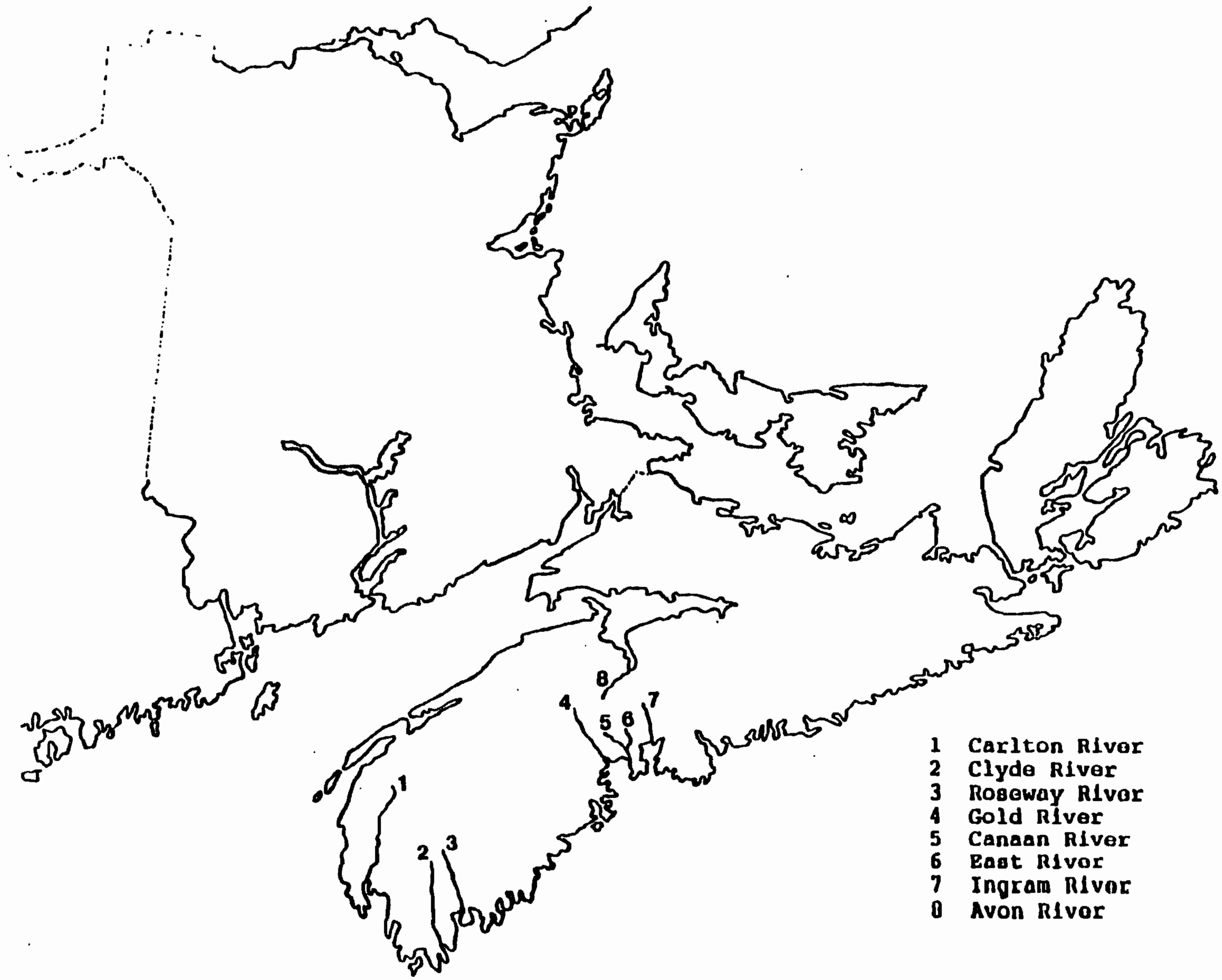
	Ambient water			Limed cages		
	mean	max	min	mean	max	min
1988						
Canaan	4.66	4.72	4.60	4.71	4.95	4.53
Gold	5.05	5.30	4.85	5.09	5.34	4.85
East	5.68	6.10	5.44	5.73	6.10	5.46
1989						
Canaan	4.86	5.10	4.60	4.91	5.42	4.53
Ingram	5.00	5.50	4.78	5.04	5.90	4.82
Avon	5.35	5.82	5.10	-	-	-
East	6.39	6.72	6.20	-	-	-

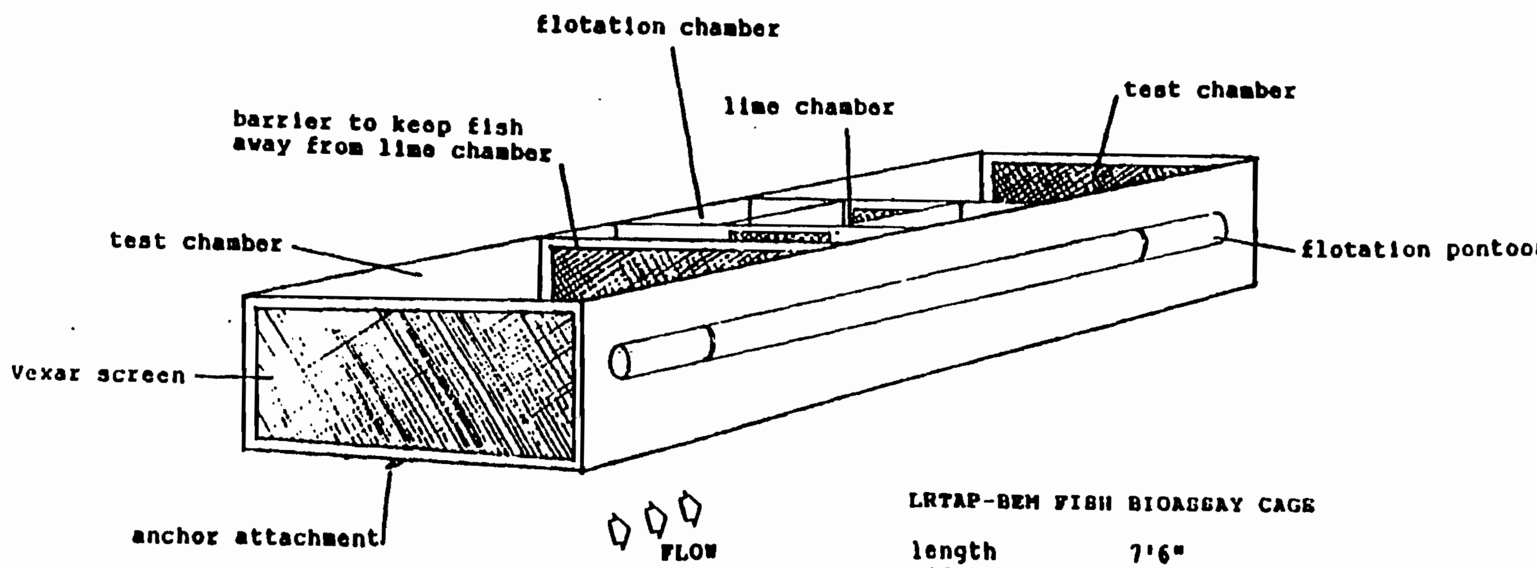
Table 2: Summary of mortality in 1988 and 1989 LRTAP-BEM caged fish bioassays.

	1988			1989		
River	pH	Mortality		pH	Mortality	
Canaan	4.66	ambient	72%	4.86	ambient	60%
		limed	10%		limed	38%
Ingram	-	-		5.00	1 fish (2%)	
Gold	5.05	none		-	-	
Avon	-	-		5.35	none	
East	5.68	none		6.39	none	

Table 3: Mortality data from LRTAP-BEM caged fish bioassays in the Canaan River, Nova Scotia.

		1988			1989		
Cage	Treatment	n	n dead	%	n	n dead	%
1	ambient	25	22	88	30	19	63.3
2	ambient	25	14	56	30	17	56.6
3	limed	26	3	11.5	30	14	46.6
4	limed	25	2	8	30	9	30


1 Carlton River
2 Clyde River
3 Roseway River
4 Gold River
5 Canaan River
6 East River
7 Ingram River
8 Avon River



LRTAP-BEM FISH BIOASSAY CAGE

length	7'6"
width	2'0"
height	1'0"
freeboard	~4"
volume of lime	.66cuft
dimensions of test chambers	3'X 2'X .66'

Figure 2:

Figure 3: Comparison of ambient and limed cage pH

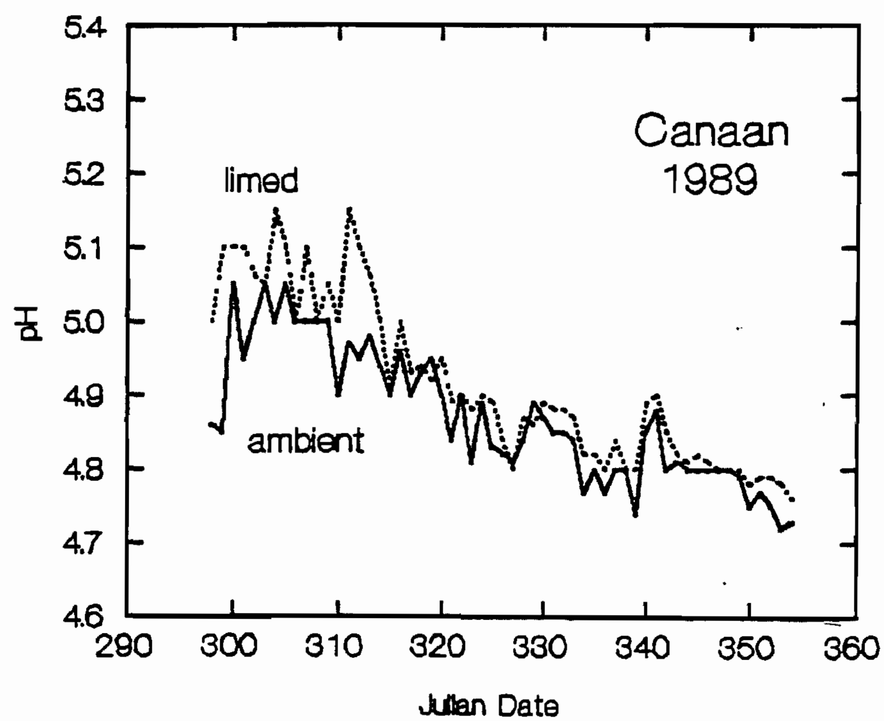


Figure 4: Comparison of ambient pH in four rivers

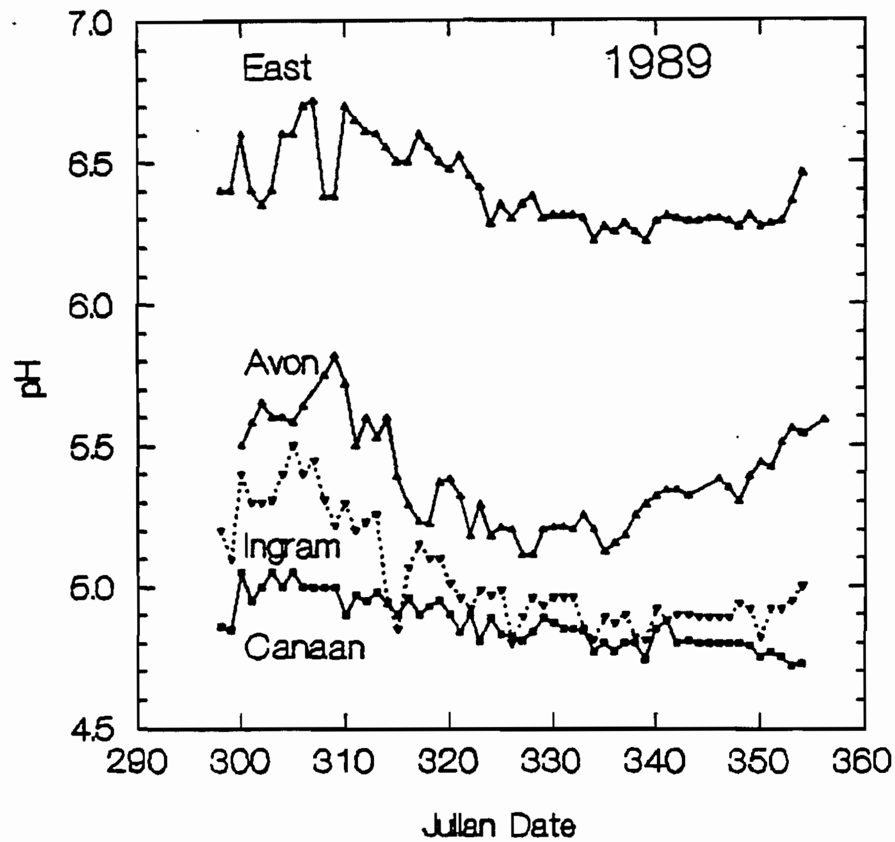


Figure 5: Mortality with time in Canaan River

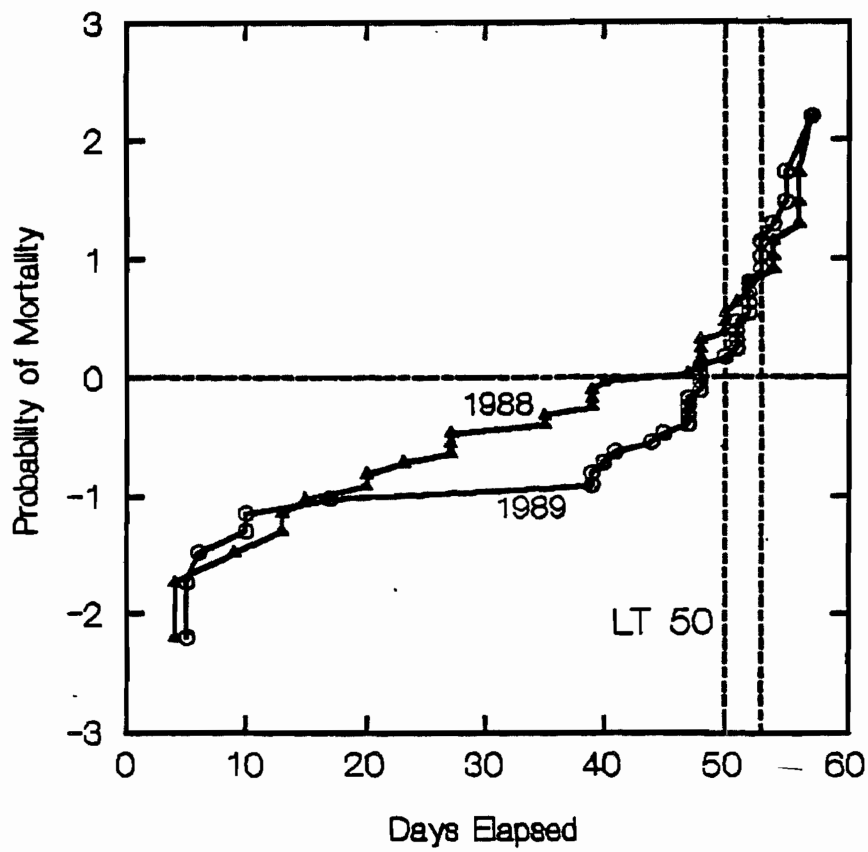
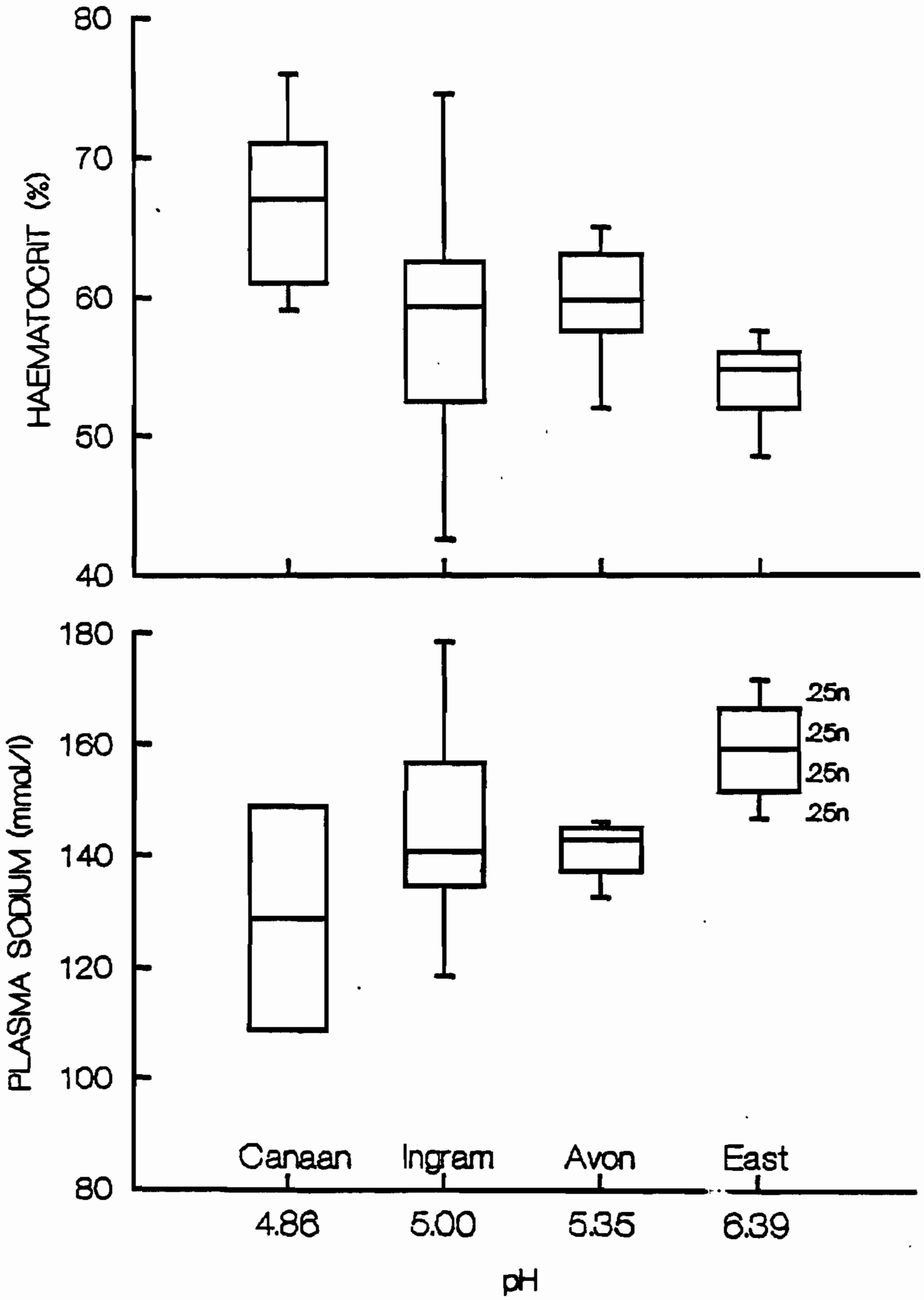


Figure 6: Box plots of haematology



A Multivariate Method of Analysing Relative Abundance Data, Employing the Weighted Mean Proportions

by

Raj. K. Misra, Nelson Watson, John F. Uthe, and Ian Davies

Let K (= 7) denote the number of populations Q_i, i = 1, . . ., 7, identified by their collection dates, and r + 1 (= 5) the number of orders. These populations and orders are numbered as shown in Table 1. Table 2 shows the frequency distributions of specimens grouped into five orders for seven samples. Table 2 shows population characteristics in the form of attributes. Five attributes (orders) are shown in these data which are essentially qualitative. It is possible to assign numerical values to these qualitative characteristics, which will distinguish between the presence and absence of an attribute. As explained in the following, this is done by numerically coding attributes as 0 - 1 variables. These numerical values are then employed to analyse proportions at the univariate level (see, e.g. Neter et al. 1985, Armitage 1971, Li 1969) and at the multivariate level (see, e.g. Johnson and Wichern 1988, Kurczynski 1970, Balakrishnan and Sanghvi 1968).

In this presentation we denote a vector by an underscored letter and a matrix by a letter in bold. Prime denotes a transposed vector or matrix. An unprimed vector denotes a column vector.

Let p_{ij} be the number of individuals of the jth order in population Q_i, expressed as a proportion of the total number of individuals in Q_i. We note the following (Agresti 1990, Johnson and Wichern 1988, Kurczynski 1970, Balakrisnan and Sanghvi 1968, Kendall and Stuart 1958):

1. The (r + 1) orders are mutually exclusive and exhaustive. The proportions p_{ij} are the means in Q_i of variables Y_j, j = 1, . . ., (r + 1), which take the values 0 and 1 where one, and only one, of the Y_j variables can be unity on any individual. Let $\underline{Y}'$ be the vector with variables Y_j, j = 1, . . ., (r + 1), as its (r + 1) components. The sth component, Y_s, of $\underline{Y}$ is 1 if the individual is of order s and 0 otherwise.
2. For samples of n_i, i = 1, . . ., K, individuals drawn from populations Q_i, the proportions $\hat{p}_{ij}$ are the maximum likelihood (ML) estimates of the proportions of the jth order in Q_i.
3. Covariance matrix $n_i\boldsymbol{\Sigma}$, with elements $n_i\sigma_{jm}$, j, m = 1, . . ., (r + 1), of variables Y_j for the sample from Q_i is given by

$$n_i\sigma_{jm} = p_{ij}(1 - p_{ij}) \quad j = m$$

$$= -p_{ij}p_{im} \quad j \neq m \tag{1}$$

Covariance matrix of proportions p_{ij}, j = 1, . . ., (r + 1), which are the means in Q_i of variables Y_j, is $\boldsymbol{\Sigma}$.
4. For large n_i sampling distribution of $\hat{\underline{p}}_i$ with components $\hat{p}_{i1}$, . . ., $\hat{p}_{i,\overline{r+1}}$, is given as follows:

$$(n_i)^{½}(\hat{\underline{p}}_i - \underline{p}_i) \text{ is approximately } N_{r+1}(\underline{0}, \boldsymbol{\Sigma}) \tag{2}$$

i.e. a (r + 1) variate normal distribution with parameters $\underline{0}$ and $\boldsymbol{\Sigma}$ for the mean vector and the covariance matrix, respectively.
5. When the true values p_{ij} are unknown, approximation (2) remains valid when σ_{jm} of (1) are estimated by $\hat{\sigma}_{jm}$ where

$$n_i\hat{\sigma}_{jm} = \hat{p}_{ij}(1 - \hat{p}_{ij}) \quad j = m$$

$$= -\hat{p}_{ij} \cdot \hat{p}_{im} \quad j \neq m$$

Several references, which report similar results for attributes coded as 0 - 1 variables and for r + 1 = 2, are available, e.g. Snedecor and Cochran (1989), Neter et al. (1985), Armitage (1971), Li (1969). From these the following is noted:

1. For random variable Y where responses are 0 - 1 observations, let p_i be the proportion of individuals which possess an attribute, i.e. individuals with observations of 1. Variance V(Y), i.e. the variance of Y, is then $p_i(1 - p_i)$. We denote the mean response of Y estimated from a sample of n_i individuals by $\hat{p}_i$. In large samples, $\hat{p}_i$ is approximately normally distributed about the population proportion p_i with variance $p_i(1 - p_i)/n_i$. When the true value $p_i(1 - p_i)$ is unknown, we substitute the sample estimate so that $V(\hat{p}_i) = \hat{p}_i(1 - \hat{p}_i)/n_i$.
2. When responses are 0 - 1 observations, errors are not normal. However, estimates provided by the method of least squares are unbiased and asymptotically normal under quite general conditions. Hence, with large sample sizes, inferences about regression coefficients and mean responses can be made in the same fashion as when error terms are assumed to be normally distributed (Neter et al. 1985).
3. Weighted least squares can be employed to handle the problem of unequal error variances associated with 0 - 1 variables.

When there are only two orders or classes, i.e. r = 1, r + 1 = 2, the conventional Chi-Square (X^2) procedure for comparing proportions of K (≥2) populations would employ the 2 x K contingency table. For each of the observed frequencies n_{ij}, i = 1, . . ., K; j = 1, 2, an expected frequency

$E_{ij} = (n_i \sum_{i=1}^{K} n_{ij})/n$, where $n = \sum_{i=1}^{K} n_i$, is calculated.

We then calculate

$$X^2 = \sum_{i,j}^{K} (n_{ij} - E_{ij})^2/E_{ij} \qquad i = 1, \ldots, K;\ j = 1, 2 \tag{3}$$

On the null hypothesis $H_0 = p_1 = p_2, \ldots, = p_k$ (4)

X^2 of (3) is distributed approximately as $\chi^2_{(k-1)}$, i.e. χ^2 with degrees of freedom (df) = k - 1. This approximation is satisfactory as the expected frequencies E_{ij} increase in size. The restriction that no E_{ij} should be < 5 was employed in the past and if necessary, neighboring classes were combined to meet this requirement. However, it has long been realized (for earlier references, see, e.g. Armitage 1971, Snedecor and Cochran 1967, Cochran 1954) that this restriction is too strict. The χ^2 approximation is safe even with E_{ij} values which are as small as 1, provided there are not several of these, i.e. say not more than about 20% of the E_{ij} values are < 5.

The scope of these χ^2 methods is restricted almost entirely to significance testing (Armitage 1971). However, by working through weighted sum of squares (SS) of p_i, i = 1, . . ., K about their weighted mean p, analyses of 0 - 1 data can be extended to test a variety of null hypotheses (H_0) pertaining to differences between K groups (populations). For example, these hypotheses may be (i) on contrasts between K groups, or (ii) on time, space, or environmental trends by assigning a quantitative variable, X, to the K groups, such as days, months, etc. for time trends, geographical distances for spatial trends, and temperature, humidity, etc. for environmental trends. Furthermore, groups can be defined by a qualitative variable as well. Each hypothesis will be tested by χ^2 with a reduced df of 1 or some other value depending on the H_0 under test. For examples illustrating the application of this procedure see, e.g. Snedecor and Cochran (1989), Armitage (1971), and Li (1969). Consider the case of two classes and for K = 2, H_0 of (4) is

$$H_0: p_1 = p_2 \tag{5}$$

$X^2_{(1)}$ of (3) will test H_0. Alternatively, (5) is expressed as the contrast between p_1 and p_2 and tested by $X^2_{(r)}$, i.e. $X^2_{(1)}$ which is given by

$$X^2 = [n_1n_2/(n_1 + n_2)](\hat{p}_1 - \hat{p}_2)^2/\hat{p}(1 - \hat{p}) \tag{6}$$

where $\hat{p}$ (a) is the weighted mean

$$\sum_{k=1}^{2} n_i\hat{p}_i / \sum_{k=1}^{2} n_i \tag{7}$$

of $\hat{p}_i$, i = 1, 2, and (b) under the null hypothesis (5), will replace each p_i. We also note the following concerning the use of (6): Of the two (= r + 1) classes, proportions for only one (= r) class are employed to calculate X^2 of (6). It does not matter which one of the (r + 1) variables is deleted, so long as it is one of the variables involved in the prefect linear relationship (Harris 1975). Expression (6) may be rewritten as follows

$$X^2 = [n_1n_2/(n_1 + n_2)(\hat{p}_1 - \hat{p}_2)][\hat{p}(1 - \hat{p})]^{-1}(\hat{p}_1 - \hat{p}_2) \tag{8}$$

For the extended case of r ≥ 2 Kurczynski (1970) gave the following general form of X^2 and related statistics (see also Johnson and Wichern 1988, Morrison 1976):

1. $$X^2_{(r)} = [n_1n_2/(n_1 + n_2)](\hat{\underline{p}}_1 - \hat{\underline{p}}_2)'S^{-1}(\hat{\underline{p}}_1 - \hat{\underline{p}}_2) \tag{9}$$

In (9) (i) $\hat{\underline{p}}_i$ is the vector of r components $\hat{p}_{i1}, \ldots, \hat{p}_{ir}$ and (ii) S is the (rxr) common covariance matrix. Elements s_{uv} of **S**, computed by using the weighted means $\hat{\underline{p}}$ (7) of $\hat{p}_i$, i = 1, 2, are given as follows:

$$s_{uv} = \hat{p}_v(1 - \hat{p}_v) \quad u = v$$

$$= - \hat{p}_u\hat{p}_v \quad u \neq v$$

$$u, v = 1, . . ., r$$

2. Statistic (9) is rewritten as

$$X^2_{(r)} = [n_1n_2/(n_1 + n_2)]D^2_r \tag{10}$$

where

$$D^2_r = (\hat{\underline{p}}_1 - \hat{\underline{p}}_2)'S^{-1}(\hat{\underline{p}}_1 - \hat{\underline{p}}_2) \tag{11}$$

is the generalized distance which may be employed to measure similarity between two populations.

This preliminary paper assembles arguments for the analysis of proportions rather than absolute numbers (population means) in hypothesis formulation and testing for both the univariate and multivariate cases. The advantages of using proportions in analyses include the elimination of the need for data transformation and the direct relevance of proportionality to community structure. For example, the generalized distance statistic outlined above provides a measure of similarity between populations taking the correlative structure of the data into consideration and leads to parametric analysis.

Another consideration arising from this derivation is the need to relate sampling protocols to analytical requirements. The large sample sizes needed to detect rare individuals tend to "swamp" them when absolute numbers are analysed directly to measure population change or overemphasize them when log(n+1) transformations are used.

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Table 1. Populations and orders.

Date	Number	Order	Number
Oct 6/87	1	0_1	1
May 26/88	2	0_2	2
July 28/88	3	0_3	3
Sept 27/88	4	0_4	4
May /89	5	0_5	5
July 26/89	6		
Oct 6/89	7		

Table 2. Frequency distributions of specimens grouped into five orders and seven samples.

Sample	Order					Total
	1	2	3	4	5	
1	12	22	89	5	10	138
2	24	41	4	5	1	75
3	24	1	1	0	12	38
4	66	88	467	5	18	644
5	174	24	65	16	4	283
6	45	1	601	5	21	673
7	108	10	29	1	2	150

Questions and Answers

IOLA PRICE: In the East River, wherever it was you had the 30% mortality of your controlled fish, did you check them out for other causes of death? Like did they have a disease or whether there were other... Did you do histopathology?

STEVE BARBOUR: Oh, yes, we looked at them. They were thin. All the fish were thin because none of them were fed. The water was quite cold. We removed them from the hatchery and they were all randomly taken from the same hatchery pool. They just put aside a pool for me at the hatchery and I'd just take my fish all from the same place. So there's no stock differences. There's probably no disease problems. The fish look healthy superficially. They're just dead if you can call that health. There's no overt signs of disease.

IOLA PRICE: If I understand you correctly, you had quite a change in mortality in your control river from one year to the next.

STEVE BARBOUR: Oh, that was only in the cages where I was putting lime. In the ambient cages, the mortality rate was quite similar. I did change the liming method in the second year and that was the year when the mortality was higher. In the first year, we would stir up the gravel to clean it off. Each gravel chunk gets a deposit on it so we stir it up to clean it and then the fines would all wash through the cage. Now we may have actually been liming the fish. In the second year, we decided we'd better control that so we put the limestone into wire baskets and also the inert gravel, stainless steel baskets. We could then lift the basket out and plunk in a clean one without creating this great cloud of fines. We would then wash the gravel in the river downstream from the site and then that way we were no longer liming the fish and then we got higher mortalities. So it may be just the raking of the fines may have caused that difference. But in the ambient cages, there was no statistical differences between years. There was a little difference but not much.

DFO, NEWFOUNDLAND REGION

BIOLOGICAL MONITORING ACTIVITIES IN 1990

Report for the 1990 DFO LRTAP Workshop, St. John's

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Subsequent to last year's DFO LRTAP Workshop, two progress reports on the Newfoundland Region's biological monitoring activities have been published; one from last year's DFO workshop (Coady et al. 1990), and one from the Atlantic Region workshop (Ryan 1990a).

Biomonitoring of Stevenson's Pond and its tributaries, at the headwaters of Grandy Brook on the southwest coast (Table 1), has continued since 1985 under contract to LGL Consulting of St. John's. Paleoecological reconstruction of sediment cores taken in 1988, from Lake 642 on the Grandy Brook system, has indicated a moderate decline in inferred pH (about 0.3 units since the 1930's) with the lowest inferred pH values in the uppermost sediment strata (Rybak and Rybak 1990).

Biomonitoring of Harding Pond in Gros Morne National Park (Table 1), started in 1989, was conducted by P. M. Ryan with the assistance, collaboration, and logistic support of Parks Canada. The monitoring of this site, at the headwaters of the Humber River, was described in the Gros Morne Park Newsletter (Anon. 1990). Paleoecological reconstruction of Candlestick Pond, 1.4 km downstream of Harding Pond, has indicated fluctuating but declining inferred pH values since the 1800's. However, increased inferred pH (about 0.3 units) in the uppermost sediment strata is suggestive of improvements in LRTAP emission controls in recent time (Rybak and Rybak 1990).

Biological monitoring in the Experimental Ponds Area (Table 1), continued since 1977 (with the exception of 1988), was conducted, under contract, by Memorial University staff under the direction of Dr. R. Knoechel with the assistance of P. M. Ryan. A recent publication has associated reduced sulphate deposition upwind at Bay d'Espoir with decreased alkalinity deficits in the Experimental Ponds Area (Ryan, Scruton, and Stansbury 1990).

Salmonid populations in the biomonitoring lakes are censused each spring and fall using Schnabel's multiple mark-recapture method as described in Ryan (1990b). Salmonid densities have exhibited a more than tenfold variation (Table 2).

All water samples obtained during biological monitoring activities are analyzed by Environment Canada's Environmental Protection Branch in St. John's. All analyses are up to date.

Extensive 8 mm camcorder filming has been done at all biological monitoring sites. Films (about 12 hours for 1989-90) are backed up by VHS tapes and summarized for presentation at this workshop.

Three working papers were presented at the Biomonitoring Working Group meeting in Burlington in April, 1990, as follows. An analysis of benthic invertebrate catches from the Experimental Ponds Area from 1977 to 1982 and from 1987 provided evidence that the LRTAP benthic invertebrate protocol was resulting in a deficient faunal list (Ryan, Colbo, and Marshall 1990a). An analysis of artificial substrate catches from the Experimental Ponds Area suggested that the inclusion of artificial substrates in the LRTAP biomonitoring program might alleviate some of the apparent deficiencies in the existing protocol for benthos (Ryan, Colbo, and Marshall 1990b). A third working paper referenced techniques developed to test fish relative abundance estimates and census methods in Newfoundland (Ryan 1990c).

An invertebrate reference collection from the DFO Newfoundland biomonitoring collections was prepared and forwarded to the Chairman, DFO LRTAP Biomonitoring Program. This reference collection, prepared by Dr. M. H. Colbo of Memorial University, will contribute to a National Reference Collection and to quality assurance and control in the Biomonitoring Program.

All of the new freshwater benthic invertebrates (171 taxa) captured during biomonitoring activities and by other freshwater biological staff in the Newfoundland Region have been assigned computer codes and incorporated, as a supplement, to the computer code for freshwater life forms of Newfoundland (Ryan 1983).

Table 1. Physical characteristics of the biomonitoring lakes in the Newfoundland Region.

Descriptor	Stevenson's Pond	Harding Pond	Headwater Pond	Spruce Pond
Latitude	47°54'	49°38'	48°16'	48°19'
Longitude	57°30'	57°38'	55°29'	55°28'
Elevation (m)	363	465	226	215
Catchment area (km^2)	8.74	25.28	5.96	20.06
Water surface area (ha)	99.0	44.8	76.1	36.5
Maximum depth (m)	9.0	18.3	3.3	2.1
Mean depth (m)	2.7	8.2	1.1	1.0
Volume ($m^3 X10^{-3}$)	2,673.0	3,658.6	871.8	364.3
Bedrock	Granite	Gneiss	Slates and shales	Slates and shales

Table 2. Comparable densities ($fish \cdot ha^{-1}$) of brook trout, Atlantic salmon, and Arctic char in the biomonitoring lakes of the Newfoundland Region, spring and fall, 1989. Methods and methodology are detailed in Ryan (1990b).

	Harding Pond				Headwater Pond			Spruce Pond			Stevenson's Pond
	Trout	Salmon	Char	All	Trout	Salmon	All	Trout	Salmon	All	Trout
Spring	79.4	34.7	456.8	573.7	27.3	20.2	47.5	50.0	92.7	142.8	104.8
Fall	97.4	11.1	445.4	553.9	34.9	16.9	51.8	36.2	48.2	84.4	84.6
Means	88.4	24.3	451.1	563.8	31.1	18.6	49.7	43.1	70.5	113.6	94.7

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Central and Arctic Region I. Davies

The DFO Biomonitoring Programme 1989/90 Progress Report

I. Davies

At the Mont Joli workshop in 1989 eight goals were established for the DFO LRTAP Biomonitoring Programme in 1989/90. A list of these goals, together with a summary of progress made on each item in the past year and prospects for the future are given below:

1) Produce a Technical Report and a revised version of the Sampling Protocol.

Both are in progress, but incomplete at this time. The mechanics of programme co-ordination and sampling at ELA have prevented I. Davies from finishing the final draft of the Protocol. This delay has not hampered the operational aspects of the programme because each participant works from a draft copy, which differs little from the final document. Production of a Technical Report, outlining the location, description, and basic characterization of all of the monitoring sites has been put on hold until Ms. M. Shaw returns from maternity leave in January. Both the Protocol and the Technical Report will be completed in 1991.

2) Establish one standard database format and one central data repository.

Lack of a PY, and reduced funding delayed the startup of this project until mid summer. Funds set aside for risk-assessment modelling were combined with the allotment for database construction to address this priority issue. A contract has been let to Monenco, to provide a database design, and functional database containing 1987 and 1988 data by March 31 1991. The database, written in "Oracle" (a DFO standard), will reside in Burlington and will be available to all users via DFO network communications. Dr. C.K. Minns, who is the scientific authority for this project, will chair the first database design meeting immediately following the conclusion of this LRTAP workshop. Once the database has been set up, there will be a continuing need for a database manager.

3) Continue to critically evaluate methodology.

Nighttime vertical net tows for Mysis relicta and other deep-water crustacean species were eliminated (as redundant) from the lake sampling routine in Québec lakes. In three years of trials, Mysis were not found in any of the La Maurice lakes, so they were presumed absent. Any of the other creatures caught in the net tows were already sampled adequately by other methods.

It was decided to use only the 450 μm-mesh Surber sampler rather than a 450 μm and a 100 μm-mesh sampler in the stream surveys. Although the 100 μm mesh caught the earliest life stages of Ephemeroptera, Plecoptera and Trichoptera, these life stages weren't taxonomically useful. In addition the fine mesh collected large volumes of detritus which greatly increased sample processing time. Thus, it seemed that for the amount of information gained, the additional work was not warranted.
Artificial substrates were evaluated as a possible alternative to kick-and-sweep sampling in lake littoral areas, or as a cheap and simple method of providing adjunct information for these sites on species that were difficult to sample by the kick-and-sweep method. Extensive tests of one type of artificial substrate were conducted by the ELA and Sault Ste. Marie labs.

Initial indications are that the method does not provide a good alternative to kick-and-sweep sampling, and that because the substrates yield a low diversity of material, they are only useful adjuncts at stations that are difficult to sample by any other technique. A more complete analysis of results is forthcoming.

4) Improve programme Quality Assurance and Quality Control (QA/QC).

Steps to improve QA/QC have been taken on two fronts. First, a national taxonomic verification exercise was undertaken to establish a national invertebrate reference collection, and to independently verify the quality of taxonomic work done for each of the programme participants. In October 1990, a contract to do this work was awarded to Mr. B. Bilyj of Winnipeg. Reference specimens sent for verification will be returned to the participants along with either a verification of identity, or a standardized identity with notes on the fine points of the taxonomy used to arrive at that classification. Duplicate specimens will be placed in a national collection. The working group eventually plans to have this national collection housed in a museum. A summary analysis on the relative agreement among participants will be prepared once the work is complete. As the second part of the QA/QC development, I. Davies participated in two workshops held in the spring of 1990, one to design draft guidelines for QA/QC in Aquatic Biological programmes; the other (the Third Ecological QA Workshop, Burlington, ON.) designed to help refine the draft document mentioned above, and to explore on a broader scale the concepts and application of QA/QC in ecological studies. Copies of the workshop reports will be distributed to members of the Biological Monitoring Working Group. These reports will form the basis for future discussions, aimed at improving and formalizing a system of QA/QC for the LRTAP Biomonitoring Programme.

5) Evaluate techniques of data analysis.

Dr. R. Misra (DFO, Halifax) has been working to develop a multivariate statistical method for analyzing relative abundance data of the sort being generated by the DFO Biomonitoring Programme. Progress has been good. At present Dr. Misra has written a FORTRAN program and successfully tested the method with a small subset of data. Further tests and a comparative evaluation of the results obtained by this and other, more established, techniques of community analysis will be conducted in the coming year with data sets from Nova Scotia and ELA. A preliminary report describing the theoretical basis of the method is available on request from Dr. Misra or I. Davies.

6) Continue to explore interconnections with other programmes.

Dr. Peter Blanchard of the Canadian Wildlife Service remains, in his liaison capacity, as member of the DFO Biomonitoring Working Group and Mr. Warren Dunlop represents the interests of the Ontario Ministry of Natural Resources. The Ontario Ministry of the Environment continues its full participation in the programme and is represented by Mr. Ron Reid.

In the past year I. Davies (as a representative of the DFO Biomonitoring Programme) has attended the Fifth Annual Task Force Meeting of the International Co-operative Programme on Assessment and Monitoring of Acidification of Rivers and Lakes (Frieburg, Germany) and a Sampling Intercalibration Exercise for the same European programme which was held in Nalchick, USSR. Canadian participation in the European programme was in the form of a contributed paper at the Task Force meeting, intercalibration sampling and a contributed paper in the USSR, and delivery of the 1987/88 monitoring data from ELA to the European database in Norway. In addition M.

Shaw, J.R.M. Kelso, and I. Davies presented a poster, describing the DFO LRTAP Biomonitoring Programme, at the International Conference on Acidic Precipitation held in Glasgow, Scotland this fall.

Plans for 1991 are to maintain existing linkages with other programmes, to seek a more integrated approach with the DOE air and water monitoring through common database structures, and to encourage other agencies (e.g. the United States Environmental Protection Agency for its proposed EMAP monitoring) to use some of the Canadian sites as intercalibration stations, thus providing a bridge between otherwise unrelated programmes.

7) Begin work on producing an annual data report.

This activity was put on hold, pending the development of the database. Part of the database contract (see item 2 above) specifies the construction of several report generating routines. It is hoped that by having standard reporting formats, a large part of the drudgery of producing annual summaries can by handled automatically. This would allow annual reports to be produced in a timely fashion, and permit staff more time to analyze and interpret the results of the programme.

8) Maintain full sampling at all sites.

Field work for 1990 is complete or ongoing at all of the DFO monitoring sites. Samples and data from previous years are currently being analyzed by each region in preparation for transferring this information to the national database. A continuation of full sampling is planned for the coming year.

Questions and Answers

<u>SUE MILBURN:</u> Are the Provinces doing things somewhat like what you are, some of the Provinces? Are the Provincial Governments doing any similar monitoring programs?

<u>IAN DAVIES:</u> Actually one of the things that I didn't point out was that the Ontario Ministry of the Environment and, I hope, Ontario Ministry of Natural Resources as well have been informally part of our group for two years and will be contributing to this as well. OME is doing their annual sampling according to our protocol and OME is interested, we have at least 3 out of 5 lakes in common now between OME and OMNR and this is some kind of new landmark, I think, actually getting OMNR and OME to talk to each other. To date, I think those are the only formal provincial contributions to our program.

4.7. PACIFIC REGION REPORT

Pacific Region R. Wilson

PACIFIC REGION REPORT - R.C.H. WILSON AND W.J. CRETNEY

Pacific Region has only one LRTAP-funded project: to determine the flux and regional variability of chlorinated pesticides. This project has been taking place in the Ocean Chemistry Division at IOS under Dr. Walt Cretney; the principal investigator has been Dr. Lorne MacGregor. Inquiries about the project should be direct to Dr. Cretney.

The objective of the first phase of the project was to determine the levels of chlorinated pesticides in precipitation in B.C., and it is worth reviewing why we felt this was important.

In 1987, Dr. Bruce Strachan presented a paper at a meeting of the American Chemical Society [1], in which he reported his work at Kanaka Creek, B.C. Kanaka Creek is a tributary of the Fraser River, near Vancouver. Aside from measuring pH, Dr. Strachan also looked at concentrations of HCH and PCB's in precipitation. He found that, over two years, the deposition rate of HCH was 22-35 $ug/m^2/y$, while the deposition of PCB's was around 1 $ug/m^2/y$. Comparing these deposition rates with other sites in Canada, he concluded that the ratio of HCH:PCB at Kanaka Creek was the highest in the country, and he hypothesized that an Asian source for the excess HCH was consistent with general atmospheric circulation.

At about the same time, Dr. Hal Rogers had been working on the exposure of juvenile chinook salmon to organochlorines in the Fraser River between Quesnel and Prince George. The objective of this work was to look at the uptake of chlorinated phenols and chlorinated guiacols, which originated from pulp and paper mills, by juvenile chinook overwintering under the ice. Dr. Rogers had also begun to look at the uptake of chlorinated dibenzodioxins and dibenzofurans. On the basis of enzyme induction essays and organ residue levels, Dr. Rogers believed that these resident fish were stressed and that the uptake of organochlorines might possibly be high enough to have implications for survival.

Also about the same time, DFO was reaching a difficult management decision with respect to Strait of Georgia chinook stocks. These stocks are a mainstay for the recreational fishery in the area where most British Columbians live. Population levels had declined to the point where the commercial chinook fishery had to be reduced and more stringent catch limits applied to anglers.

These three factors combined to suggest that it was important to investigate the atmospheric deposition of organochlorines in the Fraser River watershed.

[1] Strachan, William M.J., 1988. Atmospheric deposition of selected chemicals in Canada, presented at the Third Chemical congress of North America, June 5-10, Toronto, Ontario, Canada.

4.7. PACIFIC REGION REPORT

Pacific Region R. Wilson

Early work on this project focused on bringing into operation a method for the collection and analysis of precipitation samplers. Rain samplers were acquired, and the procedures and locations for sampling snow in remote areas were determined. For snow, samples were to be collected in the heat-sealed teflon bags, melted in the bags[2], and pumped through a resin column prior to analysis by G.C. Due to a desire to minimize sample volumes, the thermal desorption resin Tenax was selected which allowed for adequate detection limits with a 6*l*. sample[3].

In February, 1990, snow samples were collected at 15 sites in the Fraser River watershed and two remote sites on the B.C. coast (Fig. 1). Early analysis of these samples has revealed a problem either with contamination from the teflon bags or with the combustion of organic debris during thermal desorption of the Tenax columns.

Further work on this project will be done under contract with Seachm Laboratories. A second set of snow samples will be collected during the 1990/91 winter, and analyzed by pumping a 40L sample of the melted water through XAD resin[4]. Results should be available by autumn, 1991. An attempt will also be made to clean up the samples still unanalyzed from the first sampling trip.

[2]Gresor V.J. and Gummer W.D., 1989. Evidence of Atmospheric Transport and Deposition of Oryonochlorine Pesticides and Polychlorinated Biphenyls in Canadian Arctic Snow. Environ,. Sci. Technol 23:561-565.

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[4]Hargrave, B.T., Vass, W.P., Erickson, P.F. and Fowler, B.R., 1989. Distribution of Chlorinated Hydrocarbon Pesticides and PCB's in the Arctic Ocean. Can. Tech, Ref. Fish. Aquatic. Sci. 1644: ix + 224p.

Questions and Answers

<u>JOHN SMITH:</u> Did you just run a blank through the plastic bag to heat seal it to find out if that was the problem?

<u>BOB WILSON:</u> Part of the problem here is that Lorne McGregor says that his blanks were contaminated, too. Now we're just not quite sure what his blanks were. He did not leave us an extensive set of notes and the problem with the field trip was that the bags themselves were heat sealed only about a day before he left in the field so he had no time to do what one would think would be the logical thing which would be to spend a little time in the lab looking at that whole process before he went out and took his samples.

5.0. NATIONAL LRTAP PROGRAM S. Milburn

NATIONAL LRTAP PROGRAM REPORT

National LRTAP and Acid Deposition Assessment Report

Over the past two years a major focus for the LRTAP program has been the production of the 1990 Canadian LRTAP and Acid Deposition Assessment Report. A number of DFO scientists have been involved in the drafting of the report. The report is currently in the final stages of translation and printing, and will be released late in 1990 or early in 1991.

Highlights of the report follow:

-New information gathered in the past few years has been analyzed to determine the "critical load" for aquatic ecosystems. The critical load is the highest deposition of acidifying compounds that will not cause chemical changes leading to long-term harmful effects on the overall structure or function of the aquatic ecosystem. Critical load information can be used along with information on economic and social concerns in the selection of target loads and the design of control programs.

-It is now understood that the total number of fish species and other classes of aquatic biota start to decrease when the pH of a lake falls below 6.0, well before a lake is considered to be completely acidified.

-New aquatic effects data and the new criteria of pH greater than or equal to 6.0 needed to protect aquatic ecosystems have been used in aquatic models to predict critical load values for different regions of eastern Canada. These values range from less than 8.0 to more than 20 kg/ha/yr of sulphate in precipitation in some of the less sensitive regions of Ontario and Quebec (see figure 1).

-Analyses of the effectiveness of the Canadian and U.S. SO_2 control programs have been undertaken through the use of atmospheric and aquatic models. Major improvements in lake chemistry and biota are predicted for Ontario and Quebec. The models do not predict much improvement in aquatic conditions in the very sensitive areas of New Brunswick, Nova Scotia, and southern Newfoundland even through wet sulphate deposition is predicted to be less than 14 kg/ha/yr in these areas once both control programs are fully implemented.

National LRTAP Program Commitments and Priorities

National LRTAP program requirements over the next five years will be related to three specific program areas:

1. The extension of the domestic acid rain control program and the response of the environment to reduced sulphur dioxide emissions;

2. The provisions of the Canada/U.S. Air Quality Agreement;

3. The U.N. Economic Commission for Europe LRTAP Convention and the Sulphur Dioxide and Nitrogen Oxides Protocols, and related activities.

Specific program thrusts for the research and monitoring program over the next five years are as follows:

-Monitoring (and reporting on) the effectiveness of the Canadian and U.S. SO_2 control programs in reducing ecosystem stress;

-Determining the rate and extent of aquatic recovery:

-Determining the causes of forest decline;

-Determining the effects of LRTAP on the health of Canadians;

-Understanding the role of nitrogen in acidification and developing critical loads for nitrogen (commitment to ECE NO_x Protocol);

-Research, monitoring and modelling in support of the NO_x/VOC (Volatile Organic Compounds) Management Plan.

References

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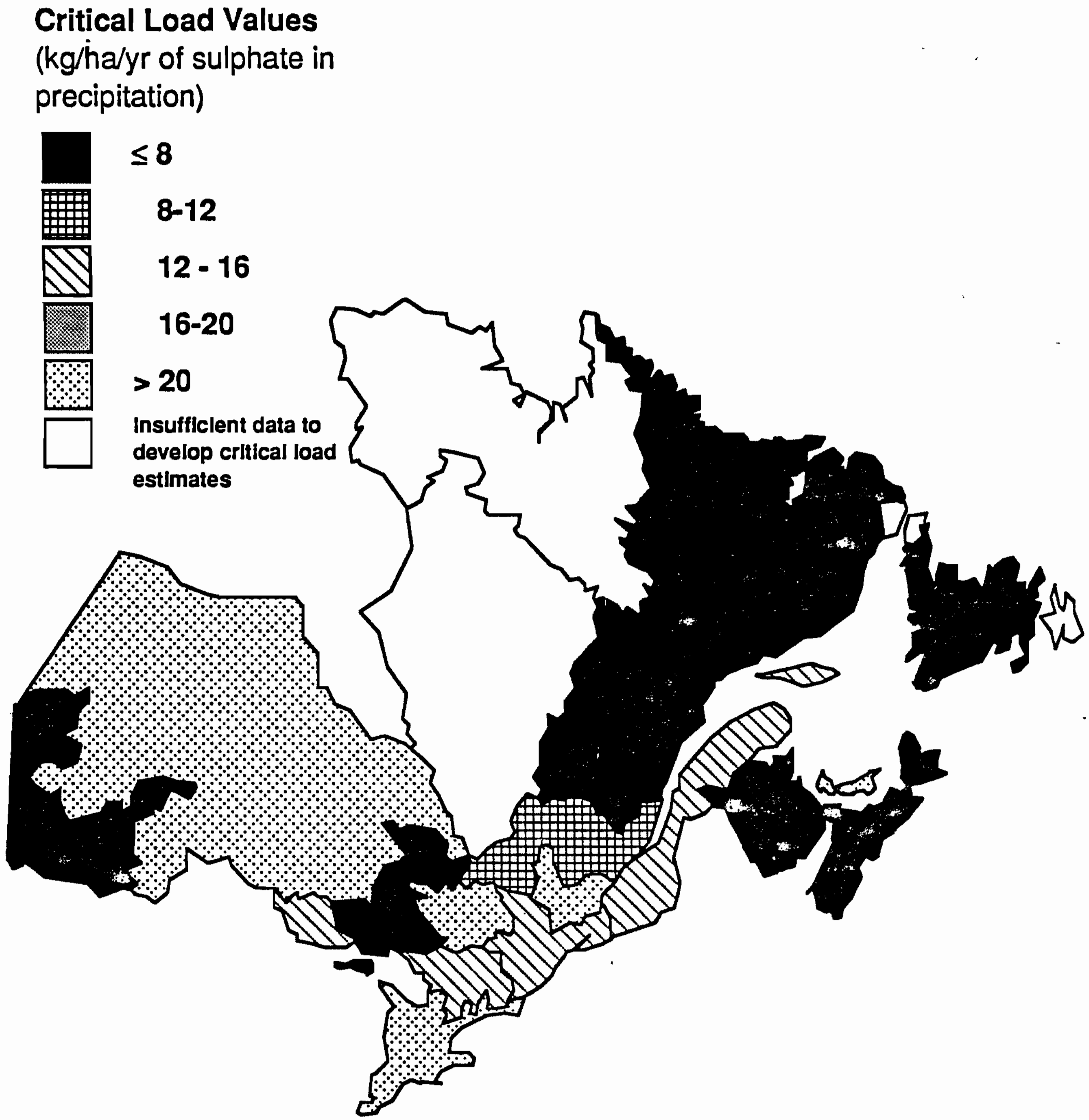

Figure 1: Critical load values. Shading indicates critical values designed to maintain at least 95 percent of the lakes in a region (aggregate) at a pH of 6.0 or higher.

Questions and Answers

PHIL BLAGDON: Sue on your first map you had, in terms of critical loads, a white spot for the Avalon Peninsula and the Northern Peninsula. Are there data gaps there?

SUE MILBURN: I'm not sure why that is. I got it from someone in Burlington and when I looked at it last night, I thought, oh, ghee, what is the problem there? I don't know what the problem is and I'll have to find out and I'll get back to you on whether or not it's a data gap.

PHIL BLAGDON: There's also a white spot on the tip of the Northern Peninsula and Southern Labrador on that map so there were a couple of areas, and if that seems to be a hole which there was colour on all sides of.

SUE MILBURN: I'll talk to Dean Jeffries and get back to you on that one. I know the atmospheric models have trouble dealing with sort of the sea interface and I know that they don't deal with precipitation amounts very well. I think there's probably some other reason why that's like that.

JOHN SMITH: Could you give me some idea of the uncertainties in the models? That is, are you talking about 14 kilograms plus or minus 10%, 50% or 100%?

SUE MILBURN: I don't know. I think there's fairly large uncertainty in that. If that's one of those ones where you have one model and then another model and then another model. Ken, do you know the uncertainty? That's why I think before we go and ask the politicians for additional controls we need to focus our efforts on firming up what the situation is in Atlantic Canada.

BOB HECKY: You're talking about the U.S./Canada air quality accord requiring regular reporting on monitoring. Is there going to be a definition within the accord of sites or what kinds of programs are going to be acceptable?

SUE MILBURN: At this point, there's something called the research annex and it's really big. I think it's going to appoint a group, to sit down and to figure out what actually we're going to put into a monitoring element of it.

BOB HECKY: Because I think that's going to be an important point if the goal is to be restore biological damage rather than to restore pH in water. Those two are not necessarily closely linked based on the kinds of recovery scenarios that we're looking at so far.

SUE MILBURN: In the past, whenever we've entered into discussions with the States they're very much focused on the emissions end of the monitoring and the deposition end of the monitoring and then they stop there. They are not willing to acknowledge any kind of effects and I don't know how far we're going to get in that discussion. But certainly anything that Canada is going to produce, we're going to be including water chemistry and the biology part of it because we find that's the most important part. That's why we're doing this.

IAN DAVIES: One of the things that concerns me about getting dragged into a U.S./Canada agreement on monitoring is at the moment the U.S. is proposing for monitoring the EMAP Program which neatly divides most of North America into hexagons. The cost of this program is multi-billion dollars and it would be the kind of monitoring that Canada just couldn't afford to be part of. Each stage of this monitoring proposal that USEPA has been putting forward has been getting bigger and bigger and bigger and they're tendency, I think, is to discredit other countries that can't match dollar for dollar what the U.S. puts out. So I think why our connections with the UNECE Program in showing that our results are roughly comparable to the European results puts the U.S. at a bit of a disadvantage because we are not standing alone. We are saying - how come this is okay for the rest of the world but not for you guys. Any comments?

SUE MILBURN: Well we certainly don't envision doing anything quite like the EMAP Program. I think when we have the Accord it's not going to ever get to that level of detail where we are going to specify that you can't do any kind of monitoring unless you have X type of monitor. I don't think it will ever get that detail. Our side puts in what we think is appropriate and they put in what they think is appropriate. I know that there have been problems with the U.S. on this kind of thing and this, indeed, is one of the reasons why we've carried on with the ECE. We've found that working through the LRTAP Convention has been a very useful way of gaining support from other countries who are doing things somewhat similar to Canada in a larger context. We have a lot of friends within the ECE and that's one of the reasons we've been involved with it and probably will continue to be involved with it.

JOHN NEWHOOK: The critical loads which you've shown on one of your slides there. I understand from what you said is they're all based on aquatic environment effects. There's nothing based on any other effects such as, for example, sugar maples in Quebec or anything like that. Is that correct?

SUE MILBURN: Yes. They're based on the criteria of pH greater than 6 for water chemistry and that's sort of where the state of the sciences is. We can do it for aquatic systems, the terrestrial environment we still don't understand very well at all so we haven't even attempted to do that.

BOB WILSON: You didn't spend any time talking about organics and I wonder if you'd share with us the rationale for that.

SUE MILBURN: Okay. The LRTAP Program to this date hasn't, at least the main part of the LRTAP Program, looked at organics at all. In fact, DFO is unique in looking at the organics and in Environment Canada we haven't considered that as part of the Program. It's something that's sort of been sitting there on the horizon and I think we know we're going to have to deal with it in some way. The activity that has been done to date within the Atmospheric Environment Service is certainly...looks at the Great Lakes and to some extent is starting to look at some of the problems in the Arctic but that hasn't been put into our activities at this point although I think it's something that we're moving towards in the future.

BOB WILSON: If I could ask a supplementary. Do you see that area being covered by another program in Environment? Is it that it's not important or that it's less important or it just doesn't fit in the LRTAP Program?

SUE MILBURN: I don't know why it's not in the LRTAP Program. I think we dealt with sort of one thing at a time and sulphur dioxide was the first thing and the nitrogen is the next thing that's coming on board. There have been attempts through the Toxic Chemicals Program to get the organics in and that really hasn't been very successful. We have a successful program in the Great Lakes under the Canada/U.S. annexes and then there's some interest in the North under the Indian and Northern Affairs Initiatives but in a larger scale it hasn't happened.

IOLA PRICE: Just wanted a little bit of expansion on exactly where the negotiations are at the moment. Whose leading for Canada and how do you see Fisheries and Oceans getting into the process? How do we get our information to you? Do you go directly or just how?

<u>**SUE MILBURN:**</u> The negotiations are being led by External Affairs and they really have the lead on the whole thing and the chief negotiator's is ... it's just slipped. I can't remember his name. We can certainly get that information to you and Environment Canada goes as support to that. The discussions are not at the level of science at all. It's very much politics. I think there have been some plans for some departmental and provincial briefings. I'm not sure where they're at. I thought that was going to happen fairly soon but I don't know where they're at this point. We can follow up and get some information to you if you'd like.

6.0. SOCIOECONOMICS B. Smith

BILL SMITH: First let me introduce myself. My name is Bill Smith. I'm with the Inland Waters Directorate of the Department of Environment and have been assigned the role of the LRTAP Socioeconomic Coordinator. I have joined the LRTAP program at a crucial time. I am not sure whether you would call it the end of the beginning or the beginning of the end.

I'm starting at the beginning. The 1990 LRTAP National Assessment has just been completed. So far the socioeconomic aspects of acidification have only received part time attention. What has been done has been an afterthought and shows it. As a result nothing much can be said because nothing much is known. I am the first fulltime Socioeconomic coordinator and at the present time I do not have a provincial counterpart. It is only since April that I have had a budget to call my own. I have the mandate to draw federal researchers together, hopefully later this fiscal year, where in a similar workshop, I hope we can draw up a blueprint for future research in this field.

To be perfectly frank, if a straightforward choice has to be made of where the biggest shorterm policy payoff will be obtained in socioeconomic research: emission controls at source or mitigation, then research on economic and regional impacts of industrial emission controls will be the number one priority. However, in the longrun we still need a basic understanding of how acidification affects sustainable resource use because our future depends on it. Although other economists may not share my point of view, I still place considerable importance on having something reliable and appropriate to say about how the future value of fisheries and wildlife are imperiled by airborne pollution.

This fall work started on a technical feasibility study of Canada's options when the current domestic emission control program lapses in 1994 because except for Ontario, efforts to control emissions or to do better could cease. So we have to look at where we can get additional emission reductions if we want to stay in the same place, and where we can get additional emissions reductions if we need them to achieve regional target deposition loadings at an acceptable cost.

Now industrial studies I'm certain are all foreign to you and I'm going to make minimum use of overheads. But the costs and possible economic impacts of any form emission control have not really been a major consideration up to now in the design of the control program. We've been very lucky because industry's response to the emission control program has been good and incidental to their own plans for plant modernizations and process improvements. Most industrial initiatives started before the acid rain program got underway and now will likely carry on for sometime.

Up to now the approach by all levels of government has been to control one pollutant at a time. Industry is beginning to say, look, we want to know where you're going overall because the choices we want them to make now may not meet their future needs, and their future compliance costs may be much higher than are absolutely necessary and unfavourably compared to any potential environmental benefits. We must start looking at the various options we have for emission controls in terms of total business costs and future competitiveness, and industrial and labour market adjustment needs.

Another thing that will be looked at very closely is the feasibility of emission trading. Up to now we've used largely a regulatory approach. That is to say we have told business how to control emissions instead of what we want in terms of results. So one of the things we'll look at are economic incentives such as tradeable permits. Emission trading has the advantage of levelling-out the cost between various industrial sources and businesses of different sizes, encouraging technological innovation and providing an incentive to shutdown dirty plants sooner. Although the US Acid Rain Bill calls for emission trading to the best of my knowledge less than 1% of the emissions have been controlled that way. The best example I can think of is the lead-in-gasoline program.

Another concern to me, as an economist, and an advocate of environmental protection is that further initiatives could be met with some degree of resistance both inside and outside government. For example, recently in the industry department, a branch has been established to look solely at the impacts of environmental regulation. So industry now has its advocates saying that soon we're going to reach some sort of regulatory gridlock. But we know based on the LRTAP Program that industry's experience hasn't really been all that negative. The costs generally have been over exaggerated. There are even industrial benefits such as greater production efficiency, improved resource recovery and marketable by-products. Environmental protection itself is an emerging industry. The other thing I would like to point out is that people assume that universally jobs are lost. The experience of anybody who's familiar with emission controls is that is not always the case. For example if you use <u>scrubber</u> technology jobs increase because it takes more people to run these things.

Let me turn now to the resource benefit or resource at risks studies that have been done. Generally it hasn't been a fruitful pursuit because the state of science doesn't support it, and there's no audience for it because decision makers have already accepted the need for emission controls. In fact some of the work that's being done now shows that the goal of zero emissions may be economically feasible.

Socioeconomic estimates of damage to fisheries resources have thus far been based on the imputed effect of acid induced changes on pH on catch and recreational fishing effort. Although this hypothesis is not without foundation it is not testable in its current form. We first require an accurate prognosis of atmospherically induced changes in water chemistry. There is a basic lack of knowledge about fisheries resources, the species and habitats that are exposed risk from acidic deposition. Fisheries scientists are not yet able to estimate reliably changes in yield or productivity from changes in pH. Catch alone is a doubtful measure of lake productivity. Surveys have shown that catch is not an important attribute of recreational anglers satisfaction. Although it is likely in a declining fishery at some point anglers will give up and go elsewhere, it is unlikely that there is a one to one relationship between catch and effort. Such socioeconomic estimates are questionable and it is doubtful that they can be extrapolated to national conclusions.

Then why have I come here? First I want to familiarize myself with what fisheries researchers are going to do in LRTAP. I'm very, very interested in this workshop, since I was told by Iola and others, that its purpose is to set research priorities. I would like to know what environmental economics you think should be done in your field. I would also like to present some suggestions and share some thoughts that I've had.

It's my view that emission controls, given even the current program, will take some time to put in place and it will take an even longer period of time for the environmental effects to be felt. So in the interim and even in the longrun there are habitats and species that will be excessively exposed to acidifying pollutants. Action may have to be taken to protect such habitat or species. Describing what would be lost in terms of either commercial, recreational or subsistence activity is a contribution that economists could make.

As well, I think that the comparison or development of ways of evaluating different mitigation methods in terms of their economic cost and feasibility, and the results you might want to achieve should be pursued.

All questions about toxics are of concern because while Health and Welfare may be working on health protection standards, the routes by which people are exposed and the population exposed are still generally unknown. So one possibility is determining the population exposed to risk through the consumption of fish and game.

Another possibility which I think might be fruitfully pursued is adding a socioeconomic module to the DFO-ESSA model. It is one of the very few attempts to draw together an integrated model of aquatic ecosystem risks, covering water,fish and wildlife effects of LRTAP. This model could provide the basis for spelling out some of the economic aspects of ecological risks.

There are lots of possibilities but the number of people that work in environmental economics is limited. I would like fisheries work to receive due consideration. If you have any questions, I'll answer them now. I hope that you now recognize that there are economists working out there on environmental issues, who have as strong an interest in air pollution and how it affects our future well being. Are there any questions?

Questions and Answers

__IAN DAVIES:__ Has the cost comparison of treatment at source versus damage caused when it's diffused been done?

__BILL SMITH:__ First, I think it's beyond dispute right now that source control is the most economical way and it's also the most sure way to reduce the risk from air pollution. There has been research done on comparing cost of control with resource benefits but it's highly speculative. But the results, for example, on the work done aren't trivial. It's just that you can shoot them full of holes because you're building on a high level of scientific uncertainty. I don't think we have to go that route now. I think, for example, in industry and people who are in the business of emission control the recognition that what was previously thought unattainable is now attainable. For example, in the sour gas business in Western Canada, the gas plants have the most efficient form of control going. It's about 98 - 99% efficient and people said we couldn't build a zero containment plant. One is being built next to Edmonton. You hear lots of complaints in pulp and paper saying that you can't economically control that source influence from pulp and paper plant but there's a zero emission plant being built in Meadowlake, Saskatchewan. So my belief upon my recent introduction is that source control is the way to go and that is it economically feasible. You have to sort of phase in the implementation of controls related to R and D and industries capacity to respond. You have to get them at the right time in terms of the business plan because they take decisions on a 15 or 20 year time frame. But it is the cheapest and surest way to go and that's where our research would go to support that. We've not done enough and we can do more. I hope it answers your question but the resource benefit side is highly speculative because of our lack of knowledge really of what's going on out there. But it's enough to convince people that it's a risk we want to avoid. Are there other questions?

7.0. MODELLING K. Minns

REGIONAL IMPACT ASSESSMENT and MODELLING

Publication: We now have three papers published in CJFAS and a fourth, on uncertainty analysis, will appear in CJFAS, completing the documentation of the DFO-ESSA regional model in its current state.

Fiscal Year 1990-1991: Most of the resources provided for this project were used to support the biomonitoring data base development. As a consequence there was no means of doing anything with the regional model. Last year I had part of a biologist's time who was also working on the biomonitoring program and we carried on some aspects of the validation work described last year. It was carried on for a few more months after that until he actually left and the PY was no longer available. We were pursuing two areas; exploiting the paleo-reconstructions of lake chemistry and looking at data sets where we had a time series that showed a change in deposition level a significant change in deposition level and significance changes in lake chemistry over the period. Only recently have more of these data sets become available. Once we had gone through that material, we decided that this was the right direction to go but that we really have enough data. We prepared a manuscript on this work and consulted collaborators. We concluded it was not adequate at that point.

Revisions for FY 1991-1992 and Beyond: The validation results led us to revise our notions of the direction for a renewed effort on the DFO-ESSA model. The approach we will pursue is the validation of the model with more data sets in conjunction with attempts to revise the model to bring in additional parameters. Nitrogen deposition is an obvious consideration but it is not clear it needs to be included. Do we have to being nitrogen into the site model to substantially improve our predictive capabilities. So rather than just assuming that we need to throw everything into the kitchen sink into the site model we want to take it step by step and not get overwhelmed. Because the nitrogen thing is going to be kind of complicated to deal with anyway.

Another aspect, which is stalled by the lack of monies this year, is the integration of the regional model with geographic information systems for both data input and visualization of model outputs. This would also allow the integration with the biomonitoring data base in terms of producing sites specific forecasts for biomonitoring sites as well as other sites you might select and the aggregate representation on a regional basis. There's more work to be done updating the model inputs. This will be partly a function of new data series that are available in different regions and additional parameters that may arise as a result of revising the site model.

This overall reconstruction will lead to other areas including implementation of further biological models. I think that includes the kind of thing Bill Smith (DOE) was just referring to when he talked of adding an economic component to the whole sequence we put together emissions to aquatic biological damage. So far the kinds of biological models we have developed are predicting biological features of systems that are not the kind needed for socio-economic assessments of resource impact. It does not mean they are irrelevant. It just means if you are looking at how catch rates for fishery would vary, predicting species diversity is not going to do you much good. So it's a question of some fine-tuning in the kinds of biological models and I think we have got options coming along that will help us in that area.

Finally in the critical load/target load area, we had already identified that. We did some preliminary work a couple of years ago but have not been able to pursue it so far. We do have some ideas along that line of developing load criteria based on biological damage and there are some interesting statistical questions in terms of actually calculating effect thresholds using regional population estimates.

DFO LRTAP BIOMONITORING DATABASE

This project had a late start as the initial budget was inadequate. Eventually the terms of reference for a contract went to DSS in June. There were considerable unexplained delays at DSS.

Contract awarded: On October 2, we awarded a contract to one of the five bidders. We awarded it to Monenco which is based in Ottawa and they have a limnological subcontractor, LGL.

St. Johns Workshop: We are holding a workshop Thursday and Friday after this meeting. We are going to deal with detail specifications for the design on the types of data sets entering the data base, how we're going to get them in, how we're going to get them out, and we will also look at the primary design of some of the constituent reports that we want to be able to do on a routine basis. So a certain portion of the results of the contract will allow us certain types of reporting. It won't be able to automatically generate an annual report at this time but we would expect to be able to do certain kinds of reporting. We expect that we will go through the data loading phase in the new year once we have agreed on the actual design criteria. The contractor has proposed a process of setting up a data design and then getting some feedback before we actually launch into loading data because we don't want to go down the wrong road. One thing I would like to stress there is that on Thursday we do want to get a good, solid start as soon as possible after lunch. We're aiming to start at one o'clock because we got only a limited amount of time available to us on Thursday and Friday.

Completion by March 1st: We expect to do everything by March 1st, with actual contract completion running a bit later than that. We should have a technical report describing the data base structure. There will not be a data report. It should capture a lot of the variability in terms of how we deal with different sampling methods, species coding, that kind of thing. All that will be in this technical report so we would have, as with the site descriptions, a central reference point for the whole data base. We will make sure the initial reports and analyses that we do specify in the contract will be ones that are actually of some immediate use to us once we have loaded two years data.

Fiscal Year 1991-1992 & Beyond: Since it is unlikely that we will ever actually get PY to run this activity, we are going to have to revise the budget in subsequent years to make sure that there are adequate resources to deal with the update, maintenance and reporting from the data base. I am looking at the kinds of costs we're getting with the development. We're going to be trying to work out a reasonable budget for maintenance and also looking at the whole question of how do we ensure that we are producing an annual data report from this system. It is logical that whoever is actually responsible for the updating and maintenance would also be told this is how we want an annual report to look and then the sub-committee would write an overview on that and so forth. I think we can find a mechanism that will work for that.

DFO-LRTAP PHASE V - SENESCENCE

This third topic is somewhat a bit different. You may not agree or you may disagree with me on this. I have some comments, observations on DFO-LRTAP, Phase V, which I have characterized senescence. The program is suffering from declining vigour, vision and visibility. The wrinkles are attracting most of the research attention now. There is sagging interest in monitoring. Sue Milburn (DOE) shakes her head. I mean sagging interest in the people actually doing. We are tired of pushing for emission controls more stringent than those adopted by our managers and leadership. These are all signs that retirement is on the horizon. For LRTAP-V to be successful, the elements of the program and the individuals involved must create new vigour and drive. Elements which were added to the program but remain peripheral should be excised. If the Greenplan thrust is towards monitoring with emphasis on sulphur and nitrogen for LRTAP, the contaminant programs should be phased out or encouraged to seek resources elsewhere. The biomonitoring program will only succeed if the individuals are given encouragement to be creative and productive. There is little cohesion in the program at present. Cutting off much of the underlying research will only serve to dampen enthusiasm. Like in the film Cocoon, LRTAP-V should be taken as a chance to avoid senescence through rejuvenation.

Questions and Answers

SUE MILBURN: Two comments. First for your modelling and if you try to start to put nitrogen into your model, you might be interested to know that Marv Olsen using the AES LRTAP model has now developed a transfer matrix, the first cut anyhow for nitrogen. Looking at nitrogen deposition. He's out of the country until January but I know the first cut is available and we could get to them to you if you want to start working in that direction. The second thing is a comment. I'm really disturbed to hear that you don't ever think you're going to get a PY for the data base. To me, why are we doing this sort of work if we don't have a good data base and we can't run it? That would be one of our top priorities and I hope that we will be able to work through what resources we do get from the green plan and what we have for A base to have a database. I don't know why we go out and do biomonitoring if we don't have a proper data base. Lecture over.

BOB HECKY: Well I think perhaps you're somewhat pessimistic on the monitoring side because your're expressing a local opinion rather than a national and global opinion. I do think that the monitoring you're referring to now has a challenge if it's really going to be written into the U.S./Canada Accord and I think... I'm going to ask a question whether or not in view of the scenarios that Sue just put up and the need or expectation that there will be monitoring to decide whether or not we're having the kinds of effects we want? Is there a need to look at the program again at this point in time or are we completely satisfied with the sites we have? I'm thinking particularly about the scenarios she put up and the maps and where things were going to change and how the DFO Program fits with that.

KEN MINNS: Yeah, I think until we're really in a position to look at the first couple of years of data, we wouldn't want to pre-judge how good or not good the particular configuration we're working with. We know there are statistical restraints on the whole scheme but I think we shouldn't condemn it out of hand.

BOB HECKY: I'm not condemning it. I think we're ahead of the game. I'm just asking the questions now that perhaps you now have some model scenarios that may be emerging, whether or not you want to take those into consideration within our biomonitoring program?

KEN MINNS: Yes, I think we should start to look at that again. Ian's got something...

IAN DAVIES: Perhaps by way of commenting, I can show you where existing sites are. At least in Atlantic Canada, in Newfoundland have very sensitive ... INAUDIBLE ... likely see some small improvement based on Sue's speculations there in the Perry Sound District and perhaps a worsening of conditions in Quebec. It's hard to say because that state in the 10 to 20 kilogram area. The problem with adding extra sites is the annual cost per site is expensive. It ranges from about $60,000.00 to $120,000.00 or $130,000.00 per group of five lakes or rivers.

KEN MINNS: Given that there's a layer of straight water chemistry monitoring that lays over this biomonitoring, I wouldn't be that worried in that respect. Any other questions?

8.0 ONGOING/FUTURE MANAGEMENT I. M. Price

Green Plan

I thought I'd say a little bit more about the Green Plan because I find, even within DFO Headquarters, there's some confusion about what it is, and whose doing what and under what circumstances.

The Green Plan started as a framework document written by DOE and it was widely circulated to the public. DOE asked for comments in writing and also accepted comments at a series of public hearings or consultations across the country. On the basis of comments received, DOE prepared and published a summary document which summarized the public's concern in response to the various chapter or page headings in the original document.

From a LRTAP point of view, that created a small problem. In the public's perception LRTAP and acid rain issues are reasonably well understood and the public expects the government to do something. We are perceived as having recognized the problem and also, I think, perceived as having done something about it. Certainly the public is very well aware that the United States is moving, albeit somewhat slowly, on resolving the issue. Therefore there was not a great deal of public comment on the acid rain chapter.

The lack of public comment on the acid rain chapter presented us with an image problem. We have an ongoing program based on research, biomonitoring, public information and a good deal of what's in the Green Plan regarding pollution control applies to LRTAP. But the public responds to emerging threats; threats that are not being properly addressed or issues that are somewhat old but have not been properly addressed in the public's eye.

Within DFO we have been working to get the LRTAP issue, the acid rain issue, addressed as a continuing function, one that should be funded on an ongoing basis. Departmental submissions on the Green Plan tend to be optimistic and they overestimate how much is needed in resources to address the issue. The political response therefore has to be to modify or dampen that request somewhat. The LRTAP program will, of course undergo some resource shifts and some changes in emphasis but will continue to provide the kind of information that Sue Milburn outlined as being needed in the ongoing discussions with the United States.

Cabinet is now considering various courses of action in relation to the total Green Plan which represents all of the public's and government's comments on government initiatives on the environmental front. It is possible that as early as October 16 there may be some response from Cabinet as to what initiatives are to be funded. Mr. DeCotret has said he would like to have the initiatives published by winter. So, we may know by then exactly where LRTAP stands and where other initiatives which touch on LRTAP such as climate change, the NOX and VOCs issues.

We are working on the acid front and we are told that organics work will be funded elsewhere. DFO has been in the forefront of funding organics work under the LRTAP banner because we recognize that these compounds are volatile and move great distances. We're waiting to see exactly under what heading the organics issues will be addressed. We will, of course, continue to keep an eye on them from the LRTAP perspective and meanwhile it's business as usual.

<u>LRTAP 1991 and Onward</u>

I'd like to turn to what we're doing this year and to what I see from a departmental perspective happening in the current fiscal year. I don't think we have ever had a consolidated report on how the LRTAP money has been spent in the department. This year I would like to see short reports on all the projects. Tell us what the objectives were, (you can take the objectives from the project proposals) and let us know how you met them. Please identify the successes and failures and I don't mean failure in any pejorative sense. Tell us how the things that didn't get done can be done next year and what we need to do to overcome these problems.

For those of you who hadn't seen it pass through your Regions, the LRTAP subcommittee considered a series of proposals which was sent out to Science Directors. These should have been circulated through the Regions. Each proposal has a number in brackets beside it and the O & M and capital assigned to that project is listed. We're asking you, the experts in the LRTAP business, to report back to us what you did with the money.

We now have a framework for LRTAP V. You will recall that this time last year we went through an ambitious exercise of how we were spending and where we should probably be putting our money. Based on that exercise the LRTAP subcommittee considered the project proposals, funded some and decided the priorities were such that others could not be funded.

We know what we want to do. It will then remain for the LRTAP subcommittee to try to place what you, the experts, and what we, the LRTAP subcommittee, identified last year as our priorities, into the resources we get from the Green Plan based on what has been decided at the Cabinet and Treasury Board level as the government's priorities. It will require a much tighter focus to allocate, within the priorities that we have set, the amount of money that we will receive.

Last year's money (1989-90) was allocated as shown in Table 1. Of the $2.505M in LRTAP funds, $1.0M came from internal reallocation within DFO. For 1990-91 we went to Treasury Board for bridge funding at LRTAP IV levels, and we got 2.6 million dollars (Table 2). It was allocated as $2.064M O&M and capital and $536M salaries. The 11 PYs went to HQ (1), Central and Arctic (4), Quebec (2), Scotia-Fundy (3) and Newfoundland (1).

We are again asking for PYs from the Green Plan and we don't know if we'll get them. In order to properly look at it we will be asking Science Directors and Biological Science Directors to confirm, or update, a 1987 table of how the PYs and dollars are allocated in A base because LRTAP resources constitute B base. DFO's A-base in 37 PYs in the LRTAP Program, and most of the dollars go to salary support.

I might add, is that government does not want to see the Green Plan to be a self serving exercise. It [government] wants the department to identify it's priorities and assess programs against current policies. We will of course be continuing to do that. They probably will not fully fund any one proposal or set of proposals such as LRTAP, Climate Change or the Arctic, as requested by the various departments. We must spend our money wisely and be prepared for some slight shifts and probable cuts to our expectations.

<u>How the LRTAP was Allocated</u>

Table 1 shows how we spent our LRTAP allocation in 1989-90. (Table 2 added in editing for comparison.) This does not include any account of how the 37 PYs were spent. Of the 2.5 million dollars, cut off just slightly over half-a- million for salaries. Of the remaining $1.99 million, we spent 29% on biomonitoring, 60% on cause and effect studies, 5.5% on mitigation studies and risk assessment and 3% on impact modelling. In the Regions, Pacific Region did not have any biomonitoring program, Central and Arctic used 30% of their allocation on biomonitoring, Quebec spent 52%, Scotia-Fundy 22%, and Newfoundland 70%. So that's how our biomonitoring effort is allocated among the Regions.

I rather suspect that your recommendations from tomorrow's meeting will be for major shifts in emphasis but I would be interested in hearing what these mini-workshops recommend by way of shifts in dollars allocated. The LRTAP Committee will also want to consider what you say. Resource shifts between the sub-programs are almost certainly needed based on what Sue Milburn has shown in the deposition scenarios, how or where emissions might be cut, based on the AES modelling data and what the U.S. might do.

Table 1 - Regional Utilization of LRTAP "B-Base"* by Category ($ 000s) 1989-90

	Region						
Research Category	Pac	C&A	Que	S-F	Nfld	NCR	Total
Biomonitoring	10	218	107	110.6	130	0	575.6
Cause & Effect: SO2 Research	0	417	74	291.8	14.5	2	799.3
: Non - SO2 Research	48.5	188	5	55.6	76.5	9	382.6
Mitigation	0	0	0	110	0	0	110
Risk Assessment & Impact Modelling	0	66	0	0	0	0	66
Socio-Economic	0	0	0	0	0	23	23
Administration * * (NCR)	0	0	0	0	0	28.5	28.5
O&M and Capital	58.5	889	186	568	221	62.5	1985
Salaries	0	189.2	94.6	141.6	47.3	47.3	520
Total	58.5	1078.2	280.6	709.6	268.3	109.8	2505

1989/90 Percent Composition by Region of LRTAP O&M and Capital "B-Base" Total

Region	%
Pacific	3
Central & Arctic	44.8
Quebec	9
Scotia - Fundy	28.9
Newfoundland	11.2
National Capital Region	3.1

1989/90 Percent Composition by Category of LRTAP O&M and Capital "B-Base" Total

Category	%
Biomonitoring	29
Cause & Effect: SO2 Research	40.3
: Non - SO2 Research	19.3
Mitigation	5.5
Risk Assessment & Impact Modelling	3.3
Socio-Economic	1.2
Administration * (NCR)	1.4

*Includes $1 million internal allocation from DFO

**Includes LRTAP Workshop, Annual Report, and Contract Work

Table 2 - Regional Utilization of LRTAP "B-Base" by Category ($ 000s) 1990-91

Research Category	Region						
	Pac	C&A	Que	S-F	Nfld	NCR	Total
Biomonitoring	0	210	136	133	139	0	618
Cause & Effect: SO2 Research	0	364	95	185	12	0	656
: Non - SO2 Research	40	215	35	38	50	0	378
Mitigation	0	0	0	205	0	0	205
Risk Assessment & Impact Modelling	0	67	0	90	0	0	157
Socio-Economic	0	0	0	0	0	0	0
Administration * (NCR)	0	0	0	0	0	50	50
O&M and Capital	40	856	266	651	201	50	2064
Salaries	0	194.9	97.5	146.2	48.7	48.7	536
Totals	40	1050.9	363.5	797.2	249.7	98.7	2600

1990/91 Percent Composition by Region of LRTAP O&M and Capital "B-Base" Total

Region	%
Pacific	1.9
Central & Arctic	41.6
Quebec	12.9
Scotia - Fundy	31.5
Newfoundland	9.7
National Capital Region	2.4

1990/91 Percent Composition by Category of LRTAP O&M and Capital "B-Base" Total

Category	%
Biomonitoring	29.9
Cause & Effect: SO2 Research	31.9
: Non - SO2 Research	18.3
Mitigation	9.9
Risk Assessment & Impact Modelling	7.6
Socio-Economic	0
Administration * (NCR)	2.4

*Includes LRTAP Workshop, Annual Report, International Meetings and Additional Regional Support

We don't have final maps. We don't know how State emission cuts will, in fact, influence the deposition scenarios for Canada and so at the moment it's a bit of a moving target.

The other thing that I would like the workshops to consider tomorrow is the impact of regional levies on your LRTAP dollars and how are those levies affect your ability to deliver a LRTAP Program. Secondly, are there serious shortfalls in the LRTAP Program as you see it now. Based on what you heard Sue Milburn say and based on what you say among yourselves and your colleagues in other departments and regionally, are there serious shortfalls that we are not addressing? How they might be addressed? There are some unspent monies, but not a great deal. Let me know what those shortfalls are and we will certainly try to address them to the best of our very limited financial abilities.

Next year the LRTAP Committee, when it meets in January, will be answering the questions "Does this Workshop need to be held each year? Is this a meeting you see of immense value?" Workshops are useful but it's expensive to move around. There's a very small turnout this year. Is that because of expenses, time constraints, or the wrong time of year?

I'd like to say something about the future. The new ADM of Science, Dr. Brian Morrissey, is asking for complete evaluations of all the major program activities. I've had the good fortune to have him start first on aquaculture so I've got an idea of what it is he's likely to ask when he gets around to the habitat and the LRTAP function. He's asking for a complete and exhaustive listing of all projects being done within the Department and then matching that with projects that are being done outside. He needs to know who's doing what so he can respond to statements such as "nothing is being done". I will be coming to you sometime within the next two years for complete listings of what's going on in your Region or in your Province so that we can complete the kind of analysis that he's asking for. It's a very interesting process that he's running through and his mind is very agile and he's a very open person. He wants to know everything that's going on and why. It's been a lot of fun trying to answer those kinds of questions and I think you'll enjoy the process with me.

I think I have covered just about everything and I will then turn it over to you.

BOB HECKEY: I guess I'm new to all this and I still have some confusion in my own mind and it may be a subtle point of whether the bridge funding this year was to start LRTAP V or are we into a new program? Was it a bridge funding to make sure LRTAP IV got finished off? Have we defined what LRTAP V objectives will be or should be? I think I'm just a little unclear in my mind as to where we are with the overall Program.

IOLA PRICE: The money was extended at LRTAP IV levels although we, in fact, went through the exercise of trying to define what we would do under LRTAP V. When it became obvious that DOE had received their LRTAP money by other means and Department of Fisheries and Oceans had not, we asked Treasury Board for the amount of money that we had identified as being necessary to start LRTAP V, but we were granted LRTAP IV levels. We had actually planned it to be a kickoff for LRTAP V. In fact in terms of biomonitoring, it was almost year 2 because this is year 3. So it's a hybrid but really much more leaning towards the LRTAP V.

BOB HECKEY: LRTAP V is it in the Green Plan?

IOLA PRICE: Well it's not called that but, yes. Sue you want to make any comments on that? But, yes, it is LRTAP V.

SUE MILBURN: Where we had started working on LRTAP V long before the Green Plan ever existed and we had the whole thing ready to go and Bill Hart worked on it for two years trying to get the thing ready to go. Then events just took over the planning process of LRTAP V and somebody high up said this thing has to go into the Green Plan. We were caught with this problem that the Green Plan was going to start the year after and we had to find bridge funding. Either Health or Forestry was in the same bind as DFO. So I think the word hybrid is a very accurate description of what it is.

BOB HECKEY: Are the funding levels in LRTAP V or whatever it is in the Green Plan likely to be like current funding levels or has there been a look at whether it should be less or more?

IOLA PRICE: We'll have to wait to see what comes up. We know what we recommended. The decisions are not ours to make and I'm sorry I can't answer the question because we don't know.

IAN DAVIES: Again, I think I share some of Bob's confusion but I've been in this all along. Last year we spent a great deal of time talking about process, about structure, about funding, about how we would divide things up. We spent almost no time on priorities for LRTAP V because everything was up in the air and we assumed we would be operating with the bridge funding. I think Ken mentioned a spark that's missing now. I think part of that spark is that we've been carrying on status quo for two or three years and there's some important questions we haven't looked at. We haven't yet defined what LRTAP V or our next 5 years where the work should be.

IOLA PRICE: Is that something we can work on tomorrow during the three mini-workshops or is there not enough time? The Regions have identified their priorities internally and they come up through the LRTAP sub-committee. It may be that we need some more work. If this Workshop then doesn't produce that, then we will have to come up with a mechanism that, in fact, does address that. To a certain extent, our priorities will be dictated by the amount of money that we get and dictated by the negotiations with the U.S. At the political level perhaps some of the problems are seen to be solved. It's up to us to try to steer some kind of course between the amount of money that we do get, the amount of money that we think we need and the political realities of what the politicians see as being the pressure points from the public.

IAN DAVIES: No. I have some concern. I guess thinking back to the origins of the LRTAP Program within DFO. Part of the secret of its vitality, I think, was that it was a bottom driven program by the scientists who said we must do this work. There are bits and pieces missing. Now it seems to be taking a totally different flavour. It's what the general public's perception and the Minister's perception of what we should be doing. I think it's about time the scientists got back into the game and said, damn it, we're missing some really important information and part of the reason the meeting's small here now is I think we've lost a number of people through attrition. They just got fed up with drifting and promises and I think we can rekindle that but what we really need is some tight definitions and there are some big problems that we haven't addressed yet.

IOLA PRICE: Can we make a start on that tomorrow in the mini-workshop?

IAN DAVIES: Yes, I think that's reasonable.

IOLA PRICE: I'll be visiting each of the three workshops to listen to the deliberations and then to hear your recommendations. I don't get the impression that the series of recommendations that are made each year from the general LRTAP Workshop itself are as useful as perhaps they originally were in 1984 or '85. Programs tend to be regionally driven and things get put in place that are almost carved in stone. There isn't an easy mechanism for changing those stones once they get chipped short of doing something by fiat.

9.0 WORKING GROUP REPORTS

9.1 Biomonitoring Working Group I. Davies, Chairperson

Each of the subgroups convened on the morning session of 11 Oct. was asked to find out what effect shortfalls in resources have had on programme delivery in the past year, determine what else needs to be done and what will be required to do it, and establish priorities for their activity under the next segment of the Departmental LRTAP programme (LRTAP V). The results of the subgroup deliberations are given below.

The Effect of Resource Shortfalls

Delays in funding, lack of a PY, and regional taxes (in some regions only) have all acted to constrain or delay parts of the Biomonitoring Programme. Methods of coping with these problems have varied. It is to the credit of each region that the Biomonitoring Programme has functioned as planned with no deletions for this year. Shortfalls of O&M have been covered off either by using up reserve stocks of sampling equipment, lab supplies, etc., or by diverting money from lower priority projects to Biomonitoring (eg. from risk assessment modelling to establishing a monitoring database). There was agreement that if shortfalls continue the programme will suffer. Because the monitoring has been designed to be a minimum effort it cannot be reduced in scope. It is likely, therefore, that when there are shortages, contracts for sample and data processing will be the first things to be cut. Requirements for this work will not disappear, the costs will simply be defrayed to future years and availability of results will be delayed. Both of these consequences were viewed as undesirable.

What Additional Things Should Be Done in The Monitoring Programme?

Two areas that are essential to successful, long-term operation of any monitoring programme are: 1) adequate Quality Assurance and Quality Control measures, and 2) database management. At present both are being addressed, in the short term, by the taxonomic verification exercise, QA/QC workshops, data analysis development, and contracted database development. Much remains to be done. The subgroup recognized a continuing need for QA/QC and recommended that an additional 5% of the annual budget was needed to carry out this function. A portion of this O&M money would be used to support routine QA/QC procedures (check samples, training sessions etc.). The residual would be used to run workshops on taxonomy, or statistical methods development as the need arose. It was proposed that the annual QA/QC budget would be most effectively used if it were administered by the DFO LRTAP Biomonitoring Working Group, rather than treating it as an addendum to each of the regional allocations.

On the subject of database management, the subgroup agreed that there was a continuing need for a database manager to import new data into the system as it becomes available, to answer requests for data, provide update information to users, to maintain linkages with other Canadian and international government departments, to supervise the production of an annual report, and to coordinate the analysis of data. Although such a function could be carried out by contractors (as it was this year) the arrangement is cumbersome, costly (we estimated a cost of $60K annually), very vulnerable to funding cuts, and not particularly secure. A much preferred option would be to use 1 PY and $25K annually to perform the function "in house". Compared to the overall investment in biomonitoring, both in terms of $ and PY's, the investment in a full time database manager is trivial. It was also be pointed out that within DOE both Inland Waters and AES have such a position, as does the European programme. The lack of a permanent database manager within DFO was viewed as a serious oversight on our part.

The projected costs for these two additional activities, together with the overall programme estimates are summarized in the table below. No adjustment for inflation has been made, nor have the regional taxes been taken into account. Budgets for QA/QC and the Database manager are treated as separate items.

Priorities Under LRTAP V

The subgroup examined the scope and objectives of the DFO Biomonitoring Programme and agreed that, while there were recognizable limitations to the programme and it would always be desirable to expand the work to include a broader spectrum of habitats and biota, what we had was adequate, except in the areas of QA/QC and database management. Beyond the basic operational requirements of the programme, these two missing items should be given highest priority under the monitoring portion of LRTAP V. There was also agreement that the list of proposed activities, as outlined by I. Davies in his report to the workshop on 10 Oct, 1990 (see above), should represent the workplan for biomonitoring in the coming year.

LRTAP V REQUESTED SUPPORT FOR BIOMONITORING ($K AND PY'S)

AREA	TYPE	90/91	91/92	92/93	93/94	94/95
NFLD	O&M	119	131	133	135	137
	CAP	21	23	11	11	11
	PY	1.5	1.5	1.5	1.5	1.5
S-F	O&M	113	103	100	100	100
	CAP	25	10	10	10	10
	PY	2.0	2.0	2.0	2.0	2.0
QUE	O&M	115	115	115	115	115
	CAP	23	13	?	?	?
	PY	2.0	2.0	2.0	2.0	2.0
C&A	O&M	186	167	167	170	175
	CAP	19	12	12	13	13
	PY	2.2	2.2	2.2	2.2	2.2
QA/QC	O&M	26	26	26	26	26
	CAP	-	-	-	-	-
	PY	-	-	-	-	-
DBASE	O&M	25	25	25	25	25
	CAP	-	-	-	-	-
	PY	1.0	1.0	1.0	1.0	1.0
TOTALS	O&M	584	567	566	571	578
	CAP	88	58	33+	34+	34+
	PY	8.7	8.7	8.7	8.7	8.7

9.2 Cause and Effects Working Group G. Lacroix, Chairperson

Cause and Effect Discussion Working Group
Summary of Priorities and Recommendations (1990)

"Cause and Effect" studies were identified as receiving 56% of LRTAP resources. It was indicated that this is somewhat misleading because it includes resources allocated to surveys/research on metallic and organic contaminants. Traditionally, these studies were directed at the cause and effects of acidic deposition. The following is a brief summary of some priorities (not necessarily presented in order of importance) identified by those in attendance at the "Cause and Effect Discussion Working Group":

1. Mechanisms and extent of chemical and biological recovery in lakes and rivers. What level of recovery or continued acidification will we have under controls presently in effect or proposed (critical/target load)? There is much ambiguity at present and findings to date indicate the process to vary greatly among regions depending upon history of acidification and geochemistry among a number of factors. Studies using experimental (i.e., whole-lake and stream manipulation) and ecological (i.e., processes and population dynamics) approaches are under way and planned.

2. Role of nitrogen deposition in acidification and development of critical loads. This is deemed to be more complex than that of sulphate deposition because of the importance of nitrogen as a nutrient and possible delays in expression of acidity. We must consider what factors determine critical loads? A study using the whole-lake manipulation approach is underway. The importance of nitrogen in acidification of rivers is more ambiguous or hidden because of the apparently low levels, the interaction of riverine processes, and the variety of other types of episodes important in acidification. Some novel approach is therefore necessary.

3. Development or refinement of a hierarchy of "site" and regional models for hydrochemical and fisheries responses in rivers and lakes to acidification and recovery for management of affected resources, hypothesis testing, identification of knowledge gaps, and in support of control programs. A project is underway using Atlantic salmon in rivers of Nova Scotia and

the extensive research information and data available for that species and region as an example. An extensive modelling exercise has been completed and published for lakes in eastern Canada.

4. Importance of fish movements (i.e., selection/avoidance responses, use of refuges) in relation to acidity episodes in rivers in describing the impact of acidification on fish populations. Some research necessary for a better understanding of observed responses in fish populations (i.e., dynamics) in relation to that predicted by stage-specific dose-response relationships, and ultimately for accurately predicting the level of control required for recovery, predicting the extent of recovery, and understanding the mechanism of recovery.

5. Development of "performance tests" to detect the sublethal effects of increasing acidity on fish from the effects of stress caused by other factors. There seems to be a desire to develop and standardize a sensitive test or battery of tests that are applicable across regions and specific enough to differentiate acid stress from stress related to other environmental factors. A study is underway to examine the potential of using sex hormone metabolism as the basis for such a test. A cross regional approach and comparison was suggested.

6. Detection of importance or lack thereof of metallic and organic contaminants in the environment and the effects of measured levels on biota. We are still at the point of determining what organic contaminants are present and important. There is a need for some level of continued search to document levels and gradients in the environment. However, research is needed to develop dose/response relationships and establish linkages to population responses because of a lack of good knowledge base to set standards. With regards to metallic contaminants, a cadmium whole-lake experiment is underway to determine effects at the ecological level and establish linkages to performance. It should address how to approach water quality standards in general. With regards to organic contaminants, a whole-lake response experiment to addition of a single organic contaminant (not yet selected) is in the planning stages.

A large proportion of the discussion time in this group was related to organic contaminants. The reason for this is probably the general lack of agreement on what direction, if any, studies of organic contaminants should follow, and under which umbrella (i.e., LRTAP, Environmental Agenda, or other programs) these studies should be funded. The organics program suffers from a lack of overall coordination or goal. This may be because it simply appeared during the last LRTAP program. Unlike projects related to acidification, it never underwent the peer review and scrutiny that the LRTAP program initially went through in order to orient and focus the program and its studies to attain specific goals and answer key questions. Such an exercise is probably overdue and necessary if the organic contaminants program is to survive.

9.3 Palaeolimnology Working Group S. Ray, Chairperson (presented by J. Smith)

Working Group Recommendations
Chairman:- Dr. Sankar Ray
Presented by:- Dr. John Smith

Paleoecology has not been given much focus at this workshop and the reason may be partly due to the fact that there has been nobody to take serious interest in this particular subject. Paleoecology is the time reversal of monitoring in its purest sense. If monitoring is important, then paleoecology is equally important because it helps in reconstructing what has actually happened in the past, (so the future can be predicted).

Yesterday we heard that the maximum allowable loading target is only 8 kilograms of sulphate per hectare per year to achieve a target pH of 6.0 or below in Nova Scotian lakes. But with the expected control program in place in the future, we expect the input to be at least 10 to 20 kilograms per hectare per year which is expected to push the pH level considerably below 6.0. It is not known what the historical pH levels were in Nova Scotian lakes or any other Maritime lake.

If we try to look at the importance of paleoecology, from an economic perspective or from a cost effective point of view then determining the ancient pH levels in these lakes is extremely valuable information to guide the thrust of our control program in the future. If we find that the levels were actually substantially below pH 6.0 in the past in many of these lakes then it will very heavily influence our activities in the future. The working group was not prepared to put a price tag on the importance of this information. However, we would like to stress that this research perspective be up there in the list of DFO priorities.

The question is, are we capable of reconstructing pH? The only major proposal or thrust that the working group is aware of is a contract that was conducted by a company called ARECO. This was completed last year (1989) and the results are presently available. A close look at the report reveals some serious concerns and it is a question of what data from the study are useful. We think that due to lack of strong scientific presence in the program there was no good quality control. At this point, we do not think the study permits us to reconstruct pH levels in Maritime lakes. However, we feel that the report should be circulated through DFO for comments and to determine what components of the study are sound. The opinion of the working group is that there may be information that we can extract from this report but we have to take an entirely new look at paleoecology in lakes in the Maritimes and Eastern Quebec.

There are two possible objectives in using paleoecology in LRTAP research. One is to go back and reconstruct the record of certain events, such as the history of lead inputs or pH changes, to try and identify the source functions for those particular inputs. The second objective is much simpler and that is to look at gross changes sort of an on/off case - i.e before and after something has happened. The ARECO proposal, attempted to reconstruct the entire history of pH changes by examining lake sediments. Basically, they attempted to develop transfer functions between diatom assemblages and pH by looking at existing lakes surface sediments and relating them to water chemistry or alternatively by using transfer functions from other regions. The objective of this study was to reconstruct the pH history inferred from diatom assemblages in dated cores. This was a huge study, and also possibly beyond the requirements of the LRTAP Program. The discussions of the working group tended to focus on a simpler objective. The objective is simply to try and identify the gross change in pH, i.e. to try and attempt to determine the pH prevailing in historic times in some of these lakes and compare them to the present day pH. Is it necessary to know the entire history of pH changes? Do we really care if the pH change occurred in the 20's, the 30's, the 50's, or the 60's? Is that really essential? From a cost effective point of view it is probably not that essential. What we want to know is what was the pH of the lakes in historic times, i.e. several hundred years ago. We have concluded that it may be appropriate to focus on the gross changes in pHs.

Our recommendations are the following:

1. We think it's important to take a fresh look at the study of paleoecology and it's application to the LRTAP Program. To further this objective we would like to establish a sub-committee with proper DFO representation. Hugh Bain has kindly consented to be the chairman of this committee. The committee will examine these questions in some detail and try and map out a more appropriate strategy for the focus of the paleoecological program. This sub-committee should also examine the ARECO proposal and consider the validity of the study and see what data are useful.

2. The type of program envisaged in the future would be one which would focus more closely on the transfer function itself, that is the relationship between the diatom assemblages and pH in the lake. We must have complete confidence in this relationship. We have discussed a number of problems, and have considered looking at putting out sediment traps in the future and looking at the diatom assemblages in the sediment traps themselves as a means of actually characterising the assemblages in the lake and the relationship to pHs in the lake. The problem with sediments, even surface sediments, is that the surface sediments of these lakes may contain a lot of material that's been mixed upwards from older time periods. Even the top few centimetres may contain material much of which may be a hundred years old. Sediment traps would be very valuable in determining if the surface sediments do give an accurate depiction of what is going on in the lake. The first thing would be to match up sediment trap diatom assemblages with what is in surface sediments. If they do not agree, then there is a problem since the surface sediments are not giving an accurate depiction of what is going on in the lake at that particular moment. This would also address the validity of many regional transfer functions that are currently in use.

3. The next step would be to collect a series of cores by a

methodology to be worked out, date these cores using several tracers. Radionuclide tracers or any other tracers that are available would be appropriate. It would require a different type of control compared to previous studies if we were not that concerned with actually reconstructing the complete historical record. We would only want to find out about the old sediments and compare them to the new sediments.

4. Finally, the diatom assemblages would be examined in the cores and in effect we would target the pH history of the lake (e.g. only for the 1800's). This work can be undertaken only if lake sediments are laminated and contain good strata. A very precise reconstruction of the pH history could be used to provide invaluable information regarding anthropogenic input.

It is pertinent to note, that one may look at a hundred lakes and not find a single one that can be precisely dated. We should conduct the study to get the most cost effective, reliable information on pre-acidification and present day pH history .

We believe that this project could be done on a three to four year time frame and that our primary objective is to determine the baseline pH levels for these lakes before any other meaningful work can be undertaken or attempts made to reduce the acidic sulphate inputs in the Maritime lakes. Other related studies can be undertaken only when the initial objective is attained. The proposed paleoecological sub-committee of experts should look at the whole problem in greater detail if the program is to be successful and provide useful results.

10.0 WORKSHOP WRAPUP I. Price

WORKSHOP WRAPUP

<u>IOLA PRICE:</u> It's 12:15 and we've already run 15 minutes over and so I think we'd better get into our wrap up. Thank you very much. I'm sorry to cut you off but I think some of those questions can probably be addressed in the sub-committees that have been set up. There are a number of points that I wanted to make just as a kind of a final wrap up and I'll run through them quickly.

First of all, in regard to regional taxes, it's my understanding that Quebec and Central and Arctic have an overhead tax of various proportions. Are there any others?

<u>BOB WILSON:</u> ... and no tax on the 2% in Pacific Region either but I would like to defend the validity of regions who do impose a tax. I think that there is a very legitimate thing to do. B base funds impose additional costs in all kinds of areas. Am I preaching to the converted here?

<u>IOLA PRICE:</u> No, not quite. I understand the reason for taxes but I'm not convinced that some of the programs aren't being disproportionately taxed.

<u>BOB WILSON:</u> Well, that's something we'll have to look at.

<u>IOLA PRICE:</u> The question was asked about the role of organics and Sue Milburn's comments yesterday. In general the "A" in LRTAP stands for acid. DFO has been in the vanguard of this kind of research and has always allocated a certain proportion of its funding for organics transplant work.

With the Green Plan money coming, it may be more appropriate to consider some of the organics work under the toxics heading. We will be talking, you and I, and the people at Headquarters to see how to maintain the momentum in this program and to ensure that none of the organic projects fall through the cracks.

If you have the mini workshops recommendations written up, would you please provide them to Michelle Roberge so they will be part of the written record of this meeting. I know you've read them off and they are being recorded but if you have a slightly different way of having it said, please make sure it gets down to them.

I'd like to turn to the recommendations that came out of the MLI Workshop and let you know at least what has or has not been happening. We talked about the need for a popular document predicated on the fact that the 1990 assessment would be out. We wanted to contract with someone to take that document and put it into a simpler and popular article that we could use to let people know what our program was set out to do and what it achieved. That popular document was to be accompanied by coloured photographs. The 1990 document as I last saw it, was extremely technical and did not satisfy the requirement that a non-technical person could understand what the LRTAP Program had achieved. I understand it's being re-written and Sue Milburn, in fact, is working on the Executive Summary. I still think that we need a popular article and in the meantime, Floyd Elders who used to work for the Inland Waters Directorate of DOE has produced something which comes fairly close to what it was I, at least, had in mind and his document could serve as the basis for a rewrite.

We also talked about criteria against which your project proposals would be judged and here I have to say that we didn't get it done. We do talk about scientific excellence and I think you all know what that is. I'm fairly well convinced that in your own minds and in your project proposals and the work that you do, you meet that test. Scientific excellence, inter-regional cooperation, inter-departmental cooperation, cooperation with the provincial counterparts, these are the catch words of the '90s and we're certainly going to give points to projects that show that, in fact, you're looking beyond your own borders.

We had originally allocated $3,000.00 for international travel but for reasons of budgetary restraint we had to restrict that to $1,000.00 Ian Davies used it to go to Russia. Next year if there is a workshop we'll ask Ian to show his slides and give us an idea of the data he obtained. I will be asking the LRTAP sub-committee if they still think that it is a good idea to have a small pot of money for international conferences to supplement regional money.

Shortfalls. If there are shortfalls or money unspent in the regional programs, let us know. This is the time of year when we start thinking about reallocations. Please let Hugh Bain know so that we can begin to address serious shortfalls in the other regional LRTAP programs.

The next question to address is "where do we meet next year, if we meet?" All programs go through curves of growth and senescence. It's been suggested, and I'm not sure that the suggestion isn't correct, that maybe this Program is in a little bit of a down swing. Do we need to meet every year? Is this the kind of meeting that charges you up and sends you back home full of enthusiasm? This meeting certainly was not held in the wrong place but it may have been held in the wrong time of the year. How do we keep this meeting going in a productive fashion? How do we get more people out to it? These are the kinds of things I want you to think about and let your regional LRTAP representative know so that we can discuss the issue when we meet in January.

Finally, or second to last, I want to say thanks to all of you for giving up all or part of your Thanksgiving Day to come here. It's very, very much appreciated. Even though we've got a small group here I do get the impression that there's a certain level of dynamism and it's up to us perhaps at Headquarters to make it more dynamic and we'll be looking for ways to do that.

For those people who wanted to discuss the Socioeconomic proposal, we had planned to meet at twelve. That would've given Ken Minns from 12:30 to 1:00 to meet with his contractor. I'm not sure what we'll do about that now that we've taken up that half hour. Bill Smith is leaving to go and catch a plane at 1:45 p.m. ... Can we meet here for a minute and decide exactly where it is we go from here?

Last but not least, a big thank you to Michelle Roberge and her team for organizing what I think is a very, very good workshop. I like the idea of the mini workshops within the workshop. It has perhaps helped focus things. Thank you very much and would you please join me in giving her a round of thanks.

Are there any final comments that people want to make before I declare the meeting adjourned? If not then, it's 12:30. Thank you very much for coming and we may see you next year.

APPENDECIES

APPENDIX 1 - PROGRAM

FIFTH ANNUAL DFO LRTAP WORKSHOP
St. John's, Newfoundland
9-11 October, 1990

Tuesday, October 9 - 08:30-16:00

REGISTRATION: 08:30-09:00

WORKSHOP OPENING:

09:00-09:10 **Welcoming Address**
A/Science Director, Newfoundland Region, J. Payne

09:10-09:20 **Introduction and Workshop Organization**
I.M. Price

RESEARCH REPORTS:

Cause and Effect Studies

09:20-09:50 Central and Arctic Region - R. Hecky

09:50-10:15 Scotia-Fundy Region - G. Lacroix

Coffee Break

10:30-10:50 Newfoundland Region - D. Scruton

10:50-11:20 Central and Arctic Region - R. Hecky

Mitigation Studies

11:20-12:10 Scotia-Fundy Region - W. Watt

Lunch Break

Organic Contaminant Studies

13:30-14:10 Central and Arctic Region - R. Hecky

14:10-14:30 Scotia-Fundy & Quebec Region - B. Hargrave

14:30-15:00 Newfoundland Region - J. Kiceniuk\S. Ray

Coffee Break

Metallic Contaminant Studies

15:20-16:00 Central and Arctic Region - S. Brown

End Of Day 1

09:00-09:20 Organics in Acid Rain Drizzle - Are They Really Important? -J. Payne

RESEARCH REPORTS: (continued)

Palaeoecology Studies

09:20-09:50 Central and Arctic Region - Bob Hecky

09:50-10:20 Scotia-Fundy Region - J. Smith

Coffee Break

10:40-1050 Newfoundland Region - S. Ray

Pacific Region Report

10:50-11:10 Pacific Region Report - R. Wilson

Biomonitoring Program

11:10-11:30 Quebec Region - A. Kemp

11:30-11:50 Scotia-Fundy Region - S. Barbour

11:50-12:10 Newfoundland Region - P. Ryan

12:10-12:30 Central and Arctic Region - I. Davies

Lunch Break

PROGRAM MANAGEMENT AND COORDINATION:

14:00-14:20 National LRTAP Program - S. Milburn

14:30-14:50 Socioecomonics - B. Smith

14:50-15:10 Modelling - K. Minns

Coffee break

15:30-16:30 Ongoing/Future Management - I. Price

End of Day 2

WORKING GROUPS:

09:00-11:00 Working Group Discussions

1. Biomonitoring (I. Davis)
2. Cause and Effects (G. Lacroix)
3. Palaeoecology (S. Ray)

WORKSHOP SUMMARY:

11:00-11:45 Summary of Working Group Discussions

11:45-12:30 Workshop Summary

APPENDIX 2. LIST OF PARTICIPANTS

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