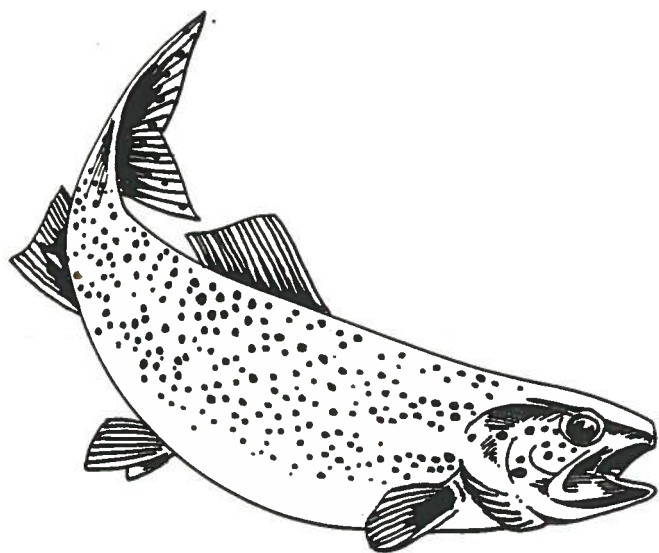

**Department of
Fisheries and Oceans**

**National Program Plan
for Studies on
Acid Rain
1981/82**



ACID RAIN

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This document contains descriptions of all of the Department of Fisheries and Oceans proposed and ongoing projects related to "acid rain". Additional copies of this document can be obtained by writing or calling the following:

catNo.
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INDEX

	<u>Page</u>
<u>I</u> Background to the Acid Precipitation Problem and its Significance for Fisheries	4
<u>II</u> Departmental Mandate for Acid Rain Research	6
<u>III</u> Departmental Goal and Objective	7
<u>IV</u> Department Strategies	8
a. Background Policy Factors	8
b. Principal Strategies	8
c. Relationship to Other Federal Programs	9
d. DFO Program Resource Summary	9
<u>V</u> Introduction to DFO Program Components	11
1. Scientific Component	11
2. Mitigation Component	12
3. Socio-Economic Component	13
4. Resource Protection Component	14
<u>VI</u> Project Descriptions	15
1. SCIENTIFIC PROGRAM COMPONENT	15
A. Intensive Field Studies - Background	16
1. Experimental Lakes Area Studies	17
<u>Project #</u>	<u>Short Title</u>
<u>Investigator(s)</u>	<u></u>
A.1.1	Acidification of Lake 302
A.1.2	Acidification of Lake 114
A.1.3	Acidification of Lake 223
Attach A.B.C.D.	25
A.1.4	Stable Isotopes of S&N
A.1.5	Crayfish Populations
A.1.6	Insect Emergence
A.1.7	1° Prod-Phyto. prod.
A.1.8	Benthic Algae
A.1.9	Crayfish physiology
A.1.10	Microbial Nitrate reduction
A.1.11	Methylation and Demethylation
A.1.12	Metals and Fish
A.1.13	Zooplanton Studies
A.1.14	Lake sediment bacteria studies
2. Algoma Watershed Studies	84
A.2.1	Algoma Watershed Program
Kelso	84

VI Project Descriptions (Cont'd.)

1. SCIENTIFIC PROGRAM COMPONENT

A. Intensive Field Studies - Background (Cont'd.)

<u>Project #</u>	<u>Short Title</u>	<u>Investigator(s)</u>	
3.	Westfield River Studies		87
A.3.1	Ecology of Atlantic Salmon	Lacroix	88
A.3.2	Invertebrate Studies	Dadswell	90
A.3.3	Sediments and Acidification History	Ray	92
A.3.4	Periphyton Communities	Wildish	93
A.3.5	Smolting of Atlantic Salmon	Saunders	95
4.	Other Field Studies		96
A.4.1	Airborne Organic Pollutants	Johnson	97
A.4.2	Fecundity and Mortality of of Brook Trout	Vigneault	99
B.	National Surveys and Inventories of Sensitive Aquatic Systems to LRTAP - Background		101
B.1.1	Ontario Headwater Lakes Survey	Kelso	124
B.1.2	Quebec Headwater Lakes Survey	Vigneault	126
B.1.3	N.B. and N.S. Headwater Lakes Survey	Peterson & Ray	128
B.1.4	Nfld. and Lab. Headwater Lakes Survey	Bruce/Scruton	129
B.1.5	Chemical Survey of Maritime Lakes & Rivers	Watt	131
B.1.6	Quebec River Survey	Dutil	133
B.1.7	Quebec North shore salmon river surveys	Vigneault	135
B.1.8	Nfld. survey of Atlantic salmon enhancement rivers	Bruce/Scruton	136
B.1.9	Assessment of survey information	Minns	138

			<u>Page</u>
<u>VI</u>	Project Descriptions (Cont'd.)		
1.	SCIENTIFIC PROGRAM COMPONENT (Cont'd.)		
	C. Laboratory Research Program - Background		140
	<u>Project #</u>	<u>Short Title</u>	<u>Investigator(s)</u>
	C.1.1	Cardiovascular/Respiratory Fish Studies	Giles 142
	C.1.2	Neuro-/Endocrine Fish Studies	Hara, Brown, Evans 144
	C.1.3	Locomotor Studies on Fish and inverts.	Scherer 146
	C.1.4	Early Development Fish Studies	Peterson 148
	C.1.5	Analytical Techniques	Ray 150
	C.1.6	Humic Acid and Al. Toxicity	Ray 151
	C.1.7	Atlantic Salmon Reproduction	Freeman 152
	C.1.8	Biochemical Toxicology	Haya 153
	C.1.9	Ecotoxicology of Aluminum	Vigneault 155
2.	MITIGATION PROGRAM COMPONENT		158
	<u>Project #</u>	<u>Short Title</u>	<u>Investigator(s)</u>
	D.1.1	Pilot Study on Lime Usage	Watt 160
	ADDENDUM		162
	B.1.10	B. C. Water Course Studies	Nassichuk/Samis 163

DEPARTMENT OF FISHERIES AND OCEANS

Program Plan

for

"Acid Rain" Studies

This outline is intended to establish the framework for the Department of Fisheries and Oceans program on acid precipitation. It will define the goals of a comprehensive departmental program on this problem, identify strategies necessary to achieve these goals and propose a tactical plan for implementation of strategies.

I Background to the Acid Precipitation Problem and its Significance for Fisheries

Pollutants carried for long distances in the atmosphere include mercury, lead, chlorinated and fluorinated hydrocarbons, carbon dioxide and a variety of acidic precursors. These contaminants are highly toxic and all pose severe consequences for the continued survival and productivity of Canada's fisheries resources, particularly over a large portion of Eastern Canada.

At the present, the phenomenon of acid precipitation is the problem of greatest immediate consequence to the fisheries resource. The sulphur and nitrogen oxides which cause acid precipitation are primarily discharged from fossil fuel burning and the smelting of sulfide ores. It has been estimated that approximately half of the Canadian problem originates from within this country, with long range transport from the U.S. supplying most of the other half. If the U.S. decision to rely more heavily on coal as an energy source is implemented, and if the predicted increasing reliance on diesel engines to cut automotive fuel consumption is implemented, the emission of sulphur and nitrogen oxides may increase. Other countries, too, will contribute to the problem as their energy demands increase because the pollutants are known to be carried around the globe. The world's energy demands are expected to increase six times in the next 50 years. Increased concentrations of sulphate have been found in the polar ice caps, indicating how widespread the dispersion of these pollutants is.

The acid rain problem which is now recognized to be emerging in Canada is similar to that which has been well documented in Norway and Sweden. The fisheries in about 20% of the lakes in the southern half of those countries have been moderately to severely affected by acid precipitation caused by European industrial emissions. Salmonid species (trouts, chars and salmon) are particularly vulnerable. The major salmon-producing rivers of Southern Scandinavia now yield nothing. Freshwater salmonid species have suffered a similar fate.

Mats of moss and fungus now cover the bottom of acidified Scandinavian lakes, rendering the habitat unsuitable for fish or their food organisms, particularly benthic crustaceans. The acidification has mobilized a number of toxic heavy metals from soils and lake sediments, causing increased concentrations in the water. Zinc, mercury, manganese, aluminum and lead are among the metals of concern.

The potential impact of acid precipitation on Canada's fisheries resource is significant because of the geological characteristics of a large portion of Eastern Canada. Hard-rock areas of the Canadian Precambrian Shield are susceptible to change by acid precipitation because there are no calcareous rock soils to neutralize the acid. Over half of Canada consists of susceptible hard rock areas (figure 1).

Recently, it has been shown that areas of Quebec and Ontario are receiving precipitation up to two to three times more acid than that which caused problems in Scandinavia. Precipitation, at least as acid as that recorded in Scandinavia, is falling even in remote regions of Northern Quebec and Labrador. Studies by the Ontario Ministry of Environment have revealed lakes in the Sudbury area acidifying at rates of 0.09 pH units per year, three times the average Scandinavian rate. Also, several lakes in the Muskoka-Haliburton area have lost up to 70 percent of their buffering capacity in under 10 years. In a statement in February 1979, the Ontario Minister of Environment predicted that 48,000 lakes in the Province were in imminent danger. In 1979, W.D. Watt and colleagues discovered that lakes in Nova Scotia had become up to 0.5 units more acid in twenty years. Populations of Atlantic salmon had been obliterated in several eastern rivers, and were endangered in several others.

It is becoming clear that the magnitude and extent of the acid precipitation problem and its consequences for Canadian fisheries and freshwater habitats have been badly under-estimated. It now appears that widespread damage to freshwater systems in Canada and the northeastern U.S. is inevitable within the next 5 to 20 years. Due to our unique combination of hundreds of thousands of acid-sensitive freshwaters and a neighbouring country which is apparently committed to pursuing acid-emitting energy policies, acid precipitation may pose the greatest threat in history to the Canadian fishery and fish habitat.

The fisheries resource which is threatened is economically and socially valuable. A preliminary economic analysis based on 1975 data places the value of the inland sport fishery (exclusive of anadromous species) at 1 billion dollars per year, in 1980. The commercial fishery is worth another 20 million dollars. In 1977, the landed value of Atlantic salmon taken in the commercial fishery totalled almost 5.5 million dollars. In the recreational fishery, the estimated angler expenditures and investment for Atlantic salmon was in excess of 19 million dollars in 1975. Although not all salmon production is threatened by acid rain, populations in extensive portions of Nova Scotia, Newfoundland and Quebec are at risk. While these estimates are based on many assumptions, the total value of the inland freshwater and anadromous fishery which is threatened probably approaches one billion dollars.

II Departmental Mandate for Acid Rain Research

The Federal Department of Fisheries and Oceans (ie DFO) of Canada is responsible for a wide range of activities which include fisheries management and research in coastal and inland waters. It is fully responsible for the management of all fisheries, both marine and freshwater, in four east coast provinces; Nova Scotia, New Brunswick, Newfoundland, Labrador and Prince Edward Island, and in the Northwest and Yukon Territories. In the four inland provinces of Ontario, Manitoba, Saskatchewan and Alberta, the management of all fisheries is a provincial responsibility. In Quebec, the provincial government manages freshwater fisheries and certain marine fisheries. In British Columbia, the fisheries for marine and anadromous species are managed by DFO while the provincial government manages freshwater fisheries.

In those provinces where administration of federal legislation has been delegated, the federal department still maintains its role in providing and approving legislation relating to fishery concerns. For example, requests by the provinces for changes in federal fisheries legislation (ie the Fisheries Act) must be reviewed and approved by the Minister of Fisheries and Oceans. Therefore at present the Federal Government has a constitutional responsibility to provide for the regulation, protection and preservation of all fisheries (inland and marine) in Canada. It should also be noted that the "fishery" as defined by the Fisheries Act includes habitat and "fish" includes crustaceans and other (lower) forms of aquatic life.

Provincial government involvement in "acid rain" research pertaining to fishery concerns is, at present, highly variable. Ontario and Quebec have devoted substantial resources to the problem as it relates to fisheries, while other Maritime provinces have rather modest programs. This fact has been taken into account, where appropriate, in designing the Department of Fisheries and Oceans program. However in all instances, for all acid rain programs, the long term goal of the respective agencies, whether federal or provincial is a common one; - to produce reliable scientific information in support of measures that will lead to the reduction of national and bilateral "acid rain" causing emissions.

III Departmental Goal and Objectives

The goal of the Departmental Program on acid precipitation is to protect freshwater and anadromous fisheries resources threatened by acid precipitation and related pollutants and ensure the long term maintenance of the social and economic benefits associated with the fisheries resources.

The departmental objectives in support of this goal will be to:

1. Develop measures to support national and bilateral controls on emissions.

DFO's first objective should be to achieve reduced emissions in Canada and the U.S. which contribute substantially to acid rain and fish contaminant loads. This means a strong effort to support the Departments of Environment and External Affairs in their efforts to achieve a Canada-U.S. Transboundary Air Treaty. This is best accomplished by provision of timely and accurate scientific information on the serious effects on Canadian fisheries, direct participation in Canada-U.S. discussions and by an escalated fisheries publicity campaign.

2. Mitigate important fishery losses.

This objective aims at mitigation for current impacted fisheries which are either of major social and economic value or which may represent special tactical importance in Canada's overall acid rain strategy. Immediate emphasis should be placed upon determining the cost-effectiveness of various mitigation techniques such as liming, hatchery stocking, and breeding acid resistant fish. DFO should place priority on those stocks directly managed by the federal government - namely the Atlantic salmon and freshwater species in the Maritimes and Newfoundland and Labrador.

IV Department Strategies

A. Background Policy Factors

The proposed strategies to be followed are based upon DFO being the federal agency responsible for managing and protecting fisheries. Provincial, U.S. and state fisheries agencies have a similar role. The environmental agencies such as DOE have different but related responsibilities. The Department of External Affairs and the U.S. State Department also play substantial roles.

In addition, DFO's strategy should recognize that the socio-economic benefits derived from Canada's fisheries now and in the future are this Department's principal concern. Emphasis should be placed upon protection of important anadromous salmon and freshwater stocks directly under the management responsibility of the Minister of Fisheries. These include the fisheries in the Maritime provinces and Newfoundland and Labrador. The Federal Minister of Fisheries has a responsibility to ensure that all provincial fisheries interests are represented in international negotiations with other countries.

One of DFO's principal objectives is to optimize the socio-economic fisheries benefits in those areas where DFO manages fisheries. Given that certain areas of Nova Scotian fisheries are already seriously impacted by acid rain, it may be more cost effective to recognize a strategy which "writes off" certain areas as being uneconomic for mitigation purposes. However, as part of Canada's overall acid rain strategy to gain public, industrial and governmental support to achieve control over emissions it could be highly effective for DFO to focus attention on the Atlantic salmon losses because of the symbolic position this species enjoys in the public perception and because it is economically important both in Canada and the U.S. Other fisheries will be given more attention by the provinces and DFO should also place emphasis where appropriate in supporting provincial agencies on other important freshwater fisheries. DFO's overall strategy should recognize that a DFO acid rain program should be complementary to the Atlantic Salmon Enhancement program and the freshwater recreational and commercial fisheries programs within the Department. Effectiveness of DFO's program strategies will be increased by close cooperation in these areas.

B. Principal Strategies

The principal strategies of DFO in support of its objectives should be to:

1. Improve Fishery Agency Cooperation.

An important DFO strategy should be to establish a close working liaison with other fisheries management agencies in U.S. and Canada. Such liaison should initially emphasize information exchange to be followed by appropriate cooperation on activities such as pressing governments for emission controls, integrated acid rain fishery impact surveys, and coordinated publicity campaigns. The U.S. Fish and Wildlife Service would be DFO's federal counterpart in the U.S. The provincial fisheries agencies are those in Quebec and Ontario.

2. Produce Scientific Information.

One of the most powerful strategic tools at the Minister of Fisheries disposal is the development of timely scientific information on the effects of acid rain. Because of DFO's mandate, it cannot directly impose emission controls and can only by scientific data impress on governments the urgency to implement adequate controls. The Canada-U.S. Bilateral Research group is an important focus between countries and that body has embarked upon a stepped up scientific program for both countries. DFO can be best served by strongly supporting this activity. The scientific program element of the DFO acid rain program should be closely linked to the DFO control strategies activities.

3. Emphasize Socio-Economic Impacts.

Development of a strong socio-economic program element is necessary to demonstrate the magnitude of harmful effects of acid rain on fisheries. Wherever possible, DFO should have the best possible socio-economic inputs in a way to maximize the benefits to fisheries.

4. Develop Public Information Program.

Publicity strategy on acid rain and fisheries should be aimed at public and government opinion in a way that will generate support for emission controls and mitigation programs for affected fisheries. Joint publicity efforts with other fisheries agencies and with other federal departments would also be effective.

C. Relationship to Other Federal Programs

The designated lead agency for the Federal Government Long Range Transport of Atmospheric Pollutants program (ie acid rain) is the Department of the Environment. The areas of responsibility included in their program include emission inventories (of SO₂, NO_x, particulates, metals, organics, etc.), the monitoring of atmospheric transport and deposition, aquatic chemistry and terrestrial studies (both wildlife and forestry). In addition, the Departments of Health and Welfare, Agriculture, and Energy, Mines and Resources also have LRTAP related studies in their respective areas of expertise (including human health, crops and geological surveys respectively). The impact of LRTAP on buildings and structures is being examined by the National Research Council and Heritage Canada.

Overseeing the coordination of these activities is a substantial committee structure that also attempts to liase and complement similar activities being carried out by provincial agencies and by Universities.

D. DFO Program Resource Summary

The following table summarizes the resources expected (as a minimum) to be devoted to "acid rain" studies by the Department of Fisheries and Oceans in each of the next 3 years.

<u>Program Component</u>	<u>Person Years</u>	<u>Total Resources</u>		
		<u>Salary</u>	<u>Operating and Maintenance</u>	<u>Capital</u>
1. Scientific	40.6	1,044.	2,262.5	289.
2. Mitigation	4.0	80.0	125.	20.
3. Socio-economic	-	-	200. ^a	-
4. Resource Protection	1.0	40.0	156.5	-
Totals	<u>45.6</u>	<u>1,164.0</u>	<u>2,774.</u>	<u>309.</u>

^a The majority of the person year effort for this component will come from work contracted outside the department.

Monetary resources are expressed in thousands of dollars.

V Introduction to DFO Program Components

1. SCIENTIFIC COMPONENT

Introduction

In view of the decisions which must be made soon in Canada and the United States with respect to energy alternatives, it is clear that international negotiations to control acid-causing emissions must be undertaken speedily. Such negotiations cannot succeed without a clear understanding of the type of extent of environmental damage, and the degree to which the damaged ecosystems can be restored. Therefore the Fisheries and Oceans acid rain program is required to supply information vital to Canada's position in negotiating with the United States and will include components aimed at documentation of damage to date and prediction of future damage.

Objectives of the Scientific Program

The goal of the Departmental program on acid precipitation is to protect freshwater and anadromous fisheries resources threatened by acidic precipitation and related pollutants and ensure the long-term maintenance of the social and economic benefits associated with the fisheries resource. To achieve that goal, the following was developed to assess and quantify the effect of atmospheric emissions of acids and acid precursors on fish and fish habitat in order to provide a basis for the formulation and implementation of a control strategy and demonstrate the feasibility, costs and benefits associated with various mitigative measures to protect commercially and genetically valuable fish stocks. Within this framework, the specific objectives of the scientific program will be as follows:

1. To provide an understanding of the processes governing the susceptibility of fish habitats to acid deposition and the mechanisms by which acidification affects fish populations and their use by man.
2. To survey the current degree of effect of acidification and other related atmospheric pollutants on fish populations and habitats and define trends in deterioration from the Manitoba-Ontario border eastward.
3. To develop the capability to predict the magnitude, geographic extent and time frame of impact on fish populations and habitats under various acid inputs.

An important extension of the scientific program is to supply a socio-economic basis for controls on emissions. This program element will define the social and economic costs associated with the loss of fisheries resources through acidification as well as the benefits which will accrue as the result of implementation of controls. The accuracy of estimates of costs and benefits will depend upon the adequacy of predictive data on the magnitude, extent and time frame for deterioration of the fishery resource.

2. MITIGATION COMPONENT

Introduction

The management of the Freshwater and Anadromous Fisheries in the Maritime Provinces, Newfoundland and Labrador is a direct responsibility of the Federal Minister of Fisheries and Oceans. It is anticipated that in these areas, certain stocks of fish in highly susceptible areas will be eliminated by acidification before adequate controls are implemented. Accordingly it will be a responsibility of this Department to carry out mitigation measures in selected watersheds to protect fish stocks which are genetically, socially, or commercially valuable.

In this area of Atlantic Canada, the most acid sensitive fish species (of significance) are the Atlantic salmon and the speckled trout. In Northern Europe the Atlantic salmon has virtually disappeared from all waters of pH less than 5.5 and the speckled trout (which is less sensitive) disappears at pH less than 5.

The impact of acid rain on these fisheries depends on the acid buffering capacity of local soils. Judging from ecological maps, approximately 70% of Newfoundland, 10% of New Brunswick and 50% of Nova Scotia may be susceptible to acidification. Prince Edward Island is not susceptible. Present data from New Brunswick, Newfoundland and Labrador indicate that pH levels are not yet dangerously low (generally greater than 6.0), and there has been no significant decline in pH even in the areas with susceptible soil characteristics. In Nova Scotia, however, there has been a very highly significant decline in the lake water pH's over the past 25 years, and in southwestern Nova Scotia the salmon angling statistics show a marked parallel decline over the same years. Comparable trout angling statistics are not available. Southwestern Nova Scotia is now one of the most extreme cases of environmental acidification in Canada.

Optimistic assumptions would suggest that the acid precipitation phenomenon will continue to grow for 10-15 more years, after which emission control measures may begin to show a significant effect. Acid precipitation will thus persist for at least 20 years. During this period fish stocks will be eliminated from extensive areas. Mitigation measures are required now at the environmental level, to maintain selected recreational fisheries and to preserve valuable genetic stocks.

It is apparent from the European experience that 100% mitigation at the environmental level is impractical. However, the Atlantic salmon stocks are genetically adapted to their native rivers, and while it is possible to replace salmon runs with stocks taken from other locales, these generally tend to be less successful than the native river stocks. It is desirable, therefore, to undertake some mitigation at the environmental level in several rivers along the Atlantic coast of Nova Scotia where it is anticipated that these native stocks will otherwise soon become extinct.

In southwestern Nova Scotia several native stocks are already lost and recreational angling for salmon and trout has been eliminated over an area of about 5,000 sq. km. A mitigation effort to restock portions of this area should be undertaken so as to restore some local angling potential.

Goals and Objectives

There are two objectives for mitigation at the environmental level:

- (a) to preserve genetically valuable fish stocks over the interim period while awaiting the implementation of effective emission controls; and,
- (b) to rehabilitate fisheries that have been destroyed by acidification.

The goal of the present program is to examine the feasibility of various environmental level mitigation techniques and to provide data for assessing the costs and benefits of each.

Program Elements

The Department of Fisheries and Oceans will be examining the feasibility of two approaches to mitigation at the environmental level:

- (a) rearing fish in hatcheries until they are large enough to survive in low pH waters; and
- (b) raising the pH of acidified lakes and rivers by the addition of lime and limestone.

There are also a number of possible combinations of these two approaches, e.g. in waters of pH less than 5, it may be necessary to add some lime before stocking fish.

3. SOCIO-ECONOMIC COMPONENT

One of the key strategies in promoting the development of effective national and bilateral control programs on emissions is the collection of information documenting the costs of acid rain to the fisheries resource. It would add considerable emphasis to the urgency of implementing meaningful controls if we were able to provide quantitative estimates of current and projected effects and costs associated with acid precipitation.

Existing information on the economic and social value of freshwater fisheries in the precambrian shield area of Canada is inadequate. In order to make reasonable estimates of the potential economic importance of acid effects on fisheries, it is necessary that a specific program component be developed to assess the social and economic aspects of the problem. This component should be closely allied to the scientific program, and in view of the provincial responsibility for freshwater fisheries management in Ontario and Quebec, should be developed cooperatively with the provinces. It would also be useful to recognize acid rain program needs in the design of the sport fishing survey which was carried out in 1980. In assessing economic and social costs associated with deterioration of the fisheries resource, it is recommended that the account system adopted by the Salmon Enhancement Program be used as a model. This would include evaluation of the threatened fisheries in terms of their contribution to national income, regional development, employment, native peoples and genetic uniqueness.

It is proposed that this program element be implemented through contracts with the private sector administered by regional and headquarters economic staff. It is estimated that additional resources of \$200K O & M would be required for this activity.

4. RESOURCE PROTECTION COMPONENT

The response of a variety of agencies of government (both Federal and Provincial) to the threat of acid rain has become extensive and complex. It is important to ensure that the interests of fisheries agencies are effectively represented in discussions regarding control, that the DFO program is well coordinated, and that links with the programs of other departments are maintained. In support of these objectives DFO will undertake an active Public Information program as well as interfacing with appropriate federal and provincial technical committees on problems of mutual concern.

VI Project Descriptions

1. SCIENTIFIC PROGRAM COMPONENT

A. Intensive Field Studies on Acid Rain

1. Experimental Lakes Area Studies
2. Algoma Watershed Studies
3. Westfield River Studies
4. Other Field Studies

A. Intensive Field Studies on Acid Rain - Background

The Department of Fisheries and Oceans Canada is presently supporting three major intensive field studies on the effects of acid rain: (1) lake acidification at the Experimental Lakes Area, Kenora, Ontario at the Freshwater Institute, Winnipeg; (2) the Turkey Lake Forested Watershed Program of the Great Lakes Biolimnology Laboratory at Sault Ste. Marie, Ontario; and (3) an intensive study of the ecology of Atlantic salmon in the Westfield River by the Biological Station, St. Andrews, New Brunswick. These programs were established because DFO has perceived a need for whole ecosystem studies to determine the complex effects of acid rain on freshwater systems. The programs are multidisciplinary and involve the cooperation of a number of other agencies and privately contracted work. The details of the projects are presented in the project activity descriptions included in this package.

- (1) The Experimental Lakes Area program is a true experimental approach which involves the purposeful and controlled acidification of lakes sensitive to acid rain. The ELA presently is not impacted by acid rain (Schindler and Ruzczynski, in prep.), pH in rain averages 4.9. The lakes have very little buffering capacity, in the range of 40 to 150 $\mu\text{eq/L}$ alkalinity. The lakes are being acidified with sulphuric or nitric acid in order to study the direct effect of lake acidification independent of complexities contributed by watershed acidification and metal addition which would occur with acid precipitation. The program includes studies on chemical effects, algal and microbiological responses, invertebrate responses, fish health, growth and population dynamics and food chain effects.
- (2) The Turkey Lake Forested Watershed program is an intensive monitoring program of a chain of lakes and streams in the Algoma district, Ontario. This area is one of sensitive geology and is presently exposed to moderate loading by long range atmospheric transport. The headwater lakes already have reduced pH's while downstream lakes are little affected. The purpose of the program is to study over the range of pH available the condition of the fish, zooplankton, phytoplankton and benthic communities. In addition, careful monitoring of chemical inputs and outputs from the watershed will allow observation of the change in the communities as acidification proceeds in the watershed. A number of other agencies are participating in this study. These include Canadian Forestry Service (forest productivity and forest soil effects), Inland Waters Directorate (hydrology, surface and ground water flow and chemistry), Ontario Ministry of Natural Resources (caged fish studies, early life histories, macroinvertebrates), and a number of university projects.
- (3) The Westfield River study of Atlantic salmon on the western coast of Nova Scotia will develop an understanding of the important stresses (pH, metals, food chain) affecting the salmon population in a river which is presently marginal for salmon reproduction. Many of the rivers in western Nova Scotia have already lost their salmon runs due to acid rain effects since the mid 1950's. Many more rivers are in jeopardy. The study will follow the expected disappearance of the salmon from the Westfield River. fish populations and benthic invertebrates will be monitored. Chemical and hydrological inputs and outputs will be established. Successful development of fish life stages will be carefully studied as these early processes in the river are most sensitive to acid rain effects. The detailed results of this study will be compared to more limited data taken from other Nova Scotian rivers ranging in pH from that below which salmon can survive to levels where no serious effect is perceived.

1. The Experimental Lakes Area

1. THE EXPERIMENTAL LAKES AREA

Introduction to Project Descriptions

The Experimental Lakes Area was established by the Government of Canada in 1968 primarily to resolve questions on the eutrophication of lakes by the experimental manipulation of whole lakes. This approach proved very useful in producing the understanding required for nutrient control strategies as well as providing insight into the basic chemical and biological processes occurring in lakes and their watersheds. The opportunities provided by the ELA have resulted in cooperative participation by many Canadian and international scientists. The basic understanding of freshwater systems at ELA has allowed the rapid assessment of potential environmental threats and design of critical experiments to provide specific knowledge toward management solutions. A more complete description of the evolution of the Experimental Lakes Area Project is available by Schindler (1980).

The acid rain program at ELA consists of three major experimental manipulations; the acidification of Lakes 223, 114 and 302. The acidification of Lake 223 was started in 1976, Lake 114 in 1979 and Lake 302 will begin in 1982. A more detailed description of these experiments is given in the project activity descriptions. In addition to the DFO participation described, there are a number of other aspects of the ELA which contribute to its integrated value. They include:

- 1) Regional monitoring of changes in alkalinity and pH (Schindler and Ruzsyczynski paper on attached list).
- 2) Servicing of CANSAP and LRTAP stations in cooperative program with Atmospheric Environment Service-DOE to discern regional acidification patterns and detailed "background" acidification data for the lake projects.
- 3) Cooperative program with U.S. DOE's Argonne National Laboratory on air sampling for LRTAP - distributed trace metals (to begin in 1981).
- 4) Embryonic "ecotoxicology" program with Argonne and University of Kansas personnel on metals and radionuclides of interest from a LRTAP perspective. Preliminary work on cadmium and zinc and their effects on phyto and zooplankton is in preparation.
- 5) Long-term monitoring of lake and precipitation chemistry to detect normal variation and long-term trends.
- 6) Programs on trace metal, radionuclide, CO₂ and sulfur isotope chemistry with Lamont-Doherty Geological Observatory, supported by the National Science Foundation. Much of the microbial work on Lake 223 was also sponsored by Lamont-Doherty during 1980-81.

While the project activity descriptions provide some detail for small projects or sub-projects, it is difficult to properly describe, and therefore assess, the value of a large integrated program from these limited descriptions. The ELA acid rain program depends on effective integration of a number of projects. This allows the maximum use to be made of the experimental manipulations and results in a synergistic effect on the development of understanding of the freshwater systems. In support of the integrated approach, we have included a proposal covering the Lake 302 experiment which was prepared in August 1980.

Project # A.1.1

PROJECT TITLE

Acidification of Lake 302

PRINCIPAL DFO INVESTIGATOR'S NAME

D.W. Schindler

ADDRESS AND TELEPHONE NUMBER

Box 313, Kenora, Ontario 807-227-5414

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Lamont-Doherty Geological Observatory (Trace Metals and Radionuclides)

DFO RESOURCES ASSIGNED

1981/82

1982/83

1983/84

- | | | | |
|---------------------------------------|--------------------|--|--|
| a) Person Years | See Attachment "A" | | |
| b) Operating and Maintenance (\$000.) | See Attachment "B" | | |
| c) Capital (\$000.) | | | |

ANTICIPATED DURATION OF THE PROJECT 6 yrs. (1981-86) (1981 will be a background year)

(Other options considered at that time).

OBJECTIVES OF THE PROJECT

To compare the potential for acidification of lakes of addition of H₂SO₄ and HNO₃. The result should serve as a preliminary index of the relative importance of SO_x vs NO_x control.

METHODS

Lake 302 will be halved with a vinyl curtain - a technique frequently used at ELA in the past. One basin of the lake will be acidified with H₂SO₄, the other with HNO₃. Rates and regimes will be set in May 1981, but will probably be similar to Lake 223.

Major emphasis in this study will be on microbial amelioration of lake metabolism of sulfur, nitrogen, carbon and methylated metals.

See detailed proposal "D", attached.

Project # A.1.1

ANTICIPATED RESULTS

See detailed proposal.

PERFORMANCE INDICATORS None so far.

Project # A.1.2

PROJECT TITLE

Acidification of Lake 114

PRINCIPAL DFO INVESTIGATOR'S NAME

D.W. Schindler

ADDRESS AND TELEPHONE NUMBER

Box 313, Kenora, Ontario 807-227-5414

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable) Lamont-Doherty Geological Observatory

Toxicology Section (Rudd et al.)

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	See Attachment "A"		
b) Operating and Maintenance (\$000.)	See Attachment "B"		
c) Capital (\$000.)			

ANTICIPATED DURATION OF THE PROJECT 5 yrs. (beginning 1979)

OBJECTIVES OF THE PROJECT

To test the rate of acidification of an extremely acid-susceptible lake under a "realistic" acid addition scheme.

METHODS

Enough H₂SO₄ is added to Lake 114 monthly to simulate lowering the pH of precipitation on the lake surface from the current 5.0 to 4.0. Chemical budgets are done as in Lake 223. Tests specific to this experiment include: 1) Tests of the role of epilimnetic sediments in sulfate reduction-alkalinity regeneration, using both direct microbial and indirect mass-balance techniques. 2) Detailed work on embryological and physiological indicators of acid stress in Pimephales, which proved extremely sensitive in L.223. 3) Detailed work on the microbial and geochemical interactions between epilimnetic sediments and overlying waters as affected by acidification.

Project # A.1.2RESULTS

Acidification initially causes decreases in pH and alkalinity almost identical to those predicted by Gran titration of lake water. There is, however, a slow "rebound" of pH after each addition. Mass-balance calculations indicate that as in the hypolimnion of Lake 223, sulphate reduction is responsible. Measurement of pore-water chemistry indicate that the reduction occurs below the sediment surface in organic sediments, and is probably diffusion limited.

The following hypotheses will also be tested:

- 1) That acidification inhibits nutrient regeneration from sediments, or otherwise causes "oligotrophication", as hypothesized by Grahn and Hultberg. These results compliment those from L.223 in a different type of ecosystem (organic sediment, no thermal stratification).
- 2) That embryological or physiological indicators of early acid stress can be discovered for Pimephales in the field before severe ecological damage results.
- 3) That very sensitive lakes can be rapidly damaged under current precipitation acidity regimes. It is therefore likely that numerous naturally-sensitive lakes have already been severely damaged.

PERFORMANCE INDICATORS

2 papers (see attached list "C").

Project # A.1.3

PROJECT TITLE

Acidification of Lake 223

PRINCIPAL DFO INVESTIGATOR'S NAME

D.W. Schindler

ADDRESS AND TELEPHONE NUMBER

Box 313, Kenora, Ontario 807-227-5414

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable) Lamont-Doherty Geological Observatory (Trace metals,
radionuclides, sulphur geochemistry).
Toxicology Section (Rudd et al.)

DFO RESOURCES ASSIGNED

1981/82

1982/83

1983/84

- | | |
|---------------------------------------|--------------------|
| a) Person Years | See Attachment "A" |
| b) Operating and Maintenance (\$000.) | See Attachment "B" |
| c) Capital (\$000.) | |

ANTICIPATED DURATION OF THE PROJECT 5 yrs. (1981 is year 5) for Phase I;

Phase II to be determined (see below)

OBJECTIVES OF THE PROJECT

- 1) to obtain quantitative mass-balance budgets for hydrogen ion, sulphate, trace metals and nutrients in order to discern acid-induced changes in biogeochemical cycles.
- 2) To determine changes in the ecological community which occur early in the acidification process.

METHODS

Lake 223 has been progressively acidified with H₂SO₄, at an approximate rate of 0.25 units per year. Detailed hydrology and chemistry allow precise estimation of effects of acidification on lake metabolism. Such studies cannot be done on "observation" "calibrated watersheds", due to the imprecision with which inputs via dry deposition can be measured.

Detailed ecological, physiological and embryological studies have been done on lake trout, white sucker, and various food organisms for fishes.

Phase II will consider several options, for example: 1) acidification to pH 5.0; 2) acid-aluminium combinations 3) acid + nutrient additions 4) material recovery 5) amelioration.

The final decision will be made after staff meetings during 1981.

Project # A.1.3ANTICIPATED RESULTS

A number of effects occur at pH 5.8-6.0, including disappearance of key food organisms for fishes. Such early effects are not documented in the literature, and may be very important in Canadian lakes, many of which have natural pH's very near the tolerance limits for key organisms in the food chain leading to fishes. These results should be useful in designing a "monitoring" program for assessing biological vulnerability of lakes, as well as the damage which has already occurred.

Chemical results should provide evidence for changes in nutrient cycles, sediment water interactions, and ability of lake metabolism to resist acidification. Eventually such results should be useful in predicting rates of lake acidification under known acid inputs.

PERFORMANCE INDICATORS

22 papers or theses have already been published on data wholly or partly from Lake 223. Several others are in preparation. See attached list "C".

ATTACHMENT "A"

It is difficult to assign man years to a specific lake project, because staff members perform their specialty on a variety of lake systems. In addition, they perform work on other studies at ELA and elsewhere. The following table gives an approximate breakdown:

	Lake 223	Lake 302	Lake 114	Other Duties
Mills (fish)	.3	.2	.2	.3
*Fish tech, "X"	.4	.4	.1	.1
Davies (benthos)	.3	.3	.2	.2
Shearer (phyto. production)	.2	.2	.2	.4
*Phyto. Prod. tech. "X"	.2	.2	.2	.4
Lindsey (chemistry)	.2	.2	.2	.4
*1/2 Chem. tech. "X"	.2	.2	.2	.4
Cruikshank (acidification, field sampling)	.3	.3	.1	.3
Braun (camp manager)		Camp maintenance		
Findlay D. (phytoplankton)	.2	.3	.1	.4
Turner (data processing, periphyton)	.3	.4	.1	.2
Schindler (project leader)	.3	.2	.1	.4
Malley (Crustacean physiology)	.5	.2	.1	.2
Chang (" " ")	.5	.2	.1	.2
*1/2 Zooplankton tech. "X"	.3	.3	.1	.3
Hesslein (heavy metals, radioisot.)	.1	.1	.1	.7
*Microbiologist "X"	.2	.3	.2	.3
Brunskill (trans-uranic chemistry)(tent.)	.1	.1	0	.8

*Indicates new acid person-years.

Note that it is impossible to cut man-years "vertically", ie. by lake. What must be done instead is a "horizontal" cut, dropping one aspect of all lake studies - usually on other studies in addition to acidification.

It is assumed that the needs of the analytical lab (Stainton et al.), the heavy metal lab (Wagemann et al.) and Toxicology section microbiology group (Rudd et al.) will be accounted for elsewhere. All are important parts of these proposals, but costs are internalized in such a way as to make assessment here very difficult.

ATTACHMENT "B"

It is equally difficult to assign a proportion of budget to the individual lakes, because the major part of funds go for camp operations to service all lake projects. The following is 75% of the required budget for the year, my estimate of the total proportion of scientific operations which are proposed to be devoted to acid precipitation and related studies. Contract costs are included.

	<u>Budget (\$1000's)</u>
Schindler	4
Camp operation and kitchen maintenance	105
Camp-general scientific	45
Communications	4
Chemistry (Linsey)	26
Primary produc. (Shearer)	8
Benthos (Davies)	4.5
Fish (Mills)	22
Crustacea-zoopl. - (Malley)	9
Radionuclide-metal Geochem. (Hesslein-Brunskill)	35
Data processing (Malley, Findlay, Davies)	12
Campbell-acid policy travels	4
	<u>278.5</u>

As in "A", Anal. Lab., metals lab., toxicology-microbiology are not included.

ATTACHMENT "C"

Acid Rain-Related Publications and Presentations of
Limnology Section, Freshwater Institute
April 1981

Publications on behaviour and effects of heavy metals in the absence of acidification are not included.

<u>Proposal</u>	<u>Primary Publications</u>
223	Jackson, T.A., G. Kipphut, R.H. Hesslein and D.W. Schindler. 1980. Experimental study of trace metal chemistry in soft-water lakes at different pH levels. Can. J. Fish. Aquat. Sci. 37(3): 387-402.
223	Kennedy, L.A. 1980. Teratogenesis in lake trout (<u>Salvelinus namaycush</u>) in an experimentally acidified lake. Can. J. Fish. Aquat. Sci. 37(12):2355-2358.
223	Malley, D.F. 1980. Decreased survival and calcium uptake by the crayfish <u>Orconectes virilis</u> in low pH. Can. J. Fish. Aquat. Sci. 37(3):364-372.
223	Müller, P. 1980. Effects of artificial acidification on the growth of periphyton. Can. J. Fish. Aquat. Sci. 37(3):355-363.
223	Schindler, D.W. 1980. Evolution of the Experimental Lakes project. Can. J. Fish. Aquat. Sci. 37(3): 313-319.
223	Schindler, D.W., R.H. Hesslein, R. Wagemann and W.S. Broecker. 1980. Effects of acidification on mobilization of heavy metals and radionuclides from the sediments of a freshwater lake. Can. J. Fish. Aquat. Sci. 37(3):373-377.
223	Kennedy, L.A. 1980. The effects of lake acidification on embryonic development of the lake trout, <u>Salvelinus namaycush</u> . In Proc. 6th Ann. Aquat. Tox. Workshop. Can. Tech. Rep. Fish. Aquat. Sci. (In press).
223 & 114	Schindler, D.W., and M. Turner. 1981. Physical, chemical and biological responses of lakes to experimental acidification. To appear in. Water, Air, Soil Pollution. Sept. issue.
223	Schindler, D.W., R. Wagemann, R.B. Cook, T. Ruzsyczynski and J. Prokopowich. 1980. Experimental acidification of Lake 223, Experimental Lakes Area: background data and the first three years of acidification. Can. J. Fish. Aquat. Sci. 37(3):342-354.

Chapters in Books, Symposia Proceedings

- 223 Cook, R.B. and D.W. Schindler. 1981. The biogeochemistry of sulfur in an experimentally acidified lake. Proc. 5th Int. Symp. on Environmental Geochemistry, Stockholm, June 1981.
- 223 Hesslein, R.H., D.W. Schindler, W.S. Broecker and G. Kipphut. 1979. Fates of metal radiotracer additions in experimental enclosures in lakes and in a whole lake (extended synopsis), p. 261. In Isotopes in lake studies. Proc. of an Advisory Group Meeting on the Application of Nuclear Techniques to the Study of Lake Dynamics. Int. Atomic Energy Agency, Vienna, Aug. 29-Sept. 2, 1977.
- 223 Malley, D.F. and P.S.S. Chang. Response of zooplankton in Precambrian Shield lakes to whole-lake chemical modifications causing pH change. In Proceedings of the International Symposium for Inland Waters and Lake Restoration, Portland, Maine, September 8-12, 1980. (In press).
- 223 Malley, D.F., D.L. Findlay and P.S.S. Chang. Ecological effects of acid precipitation on zooplankton. Proceedings of Ecological Effects of Acid Precipitation on Ecological Systems: Great Lakes Region, Lansing, Michigan. April 1-3, 1981. (Under review).
- 223 Schindler, D.W. 1980. Experimental acidification of a whole lake: a test of the oligotrophication hypothesis, p. 370-376. In D. Drablos and A. Tollan (eds.) Ecological impact of acid precipitation. SNSF Project, Oslo, Norway.
- Schindler, D.W. 1980. Implications of regional scale lake acidification, p. 533-538. In D. Shriner, C. Richmond and S. Lindberg (eds.) Atmospheric sulfur deposition. Ann Arbor. Mich. Science.
- 223 & 114 Schindler, D.W. 1980. Ecological effects of experimental whole-lake acidification, p. 453-464. In D. Shriner, C. Richmond and C. Lindberg (eds.) Atmospheric sulfur deposition. Ann Arbor, Mich. Science.
- 223 Schindler, D.W. 1980. Effects of acid deposition on Canadian lakes and fisheries, p. 61-63. In Proceedings of the Action Seminar on Acid Precipitation, Toronto, Ontario, Nov. 1-3, 1979. A.S.A.P. Organizing Comm. Fed. of Ontario Naturalists, Don Mills, Ont.
- 213 Schindler, D.W. 1980. Chemical budgets and watersged acidification, p. 13-14. In G.R. Hendry (ed.) Limnological aspects of acid precipitation. BNL 51074 UCII, Environmental Control Technology and Earth Sciences. Brookhaven National Laboratory, Upton, N.Y.

Proposal Chapters in Books, Symposia Proceedings

- 223 Schindler, D.W. 1981. Whole lake experiments. In H.H. Harvey, R.C. Pierce, P.J. Dillon, J.P. Cramer and D.M. Whelpdale (eds.) Acidification in the Canadian aquatic environment. National Research Council of Canada 19875: 315 p.
- Schindler, D.W. and 12 others. 1981. Atmosphere-biosphere interactions: toward a better understanding of the ecological consequences of fossil fuel combustion. National Academy Press, Washington, D.C.

Reports

- 223 Chang, P.S.S., D.F. Malley, I.L. Delbaere and G. Mueller. Species composition and seasonal abundance of zooplankton in Lake 223, Experimental Lakes Area northwestern Ontario: before and during acidification 1974-1979. Can. Data Rep. Fish. Aquat. Sci. (Under review).
- 223 Findlay, D.L. and G. Saesura. 1980. Effects on phytoplankton biomass, succession and composition in Lake 223 as a result of lowering pH levels from 7.0 to 5.6: data from 1974 to 1979. Can. MS Rep. Fish. Aquat. Sci. 1585: 16 p.
- Hesslein, R.H. 1979. Lake acidification potential in the Alberta Oil Sands Environmental Research Program by Freshwater Institute, Winnipeg, Manitoba. AOSERP Project HY2.2. 34 p.
- Malley, D.F. and L.J. Tinker. 1979. Calcium uptake: a sublethal test for crayfish, p. 150-159. In E. Scherer (ed.) Toxicity tests for freshwater organisms. Can. Spec. Publ. Fish. Aquat. Sci. 44.
- 223 Schindler, D.W., R. Wagemann and R.H. Hesslein. 1977. The acidification of Lake 23, Experimental Lakes Area. 1. Background data, the first year of acidification, 1976, and pilot experiments. AOSERP Sub-project AF 2.3.1 84 p.
- 223 Schindler, D.W. and M. Turner. 1981. Physical, chemical and biological responses of lakes to experimental acidification. (In press).

In Preparation

- 223 France, R.L. and D.W. Schindler. Life history of the crayfish Orconectes virilis in the Experimental Lakes Area, northwestern Ontario with special reference to a whole-lake acidification experiment. (To be submitted to Can. J. Fish. Aquat. Sci.).
- France, R.L. Experimental response of the crayfish Orconectes virilis to low pH. I. Life history. (To be submitted to Can. J. Fish. Aquat. Sci.).

ProposalIn Preparation

- France, R.L. Experimental responses of the crayfish Orconectes virilis to low pH. Acclimatization and avoidance. (To be submitted to Can. J. Fish. Aquat. Sci.).
during acidification 1974-1979. Can. Data Rep. Fish. Aquat.
- 223 France, R.L. Response of the crayfish Orconectes virilis to experimental whole-lake acidification in the Experimental Lakes Area, northwestern Ontario. (To be presented at 5th International Association of Astacology Meeting, Davis, Calif. August 1981).
- 223 France, R.L. Response of the crayfish Orconectes virilis to low pH, a field and laboratory study. M.Sc. Thesis, Univ. of Manitoba, Winnipeg, Man.
- 223 Kelly C., J.W.M. Rudd, R.B. Cook and D.W. Schindler. The importance of anoxic bacterial processes in regulating rate of lake acidification.
- 223 Malley, D.F., S.G. Lawrence, I.L. Delbaere, P.S.S. Chang and D.W. Schindler. Response of zooplankton to the experimental acidification of Lake 223, Experimental Lakes Area, northwestern Ontario, 1974-1979. Can. J. Fish. Aquat. Sci.
- 223 Nero, R.W. The decline of Mysis relicta in response to experimental whole lake acidification with an evaluation of sampling techniques. M.Sc. Thesis, University of Manitoba, Winnipeg, Man.
- Ramsey, D.J. Differential responses of planktonic crustaceans to sulfuric acid additions in experimental lake enclosures. M.Sc. Thesis. Univ. of Manitoba, Winnipeg, Man.
- 223 Schindler, D.W. and T. Rusczyński. A test of limnological data from the Experimental Lakes Area, northwestern Ontario for evidence of acidification.
- Shearer, J.A. and E.R. DeBruyn. Light extinction in the Experimental Lakes Area - 1980 data. Can. Data Rep. Fish. Aquat. Sci.

Presented Papers

- Malley, D.F. 1978. Relation of universality of low environmental pH to stage of the moult cycle in the crayfish, Orconectes virilis, 41st Annual Meeting of the American Society of Limnology and Oceanography. June, 1978. Victoria. (Abstract).

ProposalMedia Presentations

France, R.L. Acid Rain Part I, II. Manitoban, Nov. 29, Dec. 3, 1979.

France, R.L. Acid Rain, Manitoba Nature, summer 1981 issue.

ATTACHMENT "D"

STUDY PLAN FOR EXPERIMENTAL LAKE ACIDIFICATION STUDIES

August 1980

D. W. Schindler et al.

Department of Fisheries and Oceans

Freshwater Institute

501 University Crescent

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WHOLE-LAKE ACIDIFICATION STRATEGIES

A different lake than proposed originally (Fig. 1), no. 302, will be used for the comparison of sulfuric and nitric acids. Lake 310, originally proposed, proved to have a morphometry unsuitable for dividing the lake into two parts securely and inexpensively.

Lake 302 was used for a nutrient disposal experiment in 1972-1976, injecting nutrients into the hypolimnion of the north basin in a way that rendered algal response negligible (Schindler et al. 1980a). The lake has been studied in a "recovery" mode in the past few years, and 1980 data show that there is no detectable difference in phytoplankton or chemistry between the south (control) and north (experimental) basins.

Advantages of the lake are numerous. Its proximity to the ELA camp make it easy to work. Background data for the control basin have been collected since 1971. The lake has very low alkalinity, so that acid requirements are modest. The curtain needed to separate the basins is small. Populations of white sucker and whitefish in the lake have been studied for several years, and provide ideal materials for the physiological stress studies described elsewhere in this proposal.

Sulfuric acid will be added to the south basin of the lake, nitric acid to the north. During the spring melt period of each year, the pH of the basins will be decreased to identical preset values using about half of the acid to be added annually, and simulating the spring pH pulse commonly observed. Small amounts of acid will be added throughout the ice free season as required to maintain pH values. We will

decrease the pH of basins to 5.0 over 5 years, lowering it from natural values of 6.1-6.5 to about 6.0 the first year, then in increments of 0.25 pH units for the next four years.

A different strategy will be used in Lake 114 (Fig. 2). This very sensitive lake (alkalinity less than $20 \mu\text{g l}^{-1}$), will be subjected to acidification with sulfuric acid sufficient to simulate acidifying current precipitation by one pH unit (from 5.0 to 4.0). The necessary acid will be added as a monthly pulse during the ice-free season, and as a "snowpack" pulse (about 6 months winter precipitation) during ice-melt. The well-mixed nature of this lake makes it ideal for studying the interaction between water and underlying sediments when oxic conditions prevail at the interface. Close attention will be paid to sediment-water interactions which generate permanent or temporary buffering, or release toxic heavy metals.

Detailed mass balance budgets will be kept for all three basins, as described by Schindler et al. (1973a, 1980c) in order to account for added elements and alterations in natural cycles of nutrients, metals and major constituents. Due to the low ambient levels of chemicals in current precipitation and dry deposition, and the fact that most of the lakes' incomes will be added directly, sulfur and nitrogen budgets for the lakes will be possible which are many times more accurate than studies on lakes in heavily polluted areas.

Studies described below will be carried out in one or more of the above basins as appropriate to provide an overall picture of chemical and biological events which accompany acidification.

Acid-Nutrient-Productivity Studies

Contrary to current belief, no reduction in phytoplankton production was observed in Lake 223 as the pH was decreased to 5.5 (Schindler 1980). Benthic algae (chiefly Mougeotia) increased to epidemic proportions as observed in Scandinavian lakes, but these did not appear to interfere with sediment-water exchanges of nutrients as Grahn et al. (1974) and Hendrey et al. (1976) had hypothesized. We believe that the lower productivity observed in acid Scandinavian lakes may be due to a lower nutrient income, because the same factors which predispose a lake to acidification also predispose it to a low nutrient income (small watershed, insoluble geological substrates). No study other than Lake 223 has been able to compare production prior to acidification with that observed at lower pH values.

Lake 223 production studies will continue as the pH is lowered to 5.0. The same techniques will be applied in Lakes 302 and 114. The incubator technique of Fee (1973) will be used, so that data for different years can be "normalized" to similar light conditions, which confound the interpretation of in situ production measurements. Recent comparisons of incubator results with in situ bottle and whole-lake C^{14} additions have shown that the method gives superior productivity estimates (Bower et al. 1980). Companion studies of algal abundance and taxonomy will be made. Questions which will be answered by these studies are:

1. Will NO_3 added as HNO_3 to Lake 302 enhance primary production?

(Based on our eutrophication studies, we predict that the answer will be no).

2. What is the pH where productivity begins to decrease? (We predict that it will be less than 5.0).
3. What is the pH where phytoplankton standing crop and diversity begin to decrease? (We likewise predict that there will be no decrease in diversity down to a pH of 5.0, although we expect some substitution of new species).

Benthic production was not studied in Lake 223 due to a shortage of qualified manpower. We plan to investigate these benthic algal epidemics more thoroughly in Lake 302, using techniques developed by Schindler et al. 1973b and refined by M. Turner (in prep.). The following questions will be investigated:

1. Does the algal mat represent an increased productivity or is it simply a larger accumulation of biomass?
2. Does the accumulation result from elimination of benthic grazers by acidification?
3. What is the role of the algal mat in the nutrient (phosphorus and nitrogen) cycles of the lake?
4. Does depletion of zooplankton populations due to acidification cause changes in algal species or standing crop?

Acid-Heavy Metal and Acid-Radionuclide Program

Some aspects of this program have already been/will be discussed in the whole lake perturbation, microbiological and fish sections. Work on Lake 223 has shown that acidification mobilizes a number of metals from lake sediments, most notably zinc, aluminum, iron and

manganese (Schindler et al. 1980). Also of some significance is the fact that preliminary experiments at ELA have shown that metallic radioisotopes sedimented under near neutral conditions (pH 6-6.5) in poorly-buffered lakes 50 to 80 percent redissolved when the pH is lowered to pH 4.5 (S. Schiff, unpublished data). Results were nearly identical for sand and organic sediments. Among isotopes remobilized were Co-60, Zn-65, Mn-54, Fe-59, Hg-203 and Se-75. Only Cs-134 was unaffected by acidification. Many of the above isotopes are important activation products in nuclear reactor effluent, and their mobility in acidified waters may be enhanced substantially.

We will study two aspects of the effects of acidification on metal distribution, in addition to the factors discussed in other sections:

1. Monitoring the effects of acidification on concentrations in water, biota and sediment of aluminum, zinc, mercury, selenium, cadmium, iron, manganese and copper as the pH of lakes is lowered. Because the watershed of the lakes will not be modified, any increases in metals can be assumed to come from sediments. This will be checked by beaker-scale sediment-water experiments at a range of pH's. (This work is being done by Lamont-Doherty Geological Observatory on an NSF grant).
2. A comparison of isotope behavior in a whole lake before and during acidification. Metallic isotopes have already been used in large-scale geochemical and food-chain experiments in the area (Hesslein et al. 1980; Schindler et al. 1980b; Jackson et al. 1980), and methods and equipment are available. Isotopes will be chosen on

the basis of cost, availability, suitability of a gamma spectrum and decay constant for analysis over several months, importance in nuclear power generation, and as tracers for important cold metal cycles, for example Mercury-203.

Funds for the above isotope studies are being requested from Atomic Energy of Canada, Ltd.

EFFECTS OF ACIDIFICATION ON MICROBIAL PROCESSES IN FRESHWATER

I. Effects on Sulfate Reduction

Reduction of sulfate from atmospheric deposition to sulfide is known to take place in the anoxic hypolimnions of freshwater lakes, generating significant buffering against further acidification (Schindler et al. 1980c). At concentrations less than $8 \text{ mg SO}_4 \text{ L}^{-1}$, the reaction is substrate-limited. The following additional questions must be addressed to assess the importance of this process:

1. Over what range of sulfate concentrations does sulfate reduction occur in freshwater lakes? At what concentration of sulfate does the rate of reduction become saturated?
2. What are the pH^{limitations} for sulfate reduction in natural lakes? Alexander (1980) found that sulfate reduction in soils ceased at pH values less than 5.
3. Is the buffering produced in this way permanent or temporary? The produced sulfide must be permanently lost to the atmosphere or sediments for the buffering to be permanent. Hultberg and Wenblad (1980) found that buffering generated in a groundwater

aquifer by sulfate reduction disappeared quickly when oxic conditions returned, causing the system to acidify very rapidly.

Lake 223 appears to have generated at least some permanent buffering, although there is an additional seasonal component (R. Cook, in prep.).

4. Does significant sulfate reduction occur outside of anoxic hypolimnions? Evidence from marine environments indicates that surficial sediments may be an important site (Jorgensen 1977; Howarth and Teal 1980). Considerable sulfate reduction also takes place under winter ice in shallow lakes (D. W. Schindler, unpublished data).
5. What happens to reduced sulfur in environments where iron concentrations are insufficient to precipitate FeS? Is H_2S an important endproduct? Organic sulfur species? These sinks may differ in permanence from the FeS sink of Lake 223.
6. What are the limits of permanent "auxiliary buffering" due to sulfate reduction in lakes of different morphometric and productivity characteristics?

Isotopic methods for the above investigations have been developed by R. Cook (in prep.).

II. Effects on Microbial Methylation and Demethylation of Mercury

Recent reports from Quebec (Brouzes et al. 1977), Ontario (T. Brydges and J. Parks, pers. comm.), NE USA (Schofield 1978 cited in Glass and Louks 1979) and Sweden (Jernelov et al. 1976) suggest that

there is an increase in the methyl mercury concentration of fish during the early stages of lake acidification. These increases may be caused by: 1) increased atmospheric input of inorganic mercury as a result of increased combustion of fossil fuels - in particular coal (Lagerwerff 1972); 2) increased leaching of mercury from lake basins and sediments; 3) acid related changes in fish physiology which increase the rate of methyl mercury bioaccumulation, and 4) changes in in situ bacterial activities.

Environmental methyl mercury concentrations are the net results of the activities of two groups of bacteria - mercury methylators and mercury demethylators. The overall objective of this work is to examine the effects of acidification on net mercury methylation. Acidification may affect net methylation either by increasing substrate concentration (e.g. 1 and 2 above) or by changing the efficiency of the methylating or demethylating processes (4 above). The experiments outlined below will first determine if there is an effect of acidification on mercury methylation and/or demethylation. If there is, the mechanism of the effect will be investigated.

A. Methylation

Rates of mercury methylation will be assayed by a new bottle incubation technique (Furutani and Rudd 1980) in which $^{203}\text{Hg}^{++}$ is converted to CH_3Hg^+ by natural populations of mercury methylators. This is a versatile method which has been used in studies on mercury-polluted Clay Lake sediment, water column and samples of fish intestinal contents

(Furutani and Rudd 1980 and Rudd et al. 1980). The method is presently being adapted to ELA sediment and water samples. The following experimental approaches will be taken using this method:

1. Effects of hydrogen ion concentration on methylation rates

Effects of pH change will be assayed by incubating sediments from acidified and non-acidified lakes at various pH's. This will provide information on the possible enhancement of methylation at low pH. It will establish the pH range of mercury methylation and will provide information on adaptation of methylators to reduced pH. These experiments can be done now on lakes that are presently being acidified and they will also be done as the pH of Lakes 302 and 114 are decreased.

2. Effects of increased NO_3^- , NH_4^+ , $\text{SO}_4^{=}$ and $\text{S}^{=}$ on methylation rates

Acidification of lakes with nitric and sulphuric acids will substantially increase the concentrations of the above ions. Bottle incubations of sediment samples at expected concentrations of these ions will establish their effect on methylation rates. Sulfide will be of particular interest because it has the potential for sequestering Hg and HgS.

3. Long term monitoring of methylation rates during lake acidification

Epilimnetic and hypolimnetic sediments, and water column samples will be monitored on a biweekly schedule for mercury methylating activity. This will provide long term in situ information

on the whole lake effects of acidification by nitric and sulphuric acid on net mercury methylation rates.

4. Mechanism(s) of acidification effects

If increased net methylation is observed in 1, 2, or 3 there will be two possible explanations. Either the reduced pH or increased ion concentrations will have increased substrate (dissolved Hg^{++}) concentration or the efficiency of the methylation process will have increased. Dissolved ^{203}Hg concentrations in pore waters at various pH's and ion concentrations will be measured and related to rates of mercury methylation. Rate changes in excess of those expected from measured ^{203}Hg concentration changes will be interpreted as changes in the efficiency of the methylation process.

B. Demethylation

Since environmental methyl mercury concentrations are the net product of bacterial mercury methylating and demethylating activity, increases in methyl mercury concentrations in recently acidified lakes may be a consequence of decreased demethylation rather than increased methylation. The effects of lake acidification on rates of mercury demethylation will be assayed with a new bottle incubation method (Rudd, in prep.) in which $^{14}\text{CH}_3\text{Hg}^+$ is converted to $^{14}\text{CH}_4$, $^{14}\text{CO}_2$ and ^{14}Hg by natural populations ^{of} mercury demethylating bacteria.

The demethylation tests will be run under exactly the same conditions as those for mercury methylation (section A1-A4), so that results will

be comparable, providing a better understanding of the role of bacterial processes which may contribute to increased CH_3Hg in fish.

III. Effects on Denitrification

The fate of nitrate (N) in acidified lakes is unknown. It will be biologically converted to particulate and dissolved organic nitrogen, to ammonium and to nitrogen gas by denitrification.

An overall equation for microbial denitrification in a lake acidified with nitric acid is as follows:

$4\text{HNO}_3 + 5\text{CH}_2\text{O} \rightarrow 2\text{H}_2\text{CO}_3 + 3\text{CO}_2 + \text{N}_2 + 5\text{H}_2\text{O}$ where CH_2O = organic substrate
Under acidic conditions the carbonic acid would be chemically converted to carbon dioxide and water:



The overall effect of the denitrification process will be the non-reversible consumption of nitric acid since the carbon dioxide and N_2 will evade to the atmosphere. It is unlikely that significant quantities of N_2 would be biologically fixed under these conditions since nitrate will be in excess in lakes acidified by nitric acid. The net result would be to help buffer the lake against acidification. On the other hand, Alexander (1980) has found that denitrification in soils is inhibited below pH 5. There are no studies of pH effects on denitrification in freshwaters.

The objectives of this work will be to quantify the rate of denitrification and the pH range of denitrifying activity in a lake acidified with nitric acid. With this information available it will then be

possible to estimate the contribution of denitrification to buffering of the lake.

A. Methodologies

Denitrification rates will be measured either by the acetylene inhibition method (e.g. Chan and Knowles 1979) or by an N-15 stable isotope method (e.g. Sorensen 1978). The acetylene inhibition method is preferred because it is more sensitive, in situ substrate (NO_3^-) concentrations could be used and it is a much less time consuming method than the N-15 method. However, at the present time it is not known if rates measured by the acetylene inhibition method correspond to true rates of denitrification. Crosschecks with N isotopes and acetylene (Sorensen 1978 and Smith et al. 1978) are incomplete. An in depth study of the reliability of the acetylene method is presently funded and underway at ELA. The results of this study will determine the primary method for the study.

B. Proposed Studies

This work will consist of two approaches:

1. Estimation of in situ rates of denitrification in the water column and sediments. This will be done on a biweekly basis in Lake 302N, as the pH is reduced by additions of HNO_3 . It will provide information on the importance of denitrification as a buffering mechanism at the various pH's. It will also provide information on the pH tolerance of denitrifying bacteria.

2. Laboratory investigations of the mechanisms controlling aquatic denitrification. Fresh sediment samples from acidified and non-acidified lakes will be incubated for short time periods in the lab at various pH's and at various concentrations of NO_3^- and NH_4^+ . This will provide information on the range of adapted and non-adapted denitrifying populations and the effect of varying inorganic nitrogen concentrations on the denitrification process at various pH's.

IV. Effects on Decomposition

In Lake 223, decomposition did not decrease as the result of decreasing the pH from 7 to 5.5 (Schindler 1980). This work will continue to lower pH values. In addition, we need to know:

1. How does pH affect the partitioning of decomposition products between methane and CO_2 ? (This may be a key element in the mercury methylation work mentioned above).
2. How does pH affect the degradation of dissolved organic carbon? Methods for the above work have been developed by Bower et al. (1980) and Kelly et al. (1980a, b).
3. Are methane production rates good predictors of a lake's potential for increased $\text{SO}_4^{=}$ and/or NO_3^- reduction? Organic carbon used in generating $\text{CO}_2 + \text{CH}_4$ by methanogenesis may be the only "extra" carbon available for nitrate and sulfate reduction. Could all of this organic carbon be used, or would diffusion of NO_3^- and/or $\text{SO}_4^{=}$ into the sediments limit its availability? This can probably be answered as acidification proceeds in L223 and 302.

EFFECTS OF ACIDIFICATION ON FISH

A. Introduction

While a wealth of laboratory investigations has been conducted on the effects of acidification (Fromm 1980) and heavy metals (Leland et al. 1974 to 1979) on fish, very few studies have attempted to understand the fundamental mechanisms of "acidification" effects on fish in the natural environment. These effects have largely been evaluated at the population level. For example, Beamish (1974, 1976) has documented the rate of decline and relative species sensitivity of fish stocks in the La Cloche Mountains on Ontario. Work of this nature is essential for assessing the overall impact of acidification and for determining the relative differences in resistance of fish species, but it does not provide fundamental and mechanistic understanding required to treat the problem.

By evaluating biochemical responses of natural fish stocks exposed to acid rain, Lockhart and Lutz (1977) provided some relevant speculations on the mechanism of calcium in delaying adverse effects. In laboratory studies on juvenile and adult fish, calcium regulation, sodium and chloride retention, and oxygen transport appear to be the essential life-sustaining processes first affected by acid (Fromm 1980; Klaverkamp 1980; Spry and Wood 1980). Defective calcium regulation also probably underlies the fish recruitment failure observed in acid-impacted lakes.

There are conflicting observations on the most sensitive life history stage in studies on this recruitment failure. Several investigators (Beamish et al. 1975; Lockhart and Lutz 1977; Ruby et al. 1977) have

concluded that gametogenesis, especially oogenesis, is the most sensitive stage. Acidification is thought to produce decreased serum calcium which causes egg resorption. On the other hand, Kennedy (1980) has recently provided evidence which demonstrates that embryogenesis is the most acid-sensitive stage of the life history.

The acid rain problem is complicated by the fact that the effects on fish are not simply due to an increase in hydrogen ion concentration. Other contaminants, e.g. heavy metals, are also entering the aquatic environment through atmospheric fall-out, by mobilization from the sediment and from terrestrial run-off. Examples from atmospheric fall-out alone include the deposition of iron, nickel and copper at 14,500 2,000, and 1,800 tonnes per year, respectively, from smelter stack emissions at Sudbury, Ontario (Beamish 1976); of zinc, cadmium, arsenic and lead at 1,600, 8, 4, and 55 tonnes per year, respectively, from emissions of a base metal smelter at Flin Flon, Manitoba (Franzin et al. 1979); and of selenium (Demayo et al. 1978) and mercury (Lagerwerff 1972) at 9,000 and 5,000 tonnes per year, respectively, from the combustion of fossil fuels. With chemicals, such as mercury, some of the early effects of acid rain may be on the fish consumer. Recent reports from Quebec (Brouzes et al. 1977), Ontario (T. Brydges, pers. comm.), Minnesota (Glass and Loucks 1979), northeastern United States (Schofield 1978 cited in Glass and Loucks 1979) and Sweden (Jernelov et al. 1976) suggest that there is an increase in mercury contamination of fish in the early stages of acidification.

Aluminum has attracted considerable attention in conjunction with

acid rain because of high enrichment (Cronan and Schofield 1979) and pronounced increases in toxicity to fish with decreases in pH (Freeman and Everhart 1971; Freeman 1973; Schofield 1977). This increased toxicity is associated with pronounced gill damage over the pH range of 4.4 to 5.2 (Schofield 1977) and with rapid loss of sodium and chloride from serum (Muniz and Leivestad 1980).

B. Proposed Studies

Biochemical parameters indicative of impaired calcium, sodium, chloride and oxygen transport will be obtained on mature suckers and lake trout from Lake 223 and compared to fish from three or four control lakes. These parameters include calcium, sodium and chloride concentrations in serum and oocytes, concentrations of glycogen and lactate in liver and muscle, and erythrocyte hemoglobin and adenosine triphosphate (ATP) concentrations. All of these concentrations will be expressed in terms of tissue or organ protein content.

Other biochemical indicators of the health of these fish will be evaluated on an on-going basis. These indicators will be selected from laboratory studies on the toxicology of acid and metals in fish. In the first year, activities of leucine aminonaphthylamidase, a lysosomal, proteolytic enzyme indicative of dying or dead cells (Bouck 1979 and 1980), in gill and gut will be obtained.

To determine the significance of the biochemical observations to the survival of fish populations, estimates of population size, survival and recruitment will be obtained and suckers and white fish in Lake 302 using

Jolly-Seber tag and recapture analyses. The biochemical parameters described above will be obtained on these fish in Lake 302 throughout the ice-free season. Heavy metal analyses described in a previous section will be related to these biochemical observations and to histological examination of the gills.

Investigations to determine the relative sensitivity of gametogenesis (Ruby et al. 1977; McCormick et al. 1980) and embryogenesis (Kennedy, 1980) in fathead minnow (L114), lake trout (L223) and sucker (L223 and L302) will be conducted. Histological examination of gametogenesis in these three species, representing Summer, Fall and Spring spawners will be conducted on fish from these experimentally acidified lakes and compared to fish from control lakes. Comparisons will also be made on developing embryos using in situ lake incubators similar to those described by Kennedy (1980).

To determine the significance of increased mercury availability caused by acid alone, liver and muscle mercury concentrations in lake trout and suckers from Lake 223 will be compared to concentrations in these fish from three control lakes. Changes in time will also be determined since lake trout from Lake 223 have been sampled from 1977 to the present. Selenium concentrations in these organs will be determined because of selenium-mercury interaction phenomena (Rudd et al. 1980).

Experiments on the effects of acid on radioactive mercury uptake in pearl dace will provide knowledge on the significance of mercury input from the atmosphere. Tubes of 1 m in diameter and 2.5 m in depth will be located in Lake 302 and used to determine these effects and the

influence of calcium and selenium. These experiments may provide information necessary for designing whole-lake acid-mercury-selenium interaction experiments.

Concentrations of metallothionein (Cherian and Goyer 1978; Noel-Lambot et al. 1978) in gill, gut and liver of suckers from a highly contaminated Flin Flon lake (atmospheric input from a base-metal smelter), from Lake 223 and from two control lakes (224 and 302) will be obtained this Fall. The metallothionein concentrations will be compared to those obtained in laboratory studies (Duncan and Klaverkamp 1980) designed to evaluate the protective role of this metal-binding protein in this fish species as a metal-induced adaptive response. If these analyses demonstrate a significant adaptive role for metallothionein, they will be extended to other fish species in lakes 114, 223 and 302.

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Manpower Needs	1981
1 Chemist - nutrient analyses	15,000
1 Chemist - heavy metal analyses	15,000
1 Microbial technician	15,000
½ Ph.D. microbiologist	10,000
1 Fisheries technician	15,000
1 Primary Production technician	15,000
½ Zooplankton technician	7,500
	92,500
Equipment Needs	
Electron-capture gas chromatograph	8,000
Materials and Supplies	
Curtain construction	4,000
Acids and their transport to lakes	4,000
Expendable field equipment	4,000
Lab chemicals and supplies	2,500
TOTAL	\$115,000

LAKE 114

SCALE METERS
0 50 100 200

CONTOUR INTERVAL ONE METER

BR = BEDROCK

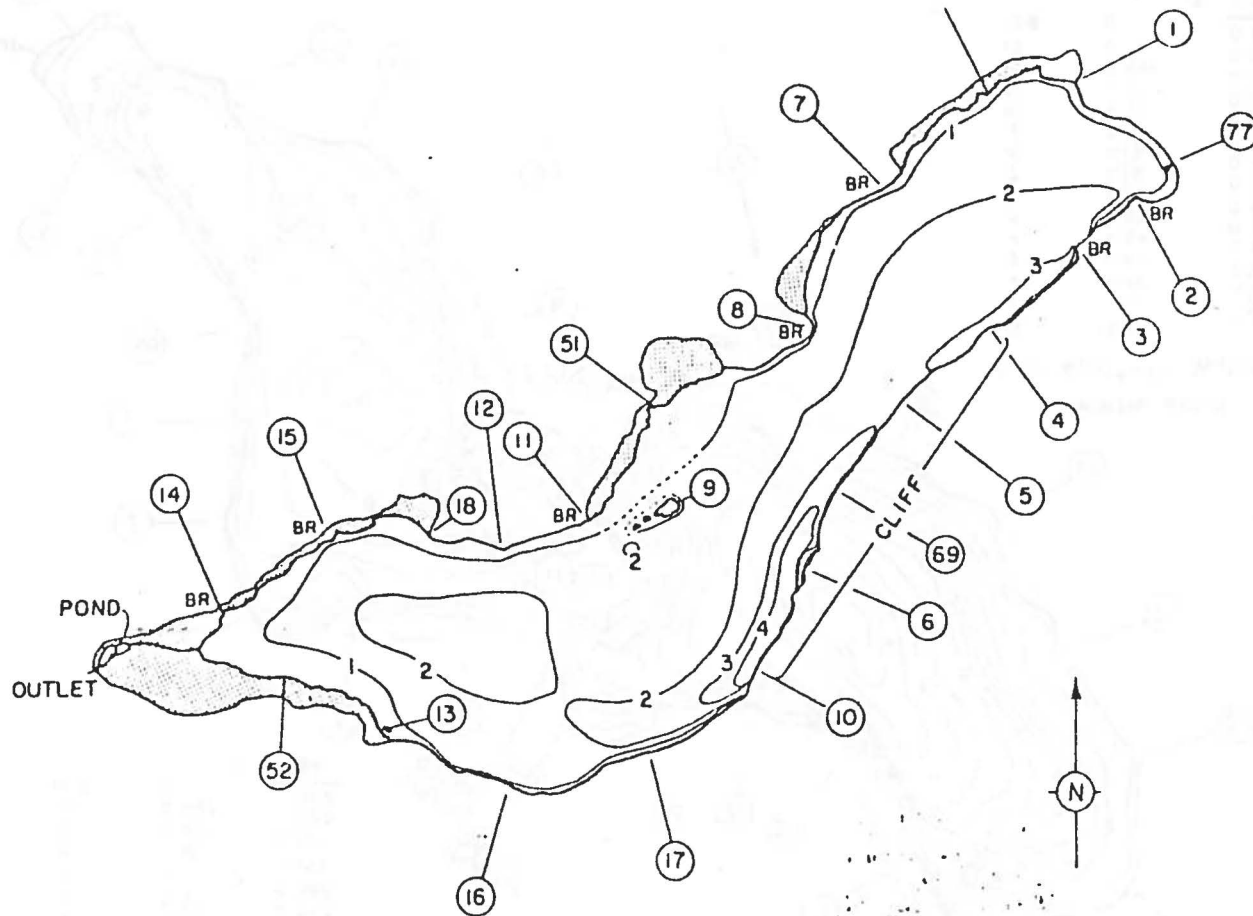
☐ = BOG

② = STATION NUMBERS

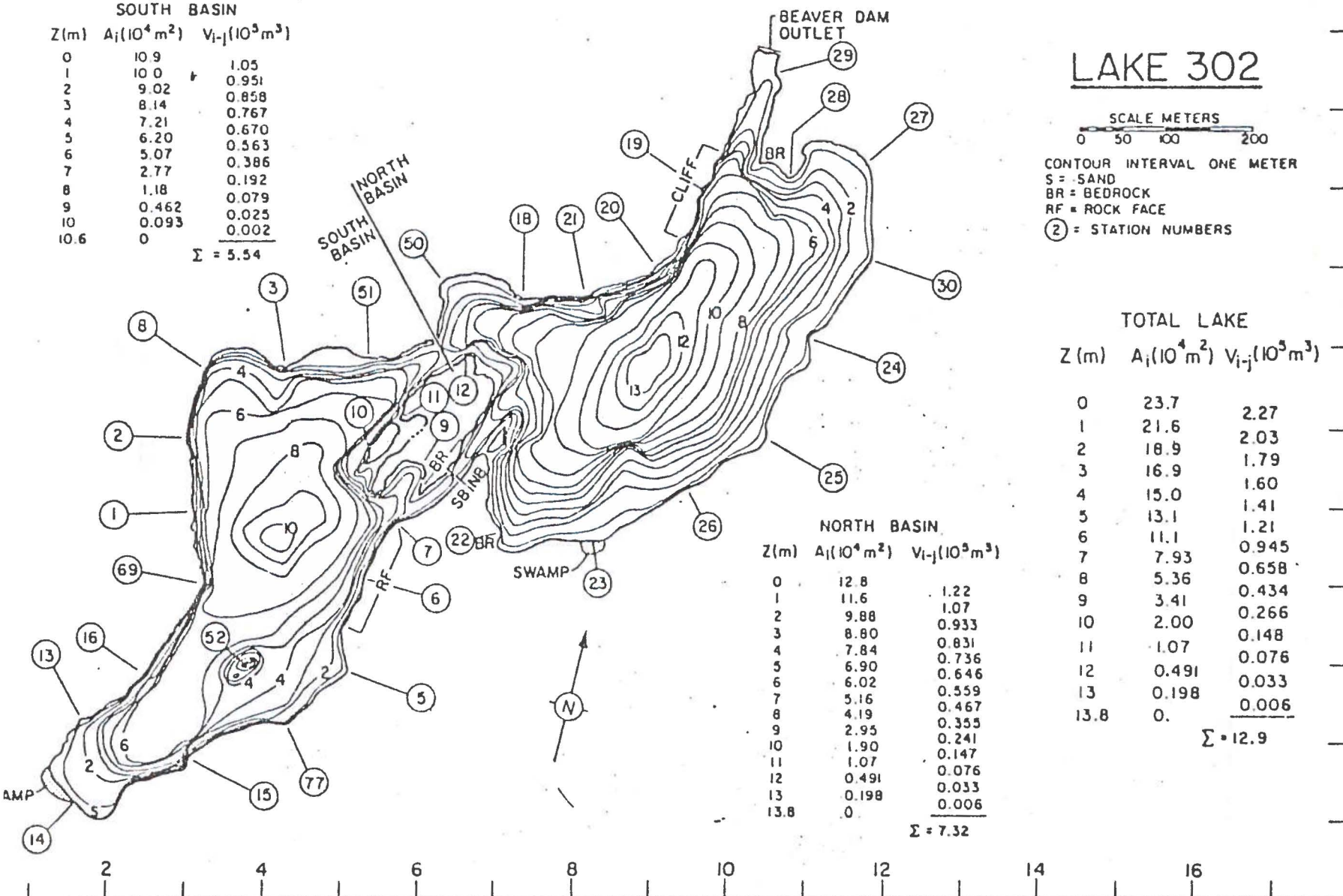
Z (m) $A_i (10^4 m^2)$ $V_{i-1} (10^5 m^3)$

0	12.1	1.12
1	10.3	0.698
2	4.15	0.213
3	0.631	0.038
4	0.172	0.005
5	0	

$\Sigma = 2.07$



SOUTH BASIN		
Z(m)	A _i (10 ⁴ m ²)	V _{i-j} (10 ³ m ³)
0	10.9	1.05
1	10.0	0.951
2	9.02	0.858
3	8.14	0.767
4	7.21	0.670
5	6.20	0.563
6	5.07	0.386
7	2.77	0.192
8	1.18	0.079
9	0.462	0.025
10	0.093	0.002
10.6	0	
Σ = 5.54		



LAKE 302

SCALE METERS
0 50 100 200

CONTOUR INTERVAL ONE METER
S = SAND
BR = BEDROCK
RF = ROCK FACE
(2) = STATION NUMBERS

TOTAL LAKE		
Z(m)	A _i (10 ⁴ m ²)	V _{i-j} (10 ³ m ³)

0	23.7	2.27
1	21.6	2.03
2	18.9	1.79
3	16.9	1.60
4	15.0	1.41
5	13.1	1.21
6	11.1	0.945
7	7.93	0.658
8	5.36	0.434
9	3.41	0.266
10	2.00	0.148
11	1.07	0.076
12	0.491	0.033
13	0.198	0.006
13.8	0.	
Σ = 12.9		

NORTH BASIN		
Z(m)	A _i (10 ⁴ m ²)	V _{i-j} (10 ³ m ³)
0	12.8	1.22
1	11.6	1.07
2	9.88	0.933
3	8.80	0.831
4	7.84	0.736
5	6.90	0.646
6	6.02	0.559
7	5.16	0.467
8	4.19	0.355
9	2.95	0.241
10	1.90	0.147
11	1.07	0.076
12	0.491	0.033
13	0.198	0.006
13.8	0.	
Σ = 7.32		

Project # A.1.4

PROJECT TITLE Stable Isotopes of Sulfur and Nitrogen as tracers in experimental Lake Acidification and as indicators of industrial acidification of Lakes.

PRINCIPAL DFO INVESTIGATOR'S NAME

Dr. Raymond H. Hesslein

ADDRESS AND TELEPHONE NUMBER

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PH: 204-269-7379 Ext. 425
Winnipeg, Man. R3T 2N6

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable) Lamont-Doherty Geological Observatory
Drs. W.S. Broecker, C. Kelly

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	1.5	1.5	1.5
b) Operating and Maintenance (\$000.)	19	21	18
c) Capital (\$000.)	2	1	0

ANTICIPATED DURATION OF THE PROJECT 6 years

OBJECTIVES OF THE PROJECT

1. To trace the pathways and reactions of added sulphur and nitrogen (having significantly different isotopic ratios than natural S & N) in lakes 223, 114, 302 in the Experimental Lakes Area.
2. To establish the pattern of isotopic abundances of sulphur and nitrogen in lakes unaffected by acid precipitation. Water, suspended matter and sediments will be studied.
3. Using the understanding gained in 1 & 2, to establish stable isotope methods for establishing the historic acidification or onset of acidification in lakes in impacted areas.

METHODS

High resolution gas source mass spectrometry will be used to determine the isotopic ratios of sulphur and nitrogen. Samples will be taken from water, suspended particulate and sediments. Fractions will be collected from these samples, such as SO₄, H₂S, organic sulfur from water, and acid volatile sulphur, pyrite, elemental sulphur and organic sulphur from sediments. Methods for most of the extractions have been developed by workers in this field and many were tested by R. Cook in a PhD thesis finished last year at ELA. Nitrogen will be approached in a similar fashion.

Project # A.1.4

Sulphuric acid presently being used in Lake 223 has a 34/32 signal of +17% vs Canyon Diabolo as compared to natural lake sulphur of +3-5%. This difference is large enough to use without changing the isotopic composition of the acid. The composition of the Nitric Acid is not yet known but 15N-NO3 will be added if necessary to make the signal sufficiently large.

ANTICIPATED RESULTS

We expect to learn how to interpret the sulphur and nitrogen isotope ratios in both acidified and controlled lakes by isotope budgets and rates of change and comparison to chemically and microbiologically measured rates by other ELA workers. We expect to be able to quantify rates of pyrite formation and denitrification in the whole lake. Both of these processes lead to permanent removal of acidity.

We expect to develop, using the sedimentary isotope records and radio-isotope dating (210 Pb), a means of detecting the impact of industrial source sulphur and nitrogen in lakes in impacted areas. sulphur of industrial source has a definite isotopic "finger print" as has been shown by Krause (1977) for fossil fuels and Nriagu and Coker, (1978) for mineral or sulphur. We believe the sediment record will show the onset and extent of the influence of these sources.

PERFORMANCE INDICATORS

Introductory work in:

Cook, R.B. 1981 - The Biogeochemistry of Sulfur in two small lakes, PhD Dissertation, Columbia University, New York 2342

Other references:

Krouse, H.R. 1977, Sulfur isotope studies and their role in petroleum exploration. J. Geochem. Explor, F:189-211

Nriagu, J.O. and R.D. Coker, 1978. Isotopic composition of sulfur in atmospheric precipitation around Sudbury, Ontario. Nature, 274. 883-885

Project # A.1.5PROJECT TITLE

Experimental Lakes Area, Lake 223: Crayfish Population Program

PRINCIPAL DFO INVESTIGATOR'S NAME

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Freshwater Institute,
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Winnipeg, Manitoba
R3T 2N6
204-269 7379 (Ext. 298)

or Experimental Lakes Area Camp
P.O. Box 313
Kenora, Ontario
P9N 3X4
807-227 5414

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Experimental Lakes Area (General)

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	1.5	1.5	1.5
b) Operating and Maintenance (\$000.)	7.5	5	5
c) Capital (\$000.)	0.5	0.5	0.5

ANTICIPATED DURATION OF THE PROJECTOctober 1984 or one field season after a major crayfish population collapse.OBJECTIVES OF THE PROJECT

To monitor population size, growth, fecundity and recruitment of a crayfish population (*Orconectes virilis*) in L-223, a lake which is undergoing a controlled experimental acidification.

METHODS

- 1) Population size is monitored by SCUBA divers who count crayfish present along strip transects in the lake. Counts are done at night when crayfish are out foraging on the substrate. DATA are stratified by depth.
- 2) SCUBA divers carry out regular nighttime collections of crayfish to monitor growth, fecundity and population structure. Collections are stratified by depth.
- 3) Lab measurements of animals collected in 2) are: sex, carapace length, wet weight, dry weight, egg counts and physiological condition. Representatives from each collection are frozen and saved for future reference or chemical analysis (e.g. calcium content).

Project # A.1.5ANTICIPATED RESULTS

The monitoring program has been underway since 1976. During this period methods have been refined and the lake pH has been reduced from 6.5 to 5.25.

Population structure, recruitment, and growth have remained relatively constant from 1976-1980. Fecundity and egg development have remained normal for the most part except that in recent years a few females each season produce (or carry) an abnormally small number of eggs. The ability of animals to harden after moulting seems somewhat impaired though changes to this point are marginal.

Continued softening of the population due to decalcification of the exoskeleton and a recruitment failure at a lower lake pH is the anticipated result. Complimentary work on crayfish physiology is currently under investigation by Dr. D. Malley of the ELA project. Alternatively an overall population failure may result if acid stress induces a higher incidence of a microsporozoan parasite infection currently present at low levels in the crayfish of L-223.

PERFORMANCE INDICATORS

Publications in referenced journals, internal technical or data reports and papers presented at conferences will constitute the final result of the project.

Results will also be incorporated into overview papers by other project personnel.

Project # A.1.6PROJECT TITLE

Experimental Lakes Area, L-223: Insect Emergence Program

PRINCIPAL DFO INVESTIGATOR'S NAME

Ian Davies

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204-269 7379 (Ext. 298)

or

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Kenora, Ontario P9N 3X4
807-227 5414

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Experimental Lakes Area (General)
ELA Phytoplankton Program

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
Excluding crayfish study	1.5 (0.5)	1.5 (0.5)	1.5 (0.5)
a) Person Years			
(Including crayfish study)			
b) Operating and Maintenance (\$000.)	7.5	5	5
c) Capital (\$000.)	5	nil	nil
(Nikon Dissecting Microscope)			

ANTICIPATED DURATION OF THE PROJECT

1984 or until recovery of L-302 and L-223 is well progressed.

OBJECTIVES OF THE PROJECT

To monitor changes in the number, biomass and species composition of insect emergence in lakes undergoing experimental acidification with H₂SO₄ (L-223, L-302S) and HNO₃ (L-302N).

METHODS

Submerged conical emergence traps are placed at several depths along transects in each lake. Collections are made from these traps for one 24 hr. period each week throughout the ice free season.

Insects caught in the traps are killed, then counted, and either dried for biomass determinations or saved for taxonomic identification. Identifications are to be contracted out (\$4,000 - \$4,500 O&M annually, the residual \$500 each year is used for emergence trap materials).

Project # A.1.6ANTICIPATED RESULTS

Current European hypotheses about the acidification process predict a gradual oligotrophication as lakes become more acid.

Our evidence to date suggests the contrary, at least for the initial phases of acidification. Oligotrophication may occur at lower pH's but the transition may be as a catastrophic collapse.

A monitoring program has been in place on L-223 since 1975 and in L-302 from 1973-1974 and 1981. Although the Chironomidae are among the most acid resistant organisms, their species composition will be affected by changes in lake pH.

Previous work by Davies at ELA has shown a close correlation between planktonic primary production and Dipteran emergence. Both variables are being monitored in L-223 and L-302N&S to determine the validity of the oligotrophication hypothesis and to look for the differential effects of H₂SO₄ and HNO₃ treatments.

Because Dipteran insects are a major food resource for fish, a knowledge of their response to acidification is essential.

PERFORMANCE INDICATORS

Publications in refereed journals, internal technical or data reports and papers presented at conferences will be the end result of this study.

Results will also be incorporated into overview papers summarizing the L-223 and L-302 experiments by other project personnel.

Project # A.1.7

PROJECT TITLE

E.L.A. Primary Production - Phytoplankton productivity

PRINCIPAL DFO INVESTIGATOR'S NAME

John A. Shearer

ADDRESS AND TELEPHONE NUMBER

501 University Crescent
Winnipeg, Manitoba R3T 2N6
(204) 269-7379

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

DFO RESOURCES ASSIGNED

	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	1.5	1.5	2
b) Operating and Maintenance (\$000.)	\$11	\$12	\$15
c) Capital (\$000.)	5	?	?

ANTICIPATED DURATION OF THE PROJECT

5-6 years

OBJECTIVES OF THE PROJECT

To determine the responses of phytoplankton populations to artificial acidification schemes and to monitor changes in light attenuation in acidified lakes.

METHODS

Phytoplankton productivity, measured as ^{14}C uptake, is monitored at 2-week intervals on each acidified lake, using the incubator technique developed at E.L.A. by E.J. Fee. Control basins are also monitored.

Light attenuation is measured on each lake at 2-week intervals using quantum-sensing equipment.

Project # A.1.7ANTICIPATED RESULTS

Results to date indicate that the transparency of acidified lakes increases, probably through a reduction of the humic colouring. There has been no detectable reduction in phytoplankton productivity, however. In fact, there has been a trend toward higher productivity, probably because of the increased availability of light within the water column. This trend can be expected to continue. It confirms observations made on some southeast Ontario lakes and opposes the Scandinavian theory that acid rain leads to lake oligotrophication.

PERFORMANCE INDICATORS

Data from past years has been published in two "AUSERP" Reports and in a series of annual data reports on E.L.A. light attenuation and phytoplankton productivity. This series of data reports will be continued. It is also anticipated that a more complete discussion of the findings will be published in a scientific journal.

Project # A.1.8

PROJECT TITLE

The influence of acidification upon benthic algae.

PRINCIPAL DFO INVESTIGATOR'S NAME

Michael A. Turner (A)

ADDRESS AND TELEPHONE NUMBER

Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
204 - 269 7379 Ext. 327 (Nov. to Apr.)
807 - 227 5414 (May to Oct.)

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

ELA: Ed deBruyn and John Shearer (B): phytoplankton photosynthesis

David Findlay (C): algal enumeration and taxonomy

Garry Linsey (D): aquatic chemistry

DFO RESOURCES ASSIGNED

	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	0.85*	1.10*	1.10*
	(Student		
b) Operating and Maintenance (\$000.)	3.5	0.1) 4.0	4.6
c) Capital (\$000.)	0	1.0	0.5

ANTICIPATED DURATION OF THE PROJECT

Until 1986, i.e., to continue for the duration of the 302 sulphuric-nitric acidification experiment.

OBJECTIVES OF THE PROJECT

To assess the influence of sulphuric and nitric acidification upon benthic algal photosynthesis and taxonomy.

METHODS

As described by Schindler, 302 N&S will be used for the sulphuric and nitric acid additions. L.239, and less frequently L.240, will be used as reference basins to assess seasonal and year to year variation. Transect locations will be selected in each basin, with spatial heterogeneity studies to be conducted in 302S and 239 to determine their suitability. Artificial substrates (vitrified clay) will be used, with comparisons with natural communities to be made. A light-incubator technique (Turner 1981) will be used to establish photosynthesis-irradiance curves characteristic of the experimental populations, analogous to the strategy used in phytoplankton studies (Fee 1973). This will involve monitoring uptake of dissolved inorganic carbon from the water overlying the benthic sample (Schindler et al. 1973) at several irradiances. Parallel samples will be taken for algal taxonomy, chlorophyll a and particulate C, N and P.

Project # A.1.8ANTICIPATED RESULTS

In acidified lakes in Scandinavia, and in the experimentally-acidified Lake 223, the green alga, Mougeotia sp., has been observed to dominate the benthic flora (several papers in Drablos and Tollan 1980, Schindler et al. 1980). Occasional observations of benthic photosynthesis in a short term enclosure experiment suggested that the productivity of a Mougeotia mat in the ca. pH5 enclosure was greater than that of algae in a control (Muller 1980). It appeared that benthic algae in an oligotrophic lake were P-sufficient; and it was implied that benthic algae are limited in the substrate surface area available (Turner 1981). Given that the filamentous aspect of Mougeotia can provide such needed surface area, in conjunction with the above observations, we will observe stimulation of benthic photosynthesis, development of Mougeotia and a concomitant reduction of species diversity in response to acidification.

A recent addition of NH_4NO_3 to the oligotrophic Castle Lake appeared to stimulate benthic photosynthesis although phytoplankton productivity was unchanged (John Reuter and Stan Loeb pers. comm.). Given the interplay of nutrient availability and concomitant production of alkalinity, it is possible that nitric acidification will be less efficient than with sulfuric acid. Thus, at a given pH, nitric acidification may preferentially stimulate benthic photosynthesis.

PERFORMANCE INDICATORS

Publication of manuscripts, technical and data reports.

Although subject to change in the future, the following output is anticipated through 1984:

- i) Benthic incubator design (Can. Fish. Mar. Serv. Tech. Rep. in 1982)
- ii) Detailed protocol of methodology, plus 1981 time-series observations (C.F.M.S. Tech. Rep. in 1982). Future time-series to be published as data reports.
- iii) Benthic methodological questions: 1981 and early 1982 results of spatial and temporal variation within and among control lakes (Can. J. Fish. Aquat. Sci. in 1983 or as part of book on periphyton productivity edited by R. Wetzel in 1983).
- iv) Early acidification results: 302S versus 239 and 240 with 1982 versus 1981. May wait for a second year of acidification and/or include some observations of 223 Mougeotia in 1981 and 1982. 302N versus 302S. (Can. J. Fish. Aquat. Sci. in 1983 or 1984).

With additional resources, \$ and person-years, we would pursue (not necessarily in order of priority):

- a) the role of the benthic community in the cycling of metals in systems under-going acidification, including methylation and demethylation of Hg in collaboration with Dr. J.W.M. Rudd (D.F.O., Winnipeg, Toxicology).
- b) the effect of acidification upon herbivorous grazing of benthic algae.
- c) assessing the influence of acidification upon epilithic bacterial numbers and productivity in collaboration with Dr. C. Kelly (Limnology) and Dr. J. Rudd.
- d) the variation in importance of benthic algae to whole lake photosynthesis in response to acidification.

Project # A.1.9

PROJECT TITLE

Physiological basis of adverse effects of low pH (alone and in combination with certain metals) on crayfish and other benthic crustaceans; physiological nature of adaptation by crustaceans to life in acidic waters.

PRINCIPAL DFO INVESTIGATOR'S NAME

D.F. Malley

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Experimental Limnology Project
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(204) 269-7379 ext 273

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	1.5*	1.5	1.5
b) Operating and Maintenance (\$000.)	15	15	17.5
c) Capital (\$000.)		10	

* 2 x 0.5 permanent p-y; contract (data analyst/programmer) 0.2 p-y; 1 summer student, graduate student participation desirable

ANTICIPATED DURATION OF THE PROJECT

Present until March 1984

OBJECTIVES OF THE PROJECT

1. to illucidate the major or set of major physiological responses of crustaceans to low pH or to metals in low pH which are responsible for the failure of populations in acidic waters
2. to understand the physiological adaptations of crustaceans which inhabit waters of pH 3.8 to 4.2 range. cont'd
3. on the basis of 1. and 2. to suggest physiological parameters which may be used for the selection of individuals during selective breeding of important crustacean species for restocking of freshwaters recovering from acidification.
4. to predict the effects of acidic precipitation on the geographical distribution of crayfish and other important benthic crustaceans of eastern Canada.

Project # A.1.9METHODS

1. Ca^{++} is the ion subject to the greatest rates of influx and efflux between crustacean and environment. Uptake of ^{45}Ca during the postmoult period has been used as a parameter to test the effects of pH, metals (Al, Cd to date, Zn, Mn planned) and pH-metal interactions on ionic balance in Crustaceans. Mechanism of inhibition of Ca^{++} uptake by low pH will be further studied by selective removal of other ionic species from the medium, by the use of metabolic inhibitors (e.g. for carbonic anhydrase and Na transport) and by the isolation and chemical characterization of enzyme or ion transport systems.
2. After chronic exposure to low pH and metals (Cd, Al) crayfish will be analyzed for bioaccumulation of metals and for the metal-bearing protein, metallothionein.
3. Based on the conclusions of the ionic uptake work and on the results of graduate student research and other studies underway on effects of acidification on Mysis relicta, on growth and reproduction of crayfish and uptake of tracer metals by crayfish tissues, one or two key physiological parameters will be identified. The response of these parameters in various crustacean species to ionic composition of water (esp. Ca^{++} , alkalinity and pH) and other limnological parameters will be used as a basis of predicting effects of acid precipitation on zoogeography of crayfish and several other important crustaceans.

ANTICIPATED RESULTS

Enhanced understanding of the means by which crustaceans are adapted to acidic waters. This information can be used to select more efficiently those organisms which can survive in waters made acidic by acid precipitation and on the other hand, can be used to assess more effectively the ecological impact of acid precipitation if it continues unabated.

PERFORMANCE INDICATORS

Publication of papers in primary, refereed journals and of technical and data reports as needed.

Project # A.1.10

PROJECT TITLE

The role of microbial nitrate reduction in modifying pH reduction in a lake being experimentally acidified by addition of HNO_3 .

PRINCIPAL DFO INVESTIGATOR'S NAME

John W.M. Rudd

ADDRESS AND TELEPHONE NUMBER

Department of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
R3T 2N6
(204) 269-7379

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

N. Loewen
University of Manitoba

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	0.7(1.7)*	1.0(2.0)	1.3(2.3)
b) Operating and Maintenance (\$000.)			10.0(11.5)
c) Capital (\$000.)	6.0	0.0	0.0

* Numbers in brackets are unallocated requests.

ANTICIPATED DURATION OF THE PROJECT

April 1, 1981 to March 31, 1986

OBJECTIVES OF THE PROJECT

To determine the importance of alkalinity production by microbial nitrate reducing activities in lakes. These include photosynthetic nitrate reduction and bacterial denitrification which both contribute to alkalinity.

To determine the factors controlling rates of denitrification in lakes.

To determine the effects of reduced pH and increased NO_3^- and HS^- concentrations on denitrifying bacteria.

METHODS

Denitrification rates will be assayed either by an acetylene inhibition technique or a ^{15}N technique using an emission spectrometer. An inter-comparison of these methods is underway.

Experiments will be done in intact cores and by laboratory incubations of lake sediment.

Whole lake denitrification rates will be estimated by mass balance calculation and by heavy isotope analyses of N_2 produced from denitrification of added HNO_3 .

Project # A.1.10

ANTICIPATED RESULTS

Reduction of nitrate either by bacterial denitrification or by algal photosynthesis results in an increase in alkalinity thus modifying pH reduction resulting from acid precipitation. Bacterial denitrification is a permanent alkalinity increase since the N_2 and N_2O produced escapes to the atmosphere. Burial of photosynthetically reduced nitrate may not be permanent if the reduced nitrogen is regenerated by microbial decomposition.

The experiments outlined above will be carried out in a lake that is being experimentally acidified by addition of HNO_3 . Mass balance calculation will give whole lake nitrate reduction rates. Heavy isotope and bacterial assays of denitrification will be indicative of the relative importance of denitrification vs. permanent burial of photosynthetically reduced nitrate. Experiments on pH tolerance and factors controlling rates of denitrification will establish limits for this type of microbial alkalinity producing activity.

PERFORMANCE INDICATORS

M.Sc. Thesis - N. Loewen
Refereed publication

Project # A.1.11

PROJECT TITLE

Effects of lake acidification on rates of methylation and demethylation of mercury.

PRINCIPAL DFO INVESTIGATOR'S NAME

John W.M. Rudd

ADDRESS AND TELEPHONE NUMBER

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COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

P. Ramlal
University of Manitoba

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	1	0.5	0.2
b) Operating and Maintenance (\$000.)			6 (9)*
c) Capital (\$000.)	0.0	0.0	0.0

* Number in bracket is unallocated request.

ANTICIPATED DURATION OF THE PROJECT

April 1, 1981 to March 31, 1986

OBJECTIVES OF THE PROJECT

To determine if the acidification of lakes will promote the methylation of mercury or inhibit the demethylation of mercury.

METHODS

- Two radiochemical methods have been developed to assay:
 - 1) $203\text{Hg}^{2+} \xrightarrow{\text{CH}_3} 203\text{CH}_3\text{Hg}^+$
 - 2) $14\text{CH}_3\text{Hg}^+ \xrightarrow{\text{Hg}} 14\text{CH}_4 + 14\text{CO}_2$
- these methods will be used on lake sediment samples and on laboratory incubated lake sediments at various pH's to determine pH tolerance and effects on rates of Hg methylation and demethylation.
- In addition the effects of increased HS^- concentrations on rates of mercury methylation and demethylation will be assayed.

Project # A.1.11

ANTICIPATED RESULTS

Hg concentrations in fish are thought to increase during the early stages of acidification. This may be a consequence of increased rates of mercury methylation at low pH or decreased rates of mercury demethylation. The proposed experiments will determine if methylation and demethylation rates change at reduced pH and whether this is because of changes in rates of overall microbial activity or because of changes in methylation or demethylation rates in particular.

In addition, the effects of increased sulphide concentrations present in acidified lakes on rates of methylation and demethylation will be determined. Our previous work on non-acidified systems indicate that contrary to present understandings, sulphide is not an effective inhibitor of mercury methylation.

PERFORMANCE INDICATORS

M.Sc. Thesis - P. Ramlal
Refereed publication

Project # A.1.12

PROJECT TITLE

Contamination of the Fishery by Mercury and other heavy metals from atmospheric deposition: Acclimation, Dynamics and Toxicology of Metals in Fish.

PRINCIPAL DFO INVESTIGATOR'S NAME

J.F. Klaverkamp

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COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Heavy Metal Analytical Unit; FWI:
R. Wagemann

DFO RESOURCES ASSIGNED

	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	5	5	5 amts in
b) Operating and Maintenance (\$000.)	18+(28)	(46)	(46) () are
c) Capital (\$000.)	(10)	(10)	(10) requests

ANTICIPATED DURATION OF THE PROJECT

1981-1984

OBJECTIVES OF THE PROJECT

1) To investigate the degree of heavy metal (mercury, cadmium, copper, zinc and selenium) contamination of the fishery located near the base metal smelter in Flin Flon, Manitoba; and to investigate some biological effects (e.g. increased resistance to lethal conc. of metals; metallothionein levels in gill, gut and liver; and ionoregulatory failure) of this metal fall-out to the fishery. Previous investigations (Van Loon and Beamish, 1977; McFarlane and Franzin, 1978; Franzin et al. 1979; McFarlane and Franzin, 1980) provided estimates of metal input to the lakes and contamination of some biota, but little emphasis was placed on mercury contamination of fish flesh, elevated acclimation to metals by fish, and sub-lethal toxicology of the acidification.

2) To investigate the uptake and distribution of these and other metals associated with Acid Rain in fish exposed in tubes and whole lakes;

3) To investigate the biochemical mechanisms which provide fish with the ability to tolerate higher concentrations of metals if these fish have been pre-exposed to metals in sublethal concentrations;

4) To investigate the significance of these mechanisms in natural fish stocks by bio-chemical examination of fish from metal-polluted areas, e.g. Flin Flon;

5) to investigate the effects of acidification/heavy metals on early life history stages of fish, and factors controlling the accumulation of metals in fish eggs.

Project # A.1.12

METHODS

Experimental methods for fish capture, for metal exposures, for radio-tracer detection, for biochemical analyses, and for heavy metal analyses (R. Wagemann and A. Lutz) have been developed and applied. Using radiolabelled metals, e.g. Hg203, Cd109, Zn65 and Se75, and tube enclosures, factors (viz. acid, calcium, selenium) influencing uptake and distribution in fish are examined. Using traditional laboratory acute lethality methods, increased tolerance development to metals in fish exposed to sublethal concentrations of these metals is determined. Correlation of increased tolerance to increased concentration of metallothionein in vital organs, e.g. gill, liver and gut, is determined. Increased metallothionein concentrations in fish exposed to atmospheric fall-out of metals at Flin Flon has been observed in our laboratory. Field studies on the development of fertilized fish eggs use in situ lake incubators. Laboratory toxicity testing follows standard procedures.

RESULTS TO-DATE, ANTICIPATED RESULTS, AND EXPERIMENTS IN PLANNING

We have found:

1. Suckers can substantially (up to 5x) increase their tolerance to mercury and cadmium, but not to zinc and selenium.
2. Increased synthesis of metallothionein (MTN) in liver, gill and gut may explain this increased tolerance. After the Metals Exposure lab is operational, studies to correlate rates of tolerance development to rates of MTN increases would be highest priority. Studies to determine whether elevated MTN would return to baseline with subsequent loss of tolerance when the metal exposure was stopped would be the next step in this area.
3. Flin Flon suckers from a contaminated lake have elevated (2-4x) MTN levels.
4. Se and Hg are not synergistic in toxicity to rainbow trout or lake trout eggs. Consequently we could not confirm the work of Huckabee and Griffith (1974) showing synergism in carp eggs. This work is important for a number of reasons; one being that the carp egg work is one of only two biological systems showing synergism. Most systems show antagonism (i.e. selenium protects against mercury toxicity).
5. Small increases in major cation concentration produce substantial increases (2-3x) in mercury and selenium accumulation in lake trout eggs. With the exception of calcium inhibiting Cd accumulation, these cations do not affect accumulation of Cd or Zn. It is interesting to note that the carp eggs previously mentioned were pre-treated with NaCl whereas our trout eggs were not.

During this year, we plan to:

1. Evaluate the applicability to fishes of methods for MTN analyses used in mammalian systems.

Project # A.1.12

The intent of this work would be to find a sensitive, easy, fast and inexpensive method for MTN analyses in aquatic organisms. This could then be used as a screening system for assessing the impact of metals (relevant to Acid Rain, Arctic Mining, or Metal Smelting) on aquatic organisms (MTN is ubiquitously distributed in plants and animals). The need for such screening system is two-fold:

1) Except for gross contamination, whole-animal or whole-organ metal concentrations are meaningless as far as toxicity to the animal is concerned.

2) Sub-cellular distributions of metals (especially fractions bound to MTN and to high molecular weight proteins) are good indicators of exposure history and tolerance status" (I can explain, if needed).

2. Set up a Metal Exposure laboratory and investigate correlations of tolerance development to MTN concentration increases and of loss of tolerance to MTN decreases.

3. Continue investigations on the "salt enhancement" effect on Hg and Se accumulation in fish eggs, and

4. Initiate studies to determine the ability of rainbow trout eggs to increase tolerance when exposed to sub-lethal concentrations of Hg, Se, Cd and Zn. If they can, is it due to MTN?

5. Determine the effects of elevated selenium body burdens in fish on the accumulation of mercury, cadmium and zinc. From the large amount of work in mammalian and avian systems, one would expect substantial increases in accumulation (especially Hg and Cd) in fish having elevated selenium body burdens. This would be very relevant to the Acid Rain problem since,

1. Se behaves very similar to sulfur and would probably be removed from atmospheric emissions if (when?) sulfur scrubbers are put into use; and yet

2. Se is a very potent de-toxifier of Cd and Hg.

One man-month will be spent on a field trip to Flin Flon. The objectives of the trip are four-fold:

1. to obtain first-hand information on processes involved in metal smelting.

2. to obtain water and sediment samples from 5 lakes and muscle and liver samples from two fish species (pike and suckers) from these lakes for analyses of mercury, selenium, cadmium, copper and zinc.

3. to obtain serum samples from these fish for analyses of Ca, Mg, Na, K and Cl. Depressed levels of these electrolytes would indicate sub-lethal stress induced by "acid rain" since iono-regulatory failure has been shown to be the critical mechanism of toxic action of acid on fish (for example, see: McDonald et al. 1980. J. exp. Biol. 88: 109-131).

4. to conduct simple on-shore toxicity tests using suckers to determine if the elevated MTN concentrations described earlier are relevant in terms of increased tolerance.

Project # A.1.13

PROJECT TITLE

Effects of acid alone and of acids in the presence of elevated metal concentrations on lake zooplankton diversity, biomass and reproductive capacity.

PRINCIPAL DFO INVESTIGATOR'S NAME

S.G. Lawrence

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204 269-7379 Ext. 319

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Dr. N.E.R. Campbell
Department of Microbiology
University of Manitoba
Winnipeg, Manitoba

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	3.8a	3.9c	3.9c
(2 permanent, 2 contract, 2 s.s.)			
b) Operating and Maintenance (\$000.)	29.9b	30.5	33.5
c) Capital (\$000.)	-	1.5	1.5

- a 2.4 permanent m.y., 2 6-mo. contracts, 1 summer student.
b \$6000 is currently available from Toxicology Section and is included in this figure. Also included is \$3500 for S.L. Leonhard who will spend 0.4 m.y. on an acid project, 0.6 m.y. writing and associated projects.
c 2.5 permanent m.y., 1 contract, 1 summer student.

ANTICIPATED DURATION OF THE PROJECT

To March 1984.

OBJECTIVES OF THE PROJECT

Zooplankton communities respond more definitely to lowered pH than do freshwater fish, with changes occurring in biomass and in species distribution and composition. In addition, many members of the community are very sensitive to the presence of heavy metals (e.g. as found by Marshall, Argonne National Labs and by me at ELA). They are not only important components of the food web leading to fish then, but constitute a group sensitive to stress. However, most data have been obtained either from impounded populations and/or at very low pH(4-5). So far, the invertebrates of L. 223 (to pH 5.3) have not been very adversely affected. Since more and more toxicological work is being done in field impoundments rather than in whole lakes, it is necessary to assess the various systems we use for utility in extrapolation to whole ecosystems. ELA is ideally set up to test hypotheses dealing with extrapolation since impoundments and whole lake studies tend to be done simultaneously at least at the beginning stages of lake manipulation.

Project # A.1.13

The experimental studies on zooplankton at ELA will determine whether data obtained from impounded populations can be used to predict what will happen to populations in whole ecosystems. Since 1977 we have used open and closed impoundments of 20,45,1.5x10³ and 1.5x10⁵ liter to examine the uptake and toxic effects of cadmium on zooplankton populations at several pHs. In the past year Cd109 was used to trace uptake into biota in the presence of selenium and of two concentrations of calcium. There is some likelihood of aluminum being added to L. 223 during the recovery stage (1982-83?). Very little is known of the effects of Al in lake biota, except that it is extremely toxic to fish at pH 5.3-5.5. Calcium apparently ameliorates the toxicity.

The following experiments designed to obtain data on various groups of lake biota are proposed 1) to add to the data on the movements and effects of cadmium and/or acid on invertebrate biota in impoundments, and on the effects of moderate amounts of calcium on the uptake and effects of cadmium, 2) to obtain a working knowledge of the effects and distribution of aluminum in biota and 3) to obtain data on the use and usefulness of impoundments to experimental toxicology done in the field.

METHODS

Several types and sizes of impoundments will be setup in two lakes to study effects of acid and/or metals on zooplankton. Sampling, identification and analytical methods are available for immediate use. A field sampling program is in effect so that natural zooplankton populations in three acidified lakes can be studied as whole lake experiments progress.

ANTICIPATED RESULTS

Additional data on the movements and effects of low concentrations of metals and/or acid on invertebrate biota in impoundments, verification of the use and usefulness of impoundments to experimental toxicology in the fields.

PERFORMANCE INDICATORS

Publication of a series of papers in primary, refereed journals.

Project # A.1.14

PROJECT TITLE

Effects of H^+ and accompanying ions (SO_4^{2-}/NO_3^-) on degradation of particulate organic carbon to methane and carbon dioxide by lake sediment bacteria.

PRINCIPAL DFO INVESTIGATOR'S NAME

S.G. Lawrence

ADDRESS AND TELEPHONE NUMBER

Freshwater Institute
501 University Crescent
Winnipeg, Manitoba
R3T 2N6
204 269-7379 Ext. 319

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Dr. N.E.R. Campbell
Department of Microbiology
University of Manitoba
Winnipeg, Manitoba

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84^b</u>
a) Person Years	0.5	1.0	1.0
b) Operating and Maintenance (\$000.)	3.4	9.7a	11.1b
c) Capital (\$000.)	-	-	-

ANTICIPATED DURATION OF THE PROJECT

To March 1984.

OBJECTIVES OF THE PROJECT

To ascertain how increased H^+ and/or associated ions affect sediment bacterial activity with respect to production of methane and carbone dioxide from algal organic carbon originating in the lake water column.

METHODS

- a) Laboratory: anaerobic incubation of lake sediments containing labelled particulate organic carbon under varying conditions of acidity and in the presence of various associated ions (e.g. SO_4^{2-} or NO_3^-), with subsequent recovery of methane and carbon dioxide. The carbon added will be obtained from cultures of acidophobic or acidophilic algae. Other experiments will be designed to investigate effects of acidic elements on various parts of bacterial cycles which degrade organic carbon.

a Terminal year for present student.

b If a further graduate student is admitted to the program.

Project # A.1.14

- b) Field: Impoundment systems will be placed in anaerobic lake sediments to study effects on in situ sediment bacterial production of methane and carbon dioxide from labelled algal particulate organic carbon of added acids and other ions.

ANTICIPATED RESULTS

Lake sediment bacteria return carbon to the water column of lakes by their metabolic activities, some of which are apparently inhibited by lowered pH. Bacterial groups ordinarily present in very low numbers in sediments may rise to dominance when environmental conditions change, e.g. with addition of H^+ and SO_4^- . Rates at which bacteria in sediments degrade organic carbon formed under various conditions of pH will be measured. As well, the way in which these systems shift metabolic activities to meet environmental change will be studied.

PERFORMANCE INDICATORS

M.Sc. thesis; one to several papers to be submitted to primary, referred journals.

2. Algoma Watershed Studies

Project # A.2.1

PROJECT TITLE

Biological production, community structure and success in a calibrated watershed.

PRINCIPAL DFO INVESTIGATOR'S NAME

Dr. John R.M. Kelso

ADDRESS AND TELEPHONE NUMBER

Great Lakes Biolimnology Lab.
875 Queen Street E.
Sault Ste. Marie, Ontario
P6A 2B3
705-942-2848

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

National Water Research Institute; Atmospheric Environment Service; National Hydrologic Research Institute; Great Lakes Forest Research Institute; Fisheries Research Branch, Ontario Ministry of Natural Resources; universities supported by contract, as collaborators, or with grad. student projects.

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	6.0	6.0	5.5
b) Operating and Maintenance (\$000.)	101.5	101.5	95
c) Capital (\$000.)	15	15	15

ANTICIPATED DURATION OF THE PROJECT

3 years operational, 1 year data analysis, 2 year model testing (could include system manipulation/alteration = 6 years.

OBJECTIVES OF THE PROJECT

Through operation of a calibrated system, determine the response of an aquatic system to a moderate-high loading rate (AES) by a) budgeting major ion chemistry and hydrology (NWRI) (NHRI); b) determining effect of inputs on terrestrial system and influence of terrestrial system on the input (GLFRI); c) determine biological state and response and effect on early life history of fish (DFO and OMNR).

METHODS

In a lake system having lakes ranging from a sensitive headwater lake to a downstream better buffered lake, determine inputs from the atmosphere (AES), the groundwater contribution to lake chemistry and hydrology (NHRI), create a chemical/hydrological budget (NWRI) by monitoring water flow and water chemistry, determine biological community and production in relation to lake chemistry in each lake (DFO), determine factors influencing fish well-being and production in each lake, determine success of fish early life history in the

Project # A.2.1

lakes of various pH and buffer state. Biological studies occur in 4 lakes ranging from acidic to susceptible. Fish communities range from none to mixed brook trout/lake trout.

- 1979-80 - site selection DFO, GLFRC.
- 1980-81 - description of site, communities, emplacement of monitoring program, all agencies.
- 1981-82 - budget measurements, biological production measurement of lakes and interconnecting streams.
- 1982-83 - experimental examination of metal effects on biota and interaction of metals with environment.
- 1983-84 - budget, modeling, analysis of data, planning and selection of experimental method.

ANTICIPATED RESULTS

1. Determination of rate of change in an aquatic system as a result of LRT.
2. Characterization of biological response to lake acidic state.
3. Identification of factors, particularly heavy metals influenced by buffer state which influence biological state.
4. Identification of the symptoms in biological communities that appear from stresses resulting from low pH and/or decreased buffer state.

PERFORMANCE INDICATORS

1. Kelso, J.R.M. 1979. Aquatic studies in the Algoma calibrated watershed IN Proc. of Ont.-Can. Res. Co-ord. Grp., Sept. 1979.
2. Presentations:

	i) Laurential University, January 1980
(re biological studies in	ii) Oslo, Norway March 1980
a calibrated watershed	iii) Ont.-Can. workshop February 1981
3. Overall project description and research plans completed. Turkey Lake Forested Watershed Program. February 1980
4. Workshop expected fall 1981.
5. Special session planned for IAGLR 1982 on the Algoma watershed.

3. Westfield River Studies

Project # A.3.1

PROJECT TITLE: Intensive study of the ecology of Atlantic salmon in an acidified stream.

PRINCIPAL INVESTIGATOR'S NAME: Dr. G.L. Lacroix

ADDRESS AND TELEPHONE NUMBER: Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B. EOG 2X0

COOPERATING AGENCIES AND INVESTIGATORS:
(if Applicable)

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
a) Person Years	3.5	2.5	2.5 (0.5 from existing personnel)

ANTICIPATED DURATION OF THE PROJECT: 5-10 years

OBJECTIVES OF THE PROJECT

To determine reproductive success and productivity of fish populations in the Westfield River, a stream with mean annual pH ca. 4.9 (mean discharge of 30 L/S/Km²); to determine the importance of anadromous and catadromous fish populations to stream productivity and nutrient flow within the stream ecosystem, and assess what loss of these populations through acidification means to the ecosystem; to thoroughly investigate nutrient fluxes and sources of acidity within the stream ecosystem; to determine the influence of low pH on species assemblages of freshwater stream communities; to determine the relative importance of heavy metals and pH on the fish populations.

METHODS

A permanent study area in a section of stream utilized heavily for reproduction by Atlantic salmon will be set up. Counting fences will be installed at the boundaries of the study area to assess migrations in and out of the area. Periodic stream censuses and marking procedures will be performed in the study area to assess population parameters. Nutrient (and other major ions) analyses will be performed periodically on water samples and on fish tissues to assist in generation of nutrient budgets. Productivity and nutrient content of periphyton and benthic invertebrates will be measured. Three gauging stations will be installed, such that characteristics of the hydrology of the drainage basin can be assessed and modelled. Precipitation contributions to the stream can be assessed from data being collected at the Kejimikujik calibrated watershed study. Stream drift samples will be used to assess invertebrates and particulate fluxes through the study area. Comparative studies will be performed on various aspects using other streams with differing water chemistries where necessary and appropriate.

Project # A.3.1 (cont'd)ANTICIPATED RESULTS:

Assessment of reproduction, growth rates, mortalities, population numbers, and productivities of various fish species in the Westfield River at various stages in the freshwater phase of the life cycle. Attention will be focussed on the Atlantic salmon population.

Assessment of the role of anadromous and catadromous fish species in the nutrient budgets of an acid-stressed stream.

Assessment of the responses of the water chemistry of the drainage system to seasonal fluctuations in precipitation and runoff, and the effects of these changes on fish and stream invertebrates.

Determination of the roles of low pH and heavy metals on fish reproduction in a brown water stream.

PERFORMANCE INDICATORS:

Primary publications

Project # A.3.2

PROJECT TITLE: Invertebrates of the Westfield River study area and their relationship to the food habits of the fish.

PRINCIPAL INVESTIGATOR'S NAME: M.J. Dadswell

ADDRESS AND TELEPHONE NUMBER: Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B. EOG 2X0

Telephone No.: (506)-529-8854

COOPERATING AGENCIES AND INVESTIGATORS: Aquatic Industries Limited
(Mr. Derek Knox, Ms. Leslie Linkletter)

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
a) Person Years	0	0	0
b) Operating and Maintenance (\$000)	41	42	44
c) Capital (\$000)	0	0	0

ANTICIPATED DURATION OF THE PROJECT: 3 years

OBJECTIVES OF THE PROJECT

Determine species composition, seasonal and spatial distribution, and abundance of benthic invertebrates in and on the substrate and in the drift of the Westfield River study area. Quantitatively examine fish stomachs and invertebrates to determine fish food habits and their relation to each component of available food.

METHODS

1. Survey study area using hand collecting, Surber samplers and pot samplers to determine total species composition of invertebrates and map their distribution within the study area. This general collecting will be done four times, once each in June, August, October and March.
2. Quantitatively sample benthic, drift and emergent invertebrates using Coleman-Hynes pot samplers drift nets and emergence traps. Replicate pot samples (2) are to be obtained from 12 sites along 4 transects within the study area once monthly, May to December, and in March (9 sample times). Drift nets are to be set on 2 transects during a 3-day period and sampled on a diurnal basis (sample removed in early morning and early evening). Emergence traps (4) will be placed at each transect on a weekly basis May-December and in March to collect emergent insects. Samples are to be sorted, enumerated to required taxonomic level (genus) and dry weights obtained.
3. Fish stomachs provided by Dr. R.H. Peterson will be analyzed as to taxonomic composition, numbers of individuals and total dry weights.

Project # A.3.2ANTICIPATED RESULTS:

Maps of species distribution in study area, species list in study area, catalogue of fish food items, estimate of invertebrate productivity and flux through study area.

PERFORMANCE INDICATORS:

Internal report, primary publications

Project # A.3.3PROJECT TITLE: Sediments as indicators of acidification history.PRINCIPAL DFO INVESTIGATOR'S NAME: Dr. S. RayADDRESS AND TELEPHONE NUMBER: Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B. E0G 2X0

Telephone No.: (506)-529-8854

COOPERATING AGENCIES AND INVESTIGATORS:
(if Applicable)

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
a) Person Years	0.5	0.5	0.5
b) Operating and Maintenance (\$000.)	10	10	10
c) Capital (\$000.)	0	0	-

ANTICIPATED DURATION OF THE PROJECT: 3 YearsOBJECTIVES OF THE PROJECT

To determine feasibility of using trace elements and algal deposits in sediments as an indicator of acidification history and its application in the Westfield study area.

METHODS

Sediment cores will be analyzed for trace metals and algal deposits. Leaching of trace metals will be studied in model experiments in the laboratory. Sediment cores 1 m long by 5 cm diam. will be divided into 1 cm horizons for examination. By making a stratigraphic study of the many species of diatoms in each horizon, changes in pH of the water column can be identified on the basis of specific pH preference. The vertical profile for the diatoms together with the knowledge of their pH preferences should give the history of acidification of the core samples. At the same time Pb-210 dating of the core horizons will provide sedimentation rate in the lake. The change in trace metal contents and the diatom profile, together with the age of the sediment horizons, may be a suitable indication of acidification history of the lakes.

ANTICIPATED RESULTS:

Information on historical pH levels in the lakes studied.

PERFORMANCE INDICATORS:

Primary publications

Project #A.3.4

PROJECT TITLE: Study of periphyton communities in acidified streams in Nova Scotia

PRINCIPAL DFO INVESTIGATOR'S NAME: Dr. D.J. Wildish

ADDRESS AND TELEPHONE NUMBER: Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B. EOG 2K0

Telephone No.: (506)-529-8854

COOPERATING AGENCIES AND INVESTIGATORS:
(if Applicable)

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
a) Person Years	-	-	-
b) Operating and Maintenance (\$000.)	37	37	37
c) Capital (\$000.)	0	0	0

ANTICIPATED DURATION OF THE PROJECT: 3 years

OBJECTIVES OF THE PROJECT:

Determine the influence of stream acidity on periphyton community structure.

METHODS:

Five Nova Scotian streams of the same size and character, but with different pH regimes (ranging from 4.5-6.5) have been selected. Aquatic macrophyte, epiphyte, epipellic, and invertebrate communities will be investigated. Sampling will be bi-weekly in spring through fall, monthly in the winter.

Aquatic macrophyte topography in the study areas will be determined.

Ephiphytes will be sampled and processed as described by Eminson and Moss (1980), and Moss (1981). Macrophytes will be removed from just under the water surface and retained in tubes to which filtered water and Lugol's iodine are added. These are shaken, and the resultant algal suspension reserved for counting. The section of macrophyte will be dried at 100 C and weighed so that algal counts will be expressed as per unit dry macrophyte weight.

To sample epipellic communities, rocks will be removed from the stream, covered with a plastic sheet with a 0.01 M cut-out over the rock, and the epipellic removed with a stiff brush. Cleaned area is etched after collection to avoid sampling the same area in the future. Glass slides will be used as an artificial substrate in order to compare changes in invasion diversity for each stream.

Invertebrate samples will be collected with a Surber sampler to ascertain density of g in 2 hr in relation to the periphyton community

Project #A.3.4ANTICIPATED RESULTS:

Understanding of periphyton community structure in streams with differing pH's.

PERFORMANCE INDICATORS:

Primary publications

Project #A.3.5PROJECT TITLE: Smolting of Atlantic salmon at low pHPRINCIPAL DFO INVESTIGATOR'S NAME: Dr. R.L. SaundersADDRESS AND TELEPHONE NUMBER: Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B. E0G 2X0

Telephone No.: (506)-529-8854

COOPERATING AGENCIES AND INVESTIGATORS: Dr. K. Haya, St. Andrews
(Biological Station)
Dr. C.E. Johnston, University of
Prince Edward Island

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
a) Person Years	0.5	0.5	0.5 (from existing manpower)
b) Operating and Maintenance (\$000.)	10	20	20
c) Capital (\$000.)	0	0	0

ANTICIPATED DURATION OF THE PROJECT: 1981-84OBJECTIVES OF THE PROJECT:

To determine whether juvenile Atlantic salmon undergo normal smolting processes in the Westfield River.

METHODS:

Juvenile salmon in the Westfield River will be analyzed for various parameters associated with smoltification (and migration to sea), such as salinity tolerance, and gill ATPase activity. Samples will be collected in winter and early spring when smoltification occurs.

ANTICIPATED RESULTS:

Assessment of the success of parr-smolt transformation in streams of low pH.

PERFORMANCE INDICATORS:

Primary publications

4. Other Field Studies

Project # A.4.1

PROJECT TITLE

Inputs and effects of airborne organic pollutants on aquatic ecosystems.

PRINCIPAL DFO INVESTIGATOR'S NAME

Dr. Murray G. Johnson

ADDRESS AND TELEPHONE NUMBER

Great Lakes Biolimnology Lab.
Department of Fisheries and Oceans
Box 969
Owen Sound, Ontario N4K 6H6
519-371-0040

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Ontario Ministry of Natural Resources

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	0.2	0.3	0.3
b) Operating and Maintenance (\$000.)	10.5	15.0	15.0
c) Capital (\$000.)	-	-	-

ANTICIPATED DURATION OF THE PROJECT

Depends on findings - probably 2 to 3 years after 1981/82.

OBJECTIVES OF THE PROJECT

Assess inputs of organics in rain and snow (pesticides, PCB's, RCP, and possibly PAH's, phthalates, dioxins). Determine fluxes from land to water, in lakes and in biota in lakes. Set baseline for future reference.

METHODS

Study area is undeveloped Crown land near tip of Bruce peninsula which projects north into Lake Huron.

Collect and analyse rain and snow concentrations and relate to other findings.

Collect and analyse runoff water, lake water, lake sediment and biota and relate to trophodynamic description of aquatic communities, and to other findings.

Collect sediment cores and section, determine chronology by ^{210}Cs ^{137}Cs dating and determine organic contaminant loadings through time.

Examine potential uptake (under increased loads possible in future) by fish.

Project # A.4.1

ANTICIPATED RESULTS

Probably evidence of accelerated inputs in sediment cores, to significant contemporary levels in system.

Relationship between loads and flux to biota and sediments to be examined, in comparison to other systems.

Baseline survey of organic contaminants will be useful for future reference.

Potential to contribute to understanding of kinetics and limnology of organic contaminants.

PERFORMANCE INDICATORS

Components of ecosystem profiled for organics i.e. sediments, soils, vegetation, fish, selected invertebrates as well as rain and snow.

Also "families" of organics completed e.g. PAHs, dioxins etc.

Project # A.4.2

PROJECT TITLE

Quantitative study of the effects of acidification on the fecundity and mortality of brook trout (Salvelinus fontinalis).

PRINCIPAL DFO INVESTIGATOR'S NAME

Yvan Vigneault

ADDRESS AND TELEPHONE NUMBER

Fisheries and Oceans Canada
Gare Maritime Champlain
901, Cap Diamant
Case Postale 15,500
Québec (Québec)
G1K 7Y7
Telephone: (418) 694-3478

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Bio-Conseil Inc (c/o Jacques Leclerc)
105, Côte de la Montagne
Suite 501
Québec (Québec)
G1K 4E4
(418) 692-2145

Department of Supply & Services
Unsolicited Proposals

DFO RESOURCES ASSIGNED

1981/82

1982/83

1983/84

a) Person Years	-	-	-
b) Operating and Maintenance (\$000.)	5	20	-
c) Capital (\$000.)			

ANTICIPATED DURATION OF THE PROJECT

From June 1981 to August 1982.

OBJECTIVES OF THE PROJECT

To measure the relationship between acidic input and the mortality of early stages (eggs, alevins, fry) and the specific female fecundity in a natural environment.

METHODS

Observation of vital parameters (mortality and fecundity) and water quality. Installation of an experimental apparatus (gravel incubation and retention cages) in two lakes. The two lakes are essentially similar for all parameters except for those indicating early stages of acidification in one lake and a buffered stage in the other.

Project # A.4.2ANTICIPATED RESULTS

- Relationship between developing egg mortality and acidic input by estimating the percentage of total mortality;
- Relationship between alevin mortality and acidic input;
- Relationship between fry mortality and acidic input;
- Relationship between development and growth retardation and acidic input;
- Measure of the reduction in specific fecundity in an acidified environment;
- Possible use of results in modelling of Brook trout populations at a more general level.

PERFORMANCE INDICATORS

Preliminary reports will be submitted in December 1981 and May 1982. The final report will be submitted to the scientific authority in August 1982.

B. Survey and Inventory of Sensitive Aquatic
Systems to LRTAP

Survey and inventory of sensitive aquatic systems to LRTAP

BACKGROUND

In Canada, no description of fisheries and/or habitat is available such that we may describe the status of the resource in relation to the regional differences in deposition. Scattered data bases of differing methodologies using differing lake selection criterion and differing analytical techniques exist. These data enable us to only superficially describe the Canadian state of lake acidification and its effect upon the fishery resource (Kelso and Minns in press). In Scandinavia, the admirable descriptions of lake state resulted from survey data whereby a regional fishery depletion was first identified (Jensen and Snekvik 1972). Several subsequent surveys administered through their SNSF project defined the areas in Norway with depressed pH and alkalinity and impoverished fish populations. The output of the surveys served to direct subsequent field and laboratory studies. In Europe, the surveys of extent of fisheries and habitat alteration serve as the base for negotiations in the international forum for abatement and/or compensation. Obviously, information must be developed and consolidated for eastern Canada to overcome the incomplete understanding of regional response and enable a more concrete exchange with the United States.

The intent of DFO is to establish a comprehensive data base, comparable within Canada, for a minimal number of lakes in sensitive terrain. Lakes will be sampled in a common way to determine chemical state related to atmospheric deposition, extant biological communities, body burdens of contaminants expected to result from atmospheric deposition or be influenced by acidification and lake history using core dating for a selected set of lakes. The lakes included in this sampling scenario will result from regional experience but are expected to exceed 100 in at least Ontario, Quebec, New Brunswick-Nova Scotia, Newfoundland and Labrador. Coupled with the acquisition of new data is the synthesis of existing information. Lake and stream surveys exist for most provinces; however, these data were neither collected nor analysed to gain insight into effects from LRTAP.

Streams and rivers in Canada create a significant fishery, particularly for the valuable Atlantic salmon. In addition, other lotic systems serve as spawning grounds, nursery areas or carry resident stocks of stream fishes like brook trout, smallmouth bass, walleye and other desirable species. The salmon rivers of the east coast are better understood systems but still must be examined in light of the sensitivity of many to atmospheric deposition.

Two separate but compatible approaches are necessary to describe the status of Canada's fishery resource and habitat, namely: 1) a lake description generated in a common way against which models (new/existing) may be applied and through which an understanding of lake state can be developed, and 2) a thorough examination of existing data to direct 1 above, to extend 1 above and to build current assessments of habitat and fisheries status (Minns 1981).

An attempt at establishing this necessary data base will, however, be unsuccessful unless strong cohesion (similar to SNSF in Norway), sampling comparability and quality control exists among the DFO regions involved during the collection of data and, at the final stages, a high level of integration of data. Co-ordination has been discussed among the regions, among those carrying

out the surveys, and within the DFO Scientific Advisory Committee and it has been suggested that the Great Lakes Biolimnology Laboratory with the guidance of particulars Drs. J.R.M. Kelso and C.K. Minns ensure that this need is fulfilled.

In brief, the approach necessary to define Canada's lake acidification state and its effect on fishery resources is as follows:

- | | |
|--|---|
| 1. establishment of a watershed counts and measures for each region of sensitive Canada | - counts, determination of area from topographic sheets |
| 2. common lake selection criterion criteria | - sensitive geology and soils, basin use status, lake type e.g. headwater |
| 3. common chemical keys to sensitivity/damage that fit existing (even expected) models e.g. Henriksen, Dillon etc. | - TDS, Alk, Cond, pH, Ca, Mg, SO ₄ , Al, Mn, colour |
| 4. fish community types that are dominant and representative within eastern Canada | - from index fishing, examination of collected creel census and commercial fishing data |
| 5. review historical data | - files |

Output from these studies - new data collection, synthesis of existing material - will serve, as in Scandinavia, as a basis for estimating number of lakes damaged, as a basis for extrapolating the rate of change (from calibrated and experimental watershed studies) to loss of lakes and as a basis for examining the introduction of contaminants via the atmosphere to remote aquatic systems.

It should be noted that projects like B.1.1 to B.1.4 represent collection of new lake data and its analysis and interpretation. Projects like B.1.5 to B.1.8 reflect the concern over lotic systems with Atlantic salmon or carrying other desirable fish communities. Project B.1.9 represents the examination and interpretation of both new and historical data.

An example of types of data being collected in the headwater lakes surveys is given in the following attachment.

Jensen, K.W. and E. Snekvik. 1972. Low pH levels wipe out salmon and trout populations in southernmost Norway. *Ambio* 1: 223-225.

Kelso, J.R.M. and C.K. Minns. in press. Current status of lake acidification and its effect on the fishery resources of Canada. *Amer. Fish. Soc. Symp.* August 1981.

Minns, C.K. 1981. Acid rain: A preliminary estimate of the risk to Ontario's inland fisheries. *Can. Tech. Rep. of Fish & Aquatic Sci.* #

AN EXAMPLE OF THE
GENERAL METHODOLOGY
TO BE USED IN THE

DEPARTMENT OF FISHERIES AND OCEANS
SURVEY AND INVENTORY OF HEADWATER LAKES

NOTE: The example given is from the Newfoundland program.
The methodology, for selecting lakes will vary somewhat according to the region in Canada where the survey is being carried out.

BACKGROUND INFORMATION

In an attempt to define status of Newfoundland freshwaters and freshwater and anadromous fisheries in relation to acid precipitation; water, fish, plankton (phyto and zoo) and benthos samples, together with physical and morphological data are to be collected from pre-selected headwater lakes during summer/fall, 1981. The intention is to follow the procedures included in a Canadian program which is defined to uniformly collect data to: (i) determine status of the fishery and habitat in relation to LRTAP; (ii) provide a baseline of information against which future change can be measured; and (iii) determine the contaminant body burden of fish in remote lakes where the primary sources are natural and/or anthropogenic.

The headwater lakes are to be pre-selected by the Scientific Authority while the contractor is responsible for helicopter and fixed wing charter arrangements. Water and fish samples will be analysed by the contractor while plankton and benthos samples will be presented to the Crown unanalysed in a preserved state.

The contractor is to provide two separate master files (M/F's) of data to the Scientific Authority upon completion of the work. These files should be resident on 9-track magnetic tape recorded at 1600 bpi with standard IBM labels. The two M/F's, which will be referred to as a "Lake data M/F" and a "Fish data M/F" should consist of the following:

1. Lake data M/F should contain all the records for lake morphology and water chemistry as per the coding specs. There will be one record per lake. The logical record length for the file should be 288 bytes with appropriate blocking.
2. Fish data M/F should contain all the records for the fish sampled as per the coding specs. To make future analysis simpler we request that each record on this file have the following format:

Cols 1-288 - lake data for the given lake as per the lake data M/F record format.

Cols 289-499 - fish data for the specimen as per the codings specs.

Thus, if 100 specimens are sampled from a given lake, 100 records will be generated on this M/F each having the complete information for the given lake in columns 1-288, with appropriate data for the specimen in columns 251-499. Logical record lengths for this M/F should be 500 bytes with blocking as appropriate.

The water chemistry data will also be presented on NAQUADAT data cards. All data will be presented in summary form as outlined in Tables 1-4 and maps will be produced showing: (1) location of sampling sites and (2) distribution values for pH, alkalinity, conductivity, sodium, chloride, calcium, magnesium and sulphate.

This work is to be carried out on interactive basis to allow for modifications as the work proceeds. Approximately 100-125 lakes (see Map Appended) are to be sampled with 12 of these being depth recorded to provide mean depth values. These 12 lakes are to be selected by the Scientific Authority in consultation with the contractor. All work is to be completed and submitted by December 31, 1981.

Upon arrival at a pre-selected lake, the drainage area and shoreline should be flown to visually assess suitability for sampling and a photo should be taken to include the whole lake shoreline and as much of the drainage area as possible. The photo number is to be logged with the lake number.

The factors most used to rule out sampling in a lake are:

- shallow <3 m; in bog surroundings,
- brown water,
- drainage from low cedar bog type areas,

- clear cut areas in drainage basin,
- recent burnt areas in drainage basin,
- with extensive cottage development on the lake.

The lakes to be selected are:

- areas where rock formations are visible,
- light or no emergent vegetation,
- shoreline well defined,
- drainage basin well defined.

WATER SAMPLING AND LABORATORY ANALYSES

After the helicopter (or fixed wing) sets down at/near the centre of the lake, the depth should be sounded using the telethermometer probe and cable. If the depth is 3 metres or greater, a temperature profile should be taken and the lake sampled. Bottles are to be marked as to lake number and date before water collection.

Water samples are to be collected by methods described by Ontario Ministry of Natural Resources (1980) in: "Determination of Total Inflection Point Alkalinity - Instruction Manual for Sampling and Field Titration."

Parameters to be measured in the field include:

- pH
- total alkalinity
- conductivity (ns/cm²)
- dissolved oxygen
- carbon dioxide
- secchi disc (m)
- temperature profile (0⁰)

* Alkalinity values are to be determined using methods described in the 1980 Ontario Ministry of Natural Resources report.

One 500 ml nalgene bottle is labelled, filled and stored for laboratory analysis of the following parameters:

- pH ortho phosphate
- total alkalinity nitrate
- calcium Σ Cations
- magnesium Σ Anions
- sodium sum of constituents (mg l^{-1})
- potassium turbidity
- chloride color (Hazen units)
- sulphate

(carbonate, bicarbonate and excess sulphate are to be calculated)

N.B. A major ion balance is to be performed for each sample from each lake with an error acceptability of $\pm 10\%$. If this is not achieved and an explanation is not apparent (i.e. high colour), analyses should be repeated.

One 500 ml sample of whole water is collected for trace metal analyses and is fixed with 1 ml of concentrated Nitric acid (Baker Analytical Grade). Every sample should be analysed for the following parameters:

- lead
- aluminium
- manganese
- cadmium
- iron

In addition to the above, every tenth sample (lake) should be analysed for:

- copper
- zinc
- nickel

All laboratory analyses are to be performed within a month after sampling date and are to be analysed following: "Environment Canada (1979): Analytical Methods Manual."

LABORATORY QUALITY ASSURANCE REQUIREMENTS

1. Samples from every tenth lake (water and fish) will be duplicate or blank, to be reported at no extra cost.
2. A minimum of 5 water and (5) fish standard reference material samples will be provided by the Scientific Authority and are to be analysed for every parameter requested and reported with the results.
3. Replicate samples will be included in the batch and the whole batch blind numbered. For the determination of each metal, the following conditions for the mean of the replicate analyses will be met.
 - a) If a mean value for the replicate sample has previously been established, the systematic error of the mean is less than 50% and the coefficient of variation is less than 2 times the previously established value.

or

- b) If the sample has not previously been analysed, the coefficient of variation (CV) is not larger than a limit described by the following equation:

$$CV < (X_0 / \bar{X}) 0.3 \times 100$$

or 15%, whichever is the greater, where X_0 is the detection limit of the element in question, as determined by the contractor using standard procedures, and $\bar{X}$ is the mean level of the element in the replicate sample.

4. The Scientific Authority may, upon failure of the contractor to meet any of the above requirements, reject all or part of a batch of analyses and require re-analysis, in whole or in part, of the batch samples.
5. The Scientific Authority requests that the contractor participate in at least five (5) found-robin check sample programs pertinent to the analysis described in this contract.

PLANKTON SAMPLING AND PRESERVATION

NANNO PHYTOPLANKTON

While taking the water samples from each lake, a 500 ml sample is to be preserved with Lugol's solution in a properly labelled glass bottle.

NET PLANKTON

A net plankton sample using a 20.5 cm diameter plankton net (64 μ mesh) is to be taken via a vertical haul from just off the bottom at the center of each lake. The collection bucket is removed and rinsed, with the sample being preserved in 5-10% formalin in a properly labelled glass bottle.

BENTHOS SAMPLING AND PRESERVATION

Using a 9" Eckman dredge, five grab samples are taken from each lake. Four of the five samples are placed individually in pre-numbered plastic bags (14" X 24") and preserved in 5-10% formalin. For the fifth sample, the whole sampler is placed, closed, into the bag. The top of the sampler is then opened and the pH is taken 2 cm below the surface of the sediment. After the contents of the bag are properly sieved, the insects are placed in properly labelled vials and preserved in 75% ethanol.

FISH SAMPLING AND DATA RECORDING

Fish populations are to be sampled from each lake using gillnets consisting of 7 panels each 9.1 m in length with stretch mesh sizes of 1½, 2, 2½, 3, 3½, 4, and 5 inches. The nets should always be set from shore with the smallest mesh size closest to shore.

The number and location of net sets should be recorded for each lake as well as the total catch (number and weight).

At least 50 samples of a type species (e.g. brook trout) (stratified by 1-2 cm intervals) should be taken from each lake and the following information from each fish recorded on a scale envelope. (N.B. This number may change in certain lakes depending upon catch rate. Contact must be kept with the Scientific Authority concerning fish catches).

- weight (to the nearest 1g)
- fork length (mm)
- sex (male or female)
- maturity (mature or immature)
- scale sample (a few scales are taken from the left side of each fish just posterior to the dorsal fin and above the lateral line. The scale sample is placed in a scale envelope which is properly labelled). The scales are to be read by the contractor.

METAL ANALYSES

All fish samples of the type species from one lake in each of the eight major geological zones, shall be analysed individually for the following:

- mercury
- lead
- aluminium
- manganese
- selenium
- cadmium
- nickel
- zinc
- arsenic
- total lipid content (Bligh, E.G. and W.J. Dyer 1958. Can. J. Biochem. Physical 37:911-917).

The analytical methods for these elements should be outlined in the proposal and should be well-established methods and acceptable to the Scientific Authority.

For all other lakes, 15 samples of the type species (stratified by 1-2 cm length intervals) shall be analysed individually for the same elements.

DEPTH SOUNDING

Twelve lakes (two from each of the six geographical regions) are to be

depth recorded to give an accurate estimate for mean depth. These lakes are to be selected by the Scientific Authority in consultation with the contractor.

Table 1. Lake locations, geographical and geological data.

Lake number	Region number	Geological zone	Latitude	Longitude	Distance from coast (km)	Elevation (m)	Drainage area (ha)	Lake area (ha)	Ratio drainage area to Lake area
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NAME OR NUMBER: _____
COORDINATES: _____
NAQUADAT STATION: _____
SOURCE: _____
ANALYST: _____

Date	°C Temp.	D.O.	CO ₂	Sech. Disc.	pH	Alk.	Cond.	TDS	Tot. Hard	CO ₃	HCO ₃	Ca	Mg	Na	K	Cl	SO ₄	SO ₄	Excess P	Orth	NO ₃	Σ Cat	Σ An	Turb	Color	Chlor (a)	pH	Al	Mn	Cd	Fe	Cu	Zn	Ni
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Table 3. Gross statistics for all parameters and all lakes based on concentrations for each lake

Parameter	Minimum	Maximum	Mean
<u>LAKE WATERS</u>			
pH			
Alkalinity ($\mu \text{ eq l}^{-1}$)			
Conductivity (ns/cm^2)			
Total hardness ($\mu \text{ eq l}^{-1}$)			
Carbonate ($\mu \text{ eq l}^{-1}$)			
Bicarbonate ($\mu \text{ eq l}^{-1}$)			
Calcium ($\mu \text{ eq l}^{-1}$)			
Magnesium ($\mu \text{ eq l}^{-1}$)			
Sodium ($\mu \text{ eq l}^{-1}$)			
Potassium ($\mu \text{ eq l}^{-1}$)			
Chloride ($\mu \text{ eq l}^{-1}$)			
Sulphate ($\mu \text{ eq l}^{-1}$)			
Excess sulphate ($\mu \text{ eq l}^{-1}$)			
Ortho phosphate ($\mu \text{ eq l}^{-1}$)			
Σ Cations ($\mu \text{ eq l}^{-1}$)			
Σ Anions ($\mu \text{ eq l}^{-1}$)			
Sum of Constituents (mg/l)			
Turbidity (JTU)			
Colot (Hazen units)			
Chlorophyll a. (mg/m^3)			
Lead ($\mu \text{ eq l}^{-1}$)			
Aluminum ($\mu \text{ eq l}^{-1}$)			
Manganese ($\mu \text{ eq l}^{-1}$)			
Cadmium ($\mu \text{ eq l}^{-1}$)			
Iron ($\mu \text{ eq l}^{-1}$)			
Copper ($\mu \text{ eq l}^{-1}$)			
Zinc ($\mu \text{ eq l}^{-1}$)			
Nickel ($\mu \text{ eq l}^{-1}$)			

Lake Name	Lake Number	Species	Specimen Number	L (cm)	W (g)	Age (y)	Sex	Hg	Pb	Al	Mn	Se	Cd	Ni	T.L.C.
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CODING SPEC SHEETS - ACID RAIN STUDY

Missing Values Option - Any measurable parameters (i.e. ion concentrations) that are not measured should be recorded as 9999 9.

WATER CHEMISTRY

<u>Field</u>	<u>Position</u>	<u>Codes</u>
Study type	1 (1)	1. Headwater Lakes - Contract 2. Headwater Lakes - In - house 3. Enhancement Rivers - Contract 4. Enhancement Rivers - In - house 5. 6. 7.
Region	2-3 (2)	1. Northern Newfoundland (a) 2. Central Newfoundland 3. Eastern Newfoundland 4. Avalon Peninsula 5. Southern Newfoundland 6. Western Newfoundland 7. Northern Labrador 8. Central Labrador 9. Eastern Labrador 10. Southern Labrador 11. Western Labrador 12.
Geological Formations	4-5 (2)	* 1. conglomerate, sandstone... 2. limestone, sandstone... 3. siltstone, quartzite... 4. gneiss, schist... 5. anorthosite... 6. granite... 7. gabbro, diorite... 8. peridotite... 9. acidic to mafic volcanic... 10. uncertain
Lake Number (Blocks of lakes designated to each region)	6-8 (3)	Lake Numbers 001-050 (Northern Nfld.) Lake Numbers 051-100 (Central Nfld.) Lake Numbers 101-150 (Eastern Nfld.) Lake Numbers 151-200 (Avalon Peninsula) Lake Numbers 201-250 (Southern Nfld.) Lake Numbers 251-300 (Western Nfld.) Lake Numbers 301-350 (Northern Labrador) Lake Numbers 351-400 (Central Labrador) Lake Numbers 401-450 (Eastern Labrador) Lake Numbers 451-500 (Southern Labrador) Lake Numbers 501-550 (Western Labrador)

(a) See Map Appended

* See Map Appended

Latitude	9-12 (4)	Deg ⁰ Min - to the nearest minute
Longitude	13-16 (4)	Deg ⁰ Min - to the nearest minute
River Code (where the river enters the sea)	17-23 (7)	Waldron's Code in Waldron, D.E. 1974. Codes used in the Newfoundland commercial and recreational fisheries Res. Dev. Br. Fish. Mar. Serv. Nfld. Reg. 128p
Date (when sample taken)	24-29 (6)	Year/Month/Day
Lake Surface Area	30-34 (5)	To the nearest 0.1 hectare
Mean Depth	35-37 (3)	To the nearest 0.1 m
Maximum Depth	38-40 (3)	To the nearest m
Volume of Water	41-43 (3)	0.00
Volume	44-45 (2)	To the power of 10
Shore Development (index figure)	46-48 (3)	0.00 (Welch, 1948) Shore Development = in which s is length of shoreline; a is area of lake
Elevation (above sea level)	49-52 (4)	To the nearest 0.1 m
Distance from coast (nearest point to the ocean as the crow flies)	53-56 (4)	To the nearest 0.1 km
Drainage Area	57-61 (5)	To the nearest 0.1 ha
Ratio (Drainage Area: Lake Area)	62-64 (3)	0.01
Air Temperature	65-67 (3)	To the nearest 0.1 ⁰ C
Water Sample Temperature	68-70 (3)	To the nearest 0.1 ⁰ C
Dissolved Oxygen of Water Sample (In the field)	71-73 (3)	To the nearest 0.1 mg l ⁻¹

Carbon Dioxide of Water Sample (In the field)	74-76 (3)	To the nearest 0.1 mg l^{-1}
Secchi Disc Reading of Water Sampling Site	77-79 (3)	To the nearest 0.1 m
Lake pH (Field)	80-82 (3)	To the nearest 0.01
Lake pH (Lab)	83-85 (3)	To the nearest 0.01
Precipitation pH (not measured by the contractor-put in only when available from other sources)	86-88 (3)	To the nearest 0.01
Alkalinity (Field)	89-93 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Alkalinity (Lab)	94-98 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Conductivity	99-103 (5)	To the nearest 0.1 ns/cm^2
Total Dissolved Solids (TDS)	104-108 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Total Hardness	109-113 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Carbonate	114-118 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Bicarbonate	119-123 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Calcium	124-128 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Magnesium	129-133 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Sodium	134-138 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Potassium	139-143 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Chloride	144-148 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$

Sulphate	149-153 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Excess Sulphate	154-158 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Ortho Phosphate	159-163 (5)	To the nearest $0.001 \mu \text{ eq l}^{-1}$
Nitrate	164-168 (5)	To the nearest $0.001 \mu \text{ eq l}^{-1}$
Σ Cations	169-173 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Σ Anions	174-178 (5)	To the nearest $0.1 \mu \text{ eq l}^{-1}$
Sum of Constituents	179-183 (5)	To the nearest 0.1 mg l^{-1}
Turbidity	184-188 (5)	To the nearest 0.01 JTU
Color	189-193 (5)	To the nearest 0.01 Hazen Units
Chlorophyll a	194-198 (5)	To the nearest 0.1 mg^3
Lead	199-203 (5)	To the nearest $0.1 \mu \text{ gl}^{-1}$
Aluminium	204-208 (5)	To the nearest $0.1 \mu \text{ gl}^{-1}$
Manganese	209-213 (5)	To the nearest $0.1 \mu \text{ gl}^{-1}$
Cadmium	214-218 (5)	To the nearest $0.001 \mu \text{ gl}^{-1}$
Iron	219-223 (5)	To the nearest $0.1 \mu \text{ gl}^{-1}$
Copper	224-228 (5)	To the nearest $0.001 \mu \text{ gl}^{-1}$
Zinc	229-233 (5)	To the nearest $0.001 \mu \text{ gl}^{-1}$
Nickel	234-238	To the nearest $0.001 \mu \text{ gl}^{-1}$

The following 10 fields are available for additions of fields not covered above. Once a new parameter is added it becomes fixed for all lakes & rivers and any additions should first be given approval by the Scientific Authority.

239-243 To the nearest
(5)

244-248 To the nearest
(5)

249-253
(5)

254-258
(5)

259-263
(5)

264-268
(5)

269-273
(5)

274-278
(5)

279-283
(5)

284-288
(5)

FISH

Species Code	289-292 (4)	0172 - A. salmon (landlocked)
		0173 - A. salmon (anadromous)
		0174 - Brown trout
		0175 - Rainbow trout
		0177 - Arctic char
		0178 - Brook trout
		0179 - Lake trout
		0180 - Lake whitefish
		0182 - Round whitefish
		0188 - American smelt
		0191 - Northern pike
		0261 - Lake chub
		0267 - Longnose sucker
		0268 - White sucker
		0342 - American eel
		0412 - Mummichog
		0426 - Stickleback threespine
		0428 - Stickleback ninespine
		0464 - Burbot (ling)
		0824 - Mottled sculpin

0825 - Slimy sculpin

Specimen Number	293-295 (5)	Start off with 001 and number consecutively for each species in each lake
Fork Length	298-301 (4)	To the nearest mm
Weight	302-306 (5)	To the nearest g
Age	307-308 (2)	Years
Sex	309 (1)	1 = Male 2 = Female 3 = Sex not determined
State of Maturity	310 (1)	1 = Immature 2 = Mature 3 = Not determined
Total Scale Radius	311-313 (3)	To the nearest mm (Standard Magnification 46 X)
1st	314-316 (3)	To the nearest mm
2nd Annulus Radius	317-319 (3)	To the nearest mm
3rd Annulus Radius	320-322 (3)	To the nearest mm
4th Annulus Radius	323-325 (3)	To the nearest mm
5th Annulus Radius	326-328	To the nearest mm
6th Annulus Radius	329-331	To the nearest mm
7th Annulus Radius	332-334	To the nearest mm
8th Annulus Radius	335-337	To the nearest mm
9th Annulus Radius	338-340	To the nearest mm
10th Annulus Radius	341-343	To the nearest mm
11th Annulus Radius	344-346	To the nearest mm
12th Annulus Radius	347-349	To the nearest mm
13th Annulus Radius	350-352	To the nearest mm
14th Annulus Radius	353-355	To the nearest mm

15th Annulus Radius	356-358	To the nearest mm
16th	359-361	
17th	362-364	
18th	365-367	
40th Annulus Radius	431-433	To the nearest mm
Methyl Mercury	434-436	To the nearest 0.01 μ gl ⁻¹
Lead	437-439	To the nearest 0.01 μ gl ⁻¹
Aluminium	440-442	To the nearest 0.01 μ gl ⁻¹
Manganese	443-445	To the nearest 0.01 μ gl ⁻¹
Selenium	446-448	To the nearest 0.01 μ gl ⁻¹
Cadmium	449-451	To the nearest 0.01 μ gl ⁻¹
Nickel	452-454	To the nearest 0.01 μ gl ⁻¹
Zinc	455-457	To the nearest 0.01 μ gl ⁻¹
Arsenic	458-460	To the nearest 0.01 μ gl ⁻¹
Total Lipid Content	461-463	To the nearest μ gl ⁻¹

N.B. The following 12 fields are available for additions of fields not covered above. Once a new field is added it becomes fixed for all lakes and rivers and any additions should first be given approval by the Scientific Authority.

464-466

467-469

470-472

473-475

476-478

479-481

482-484

485-487

488-490

491-493

494-496

497-499

Project # B.1.1

PROJECT TITLE

Ontario Headwater lakes assessment (part of a national lake inventory program)

PRINCIPAL DFO INVESTIGATOR'S NAME

Dr. John R.M. Kelso

ADDRESS AND TELEPHONE NUMBER

Great Lakes Biolimnology Lab.
Department of Fisheries & Oceans
875 Queen Street East
Sault Ste. Marie, Ontario P6A 2B3
705-942-2848

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Ontario Ministry of Natural Resources; National Water Research Institute.

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	3.3	2.8	2.8
b) Operating and Maintenance (\$000.)	90	60	90
c) Capital (\$000.)			

ANTICIPATED DURATION OF THE PROJECT

1984/85 - Evaluation of existing data
1985/86 - Resample Ontario lakes done 1979/80.

OBJECTIVES OF THE PROJECT

1. To determine chemical and biological status of sensitive lakes in eastern Canada (Ontario).
2. To provide a benchmark situation against which rate of change measurements (DOE, ELA experiments, calibrated watershed studies) can be applied to determine regional change and/or susceptibility.
3. To provide a benchmark against which change can be measured.
4. To determine regional distribution of toxic metals and organics in fish.

METHODS

A methodology for lake sampling was developed in 1979 (Kelso et al. 1981) and provided a reasonable standardized method for examining lakes. Some 180 lakes were sampled across Ontario using a lake selection criterion and the standard sampling/analysis techniques. In addition to buffer related chemical tests, metals in water and in fish were examined. Community structure was determined for phytoplankton, zooplankton, benthos and fish in a subset of lakes.

Project # B.1.1

For fish community structure, age class structure and growth are examined in addition to total body lipid, metal and organic body burdens.

ANTICIPATED RESULTS

1. When combined with data similarly collected in Quebec, Labrador, Newfoundland, New Brunswick and Nova Scotia, a description of lake status re LRTAP and fish response to extant conditions will be available for eastern Canada.
2. A good data set will be available against which to apply models of lake response.
3. Re-examination of lakes should provide evidence of response under extant loadings.
4. Condition of fish re human consumption is poorly understood in inland lakes. The survey will examine many species in lakes where only natural/airborne materials dominate.

PERFORMANCE INDICATORS

Kelso, J.R.M., R.J. Love, R. Dermott and J.H. Lipsit. 1981. Whole lake response. Ecological effects. Presented at Effects of acid precipitation on ecological systems. Great Lakes Region. April 1-3, Lansing, Michigan.

Kelso, J.R.M., R.J. Love, R. Dermott, and J.H. Lipsit. 1981. Chemical and biological status of headwater lakes in the Sault Ste. Marie District, Ontario. IN Proc. for the effects of Acid Precipitation on ecological systems. April 1981.

Kelso, J.R.M. 1981. Chemical and biological status of headwater lakes in the Sault Ste. Marie District, Ontario. Seminar 25/02/81, St. Johns, Newfoundland.

- publications, seminars, symposia

- provision of a Canadian scenario of lake status re LRTAP

Kelso, J.R.M. and C.K. Minns. in press. Current status of lake acidification and its effect on the fishery resources of Canada. Amer. Fish. Soc. Symp. August 1981.

Project # B.1.2

PROJECT TITLE

Quebec Headwater Lakes Survey

PRINCIPAL DFO INVESTIGATOR'S NAME

Yvan Vigneault

ADDRESS AND TELEPHONE NUMBER

Fisheries and Oceans
Champlain Harbour Station
901, Cap Diamant - P.O. Box 15500
Quebec, Que. G1K 7Y7
Tel: (418) 694-3478

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

- Consultant (as yet undecided)
- GLBL

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	1.5	1.5	1.5
b) Operating and Maintenance (\$000.)	200	225	240
c) Capital (\$000.)	20	15	15

ANTICIPATED DURATION OF THE PROJECT

From August 1981 to February 1984.

OBJECTIVES OF THE PROJECT

1. To assess the state of the lake populations (and their habitat) especially for the brook trout (Salvelinus fontinalis) following the LRTAP;
2. To build up a data bank on water quality and fish populations;
3. To determine the heavy metal content of fish flesh, as a possible consequence of LRTAP.

METHODS

1. Selection of the surveyed lakes (possibly 200 lakes will be surveyed);
2. Sampling by boat and/or helicopter or fixed wing;
3. Measure the following parameters: morphometry and morphology of the lake (mean depth, max. depth, surface, drainage basin surface), water quality (pH, conductivity, alkalinity, major ions: SO_4 , Na^+ , Cl^- , Mg^{++} , Ca^{++} , heavy metals: Al, Pb, Zn, Cu, Ni);
4. Collection of phytoplankton, zooplankton, sediments, benthos and fish. (for the two last items, one third of the lakes only will be surveyed);

Project # B.1.2

5. Analysis of fish populations and contaminants in fish flesh (lipids): Cu, Ni, Pb, Zn and major ions: Na, K, Ca, Mg.

ANTICIPATED RESULTS

- Determination of water quality and acidification level of the surveyed lakes;
- Evaluation of their productivity (by plankton biomass, diversity, mean depth, major ions);
- Evaluation of the state of surveyed fish populations;
- Assessment of the lake system community structure (plankton, benthos, fish);
- Evaluation of fish health, (by analysis of heavy metals in fish flesh).

PERFORMANCE INDICATORS

- Number of surveyed lakes;
- Qualitative distinction of fish populations from different drainage basins;
- Delimitation of "problem" zones (with high contaminants concentrations or high sensibility to acid rain, or advanced acidification state).

Project # B.1.3

PROJECT TITLE

New Brunswick and Nova Scotia Headwater Lake Survey

PRINCIPAL DFO INVESTIGATOR'S NAME

Drs. R.H. Peterson and S. Ray

ADDRESS AND TELEPHONE NUMBER

Department of Fisheries and Oceans
Biological Station,
St. Andrews, N.B. EOG 2X0
Tel: (506) 529-8854

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

- Contractor (as yet undecided)
- GLBL (John Kelso)

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	0	0	0
b) Operating and Maintenance (\$000.)	100.	200.	100.
c) Capital (\$000.)	0	0	0

ANTICIPATED DURATION OF THE PROJECT

Three (3) years.

OBJECTIVES OF THE PROJECT

Establish baseline conditions for water chemistry and fish contaminant levels (Cu, Zn, Pb, Hg, Cd, and several organics) in Maritime lakes.

METHODS

Water chemistry, fish sampling (standard gang of gill nets set overnight), and analyses of fish tissues will be performed by standard procedures (see methods used for Ontario portion of study). One vertical plankton tow and one benthic grab sample will also be done per lake.

ANTICIPATED RESULTS

Baseline water chemistry and fish contaminant levels for about 100 Maritime lakes.

PERFORMANCE INDICATORS

Approximately 1/3 of the lakes sampled each year.

Project # B.1.4

PROJECT TITLE

Newfoundland and Labrador Headwater Lakes Survey

PRINCIPAL DFO INVESTIGATOR'S NAME

W.J. Bruce
D. Scruton

ADDRESS AND TELEPHONE NUMBER

Fisheries and Oceans
Newfoundland Region
P.O. Box 5667
St. John's, Nfld. A1C 5X1
(709) 737-4492

COOPERATING AGENCIES AND INVESTIGATORS

- a) Newfoundland Department of the Environment - L. Hulett
- b) Environmental Protection Service - B. Harvey
- c) Canadian Forestry Service - S. Sidhu
- d) Atmospheric Environmental Service - J. Bursey
- e) Consulting Firm - Contract (Dobroky Seatech (Nfld.) Ltd.)
- f) GLBL - J. Kelso

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	1.5	1.5	1.5
b) Operating and Maintenance (\$000.)	347	347	347
c) Capital (\$000.)	10	10	10

ANTICIPATED DURATION OF THE PROJECT

1981 - Sample Newfoundland lakes and write-up data 1st half of 82 - Sample Labrador lakes and write-up data first half of 83. Field work in 83 will depend on success and findings of work the previous two years.

OBJECTIVES OF THE PROJECT

- a) To determine the present chemical status of a number of headwater lakes in geologically sensitive areas of Newfoundland and Labrador and determine whether they are presently being impacted by acid rain.
- b) To provide a data base (benchmark) of water quality for assessing the influence of acid precipitation in future years.
- c) To establish background concentration levels of heavy metals in fish from Newfoundland and Labrador headwater lakes.

Project # B.1.4METHODS

Approximately 100-125 headwater lakes in each of Newfoundland and Labrador will be visited by fixed wing and/or helicopter. The pH, alkalinity (Gran Titration) and conductivity of lake water will be measured in the field while one 1000 ml sample will be taken for laboratory analysis of major ions and another 250 ml sample will be fixed with HNO_3 for laboratory analysis of trace metals.

A phyto and zooplankton sample will be taken from each lake for species identification and enumeration.

Five bottom grabs will be made in each lake using an Ekman dredge for species identification and enumeration of benthic invertebrates.

Approximately 50 samples (stratified by length) of the type species (ie. brook trout) will be collected from eight lakes for age and growth analyses. These 50 fish (flesh portion) from each lake in each of the eight major geological zones will be analyzed for concentration levels of the following: mercury, lead, aluminum, manganese, selenium, cadmium, nickel and total lipid content.

Fifteen fish (depending on gill net catches) from other lakes will be analyzed for the same parameters.

ANTICIPATED RESULTS

- a) A standard data base for water quality and fish contaminant body burden of Newfoundland and Labrador headwater lakes will be established. Future changes in water quality and fish contaminants resulting from acid precipitation or other atmospheric pollutants can be measured against this data base.
- b) It is anticipated that water quality, fish body burden, geological and precipitation data might be used in a model (developed as a result of LRTAP activities) to predict the impacts of acid rain upon freshwaters and associated fisheries in a given time frame, given input data for pollutants entering the atmosphere.

PERFORMANCE INDICATORS

This marks the first systematic study for the Newfoundland Region of the impacts of acid rain on freshwater ecosystems. The success of the study depends upon ability to sample sites and applicability of comparing results to other regions where similar studies have either been done or are presently being conducted.

Publication of results in primary literature and/or DFO technical reports.

Project # B.1.5PROJECT TITLE

Chemical Surveys of Maritimes Lakes and Rivers

PRINCIPAL DFO INVESTIGATOR'S NAME

W.D. Watt

ADDRESS AND TELEPHONE NUMBER

Fisheries and Oceans, Resource Branch
 Freshwater and Anadromous Division
 P.O. Box 550
 Halifax, N.S. B3J 2S7
 426-3606

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

W.J. White - Fisheries and Oceans
 I.W.D. Water Quality Lab, Moncton - Environment Canada

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	1	1	1
b) Operating and Maintenance (\$000.)	6	6	6
c) Capital (\$000.)	1	1	1

ANTICIPATED DURATION OF THE PROJECT

Probably continuing - this project was begun in 1979.

OBJECTIVES OF THE PROJECT

1. To monitor chemical changes that have occurred as a result of acidification and to observe the rate of progress.
2. To ascertain the acid tolerance limits of natural fish populations in the Maritimes.

METHODS

1. Field sampling and pH measurements followed by detailed laboratory analyses.
2. Electrofishing and netting.

Project # B.1.5ANTICIPATED RESULTS

1. A direct comparison with 1954-55 data on river chemistry.
2. Data are being entered into the NAQUADAT system.
3. Lakes will be compared for fish species present (data already collected) vs pH.
4. River chemistry can be compared with Atlantic salmon angling data.

PERFORMANCE INDICATORS

Reports, publications, etc. Several preliminary reports have already been prepared.

Project # B.1.6

PROJECT TITLE

Winter and summer survey of water quality in the Petit Saguenay, Escoumins, Petits Escoumins and Ste. Marguerite Rivers in Quebec.

PRINCIPAL DFO INVESTIGATOR'S NAME

Jean-Denis Dutil

ADDRESS AND TELEPHONE NUMBER

Fisheries and Oceans
Champlain Harbour Station
901, Cap Diamant - P.O. Box 15500
Quebec, Que. G1K 7Y7
Tel: (418) 694-3478

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

SAGE Ltée (c/o Gilles Shooner)
3350 Wilfrid Hamel Boulevard
Quebec (Quebec) G1P 2J9
Tel.: (418) 871-2412

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years			
b) Operating and Maintenance (\$000.)	90		
c) Capital (\$000.)			

ANTICIPATED DURATION OF THE PROJECT

One year, from January 1981 to November 1982

OBJECTIVES OF THE PROJECT

To determine chemical conditions of four rivers with respect to Atlantic Salmon habitat and the possible effects of acid precipitation.

METHODS

Sampling of water and snow at each of the sampling stations (5), according to their importance for salmon reproduction. Samples are taken and preserved following approved methods. Each station will be sampled on the following dates:

- 15, 22 and 29 April 1981;
- 6, 23, 20, 27 May 1981;
- 2 June, 8 July, 12 August 1981.

Project # B.1.6ANTICIPATED RESULTS

Basic data will be available on the quality of these rivers from the following parameters: turbidity, color, temperature, conductivity, pH, alkalinity, calcium, magnesium, sodium, potassium, chlorine, iron, manganese, aluminium, copper, cadmium, nickel, lead, zinc, mercury, sulfate, nitrite, nitrate and ammonium. The parameters analyzed in the snow are: conductivity, pH, inorganic carbon, calcium, magnesium, chlorine, sulfate, nitrite, nitrate, ammonium.

PERFORMANCE INDICATORS

The number of stations sampled and the number of parameters measured will be summarized in a preliminary report in June 1981 and the final report submitted before October 30, 1981. Laboratory analytical methods must be approved by the DFO investigator.

Project # B.1.7

PROJECT TITLE

Monthly survey of water quality in Quebec North Shore salmon rivers.

PRINCIPAL DFO INVESTIGATOR'S NAME

Yvan Vigneault

ADDRESS AND TELEPHONE NUMBER

Fisheries and Oceans
Champlain Harbour Station
901, Cap Diamant - P.O. Box 15500
Quebec, Que. G1K 7Y7
Tel: (418) 694-3478

COOPERATING AGENCIES AND INVESTIGATORS

Consultant (water analysis)

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	.5	.5	.5
b) Operating and Maintenance (\$000.)	45	80	80
c) Capital (\$000.)	5	2	2

ANTICIPATED DURATION OF THE PROJECT

One year, from July 1981 to June 1982.

OBJECTIVES OF THE PROJECT

To determine chemical conditions in these rivers for assessing the potential impact of acid precipitation on Atlantic salmon habitat.

METHODS

Sampling will be done at the mouth of each river. Temperature, pH and alkalinity will be determined on the spot. Water samples will be collected and preserved following approved and recognized techniques and then shipped to the laboratory. The procedure will be repeated once a month.

ANTICIPATED RESULTS

Data will be available on the water quality of these rivers. The following parameters will be analysed with respect to temporal and spatial variability: pH, alkalinity, temperature, conductivity, colour, turbidity, major ions, trace metals and possibly nutrients.

PERFORMANCE INDICATORS

The number of rivers sampled and the number of chemical characteristics measured. These will be compiled in a preliminary report in December 1981 and in a final report in October 1982.

Project # B.1.8

PROJECT TITLE

Acid Rain Survey of Atlantic Salmon Enhancement Rivers - Newfoundland

PRINCIPAL DFO INVESTIGATOR'S NAME

W.J. Bruce
D. Scruton

ADDRESS AND TELEPHONE NUMBER

Fisheries and Oceans
Newfoundland Region
P.O. Box 5667
St. John's, Nfld. A1C 5X1
Tel: (709) 737-2128

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	1.0		
b) Operating and Maintenance (\$000.)	70	100 (contact)	100 (contract)
c) Capital (\$000.)			

ANTICIPATED DURATION OF THE PROJECT

Initiative May 81 and run to May 82. Further work will depend on results from first 12 month sampling period.

OBJECTIVES OF THE PROJECT

- a) To determine whether selected Atlantic salmon enhancement rivers are being impacted by acid rain and determine buffering capacity of these river systems of any future impacts.

METHODS

Approximately 45 rivers and major tributaries will be visited by motor vehicle and helicopter on a monthly basis. The pH, alkalinity (Gran Titration) and conductivity of river water will be measured in the field while one 1000 ml sample will be taken for laboratory analysis of major ions and another 250 ml sample will be fixed with HNO₃ for laboratory analysis of heavy metals. If pH is greater than 6.0, analyses for heavy metals will be cancelled.

Most rivers will be sampled at the mouth just above high tide mark except in the case of major tributaries which will be sampled just before its confluence with the mainstem.

Two river systems (one in a geologically sensitive zone and the other not) will be sampled at three to four sites to measure variability in chemical parameters throughout the system.

Project # B.1.8

Depending on results of water analyses, approximately 15 resident brook trout will be taken from each system for analysis of the following elements: mercury, lead, aluminum, manganese, selenium, cadmium, nickel and total lipid content.

ANTICIPATED RESULTS

- a) Results will show whether any of the planned enhancement rivers are presently being impacted by acid rain and help salmon managers choose the best rivers for enhancement purposes.
- b) Establish a benchmark for water quality of these rivers which can be re-examined at some future date to measure changes resulting from acid rain.
- c) Comparing rivers in different geological zones will help determine if bedrock geology is a good indicator of water quality in the Newfoundland Region and what effect glacial drift is having on water quality.

PERFORMANCE INDICATORS

Publication of results as data or technical reports.

Project # B.1.9

PROJECT TITLE

Assessment of the effect of LRTAP on Canada's inland sport fisheries using extant information.

PRINCIPAL DFO INVESTIGATOR'S NAME

Dr. C.K. Minns

ADDRESS AND TELEPHONE NUMBER

Great Lakes Biolimnology Lab.
Department of Fisheries and Oceans
CCIW, Box 5050
Burlington, Ontario L7R 4A6
Tel: (416) 637-4730

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Dr. J.R.M. Kelso (DFO)
Dr. M.G. Johnson (DFO)
Ontario Ministry of Natural Resources
Hough, Stansbury and Michalski (contractors for 1st phase of study)

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	.4	.4	.4
b) Operating and Maintenance (\$000.)	50	50	50
c) Capital (\$000.)			

ANTICIPATED DURATION OF THE PROJECT

Three (3) years.

OBJECTIVES OF THE PROJECT

1. To estimate the potential losses in sport fish production and fish communities in (initially Ontario's) inland lakes.
2. To develop methodology for predicting the large scale effects of acid precipitation on fishery resources.
3. To develop case histories from existing data files to demonstrate the time course of acidification and the effect of biota, particularly the fish community.

METHODS

Amass existing data bases. Develop (or use) the counts and measures for lake areas and apply (scale up) existing data bases. Continue development of the Minns (in press) approach and model. Add features like basin geology, morphometry. Apply expected, predicted or derived rates of changes to the array of Canadian lakes.

Project # B.1.9ANTICIPATED RESULTS

This will provide a first order estimate of the state of lakes in Canada through existing data. This should be compatible with new data generated from headwater lakes inventory.

The approach will highlight deficiencies in area/coverage and regional fishery for existing programs.

This approach provides a second base (in addition to headwater lakes studies) against which acidification models can be applied.

Case histories provide a strong argument for effluent control should change be demonstrated. Few changes from LRTAP have been reported likely because few investigators have tried.

PERFORMANCE INDICATORS

- Minns, C.K. (in press) Acid rain: A preliminary estimate of the risk to Ontario's inland fisheries. Can. Tech. Rep. of Fish. & Aquatic Sci. #.
- Kelso, J.R.M. and C.K. Minns (in press) Current status of lake acidification and its effect on the fishery resources of Canada. Amer. Fish. Soc. Symp. August 1981.
- Other published material.
- Contract reports.
- Input to Canada-U.S. negotiations

C. Laboratory Research Program

Laboratory Research Program

BACKGROUND

Loss of fish populations in acidified lakes and streams have frequently been attributed to reproductive failure of resident fish populations. The mechanisms responsible for recruitment failure appear to be variable, depending probably on species, overall water chemistry of the drainage system, and seasonal relationships between spawning and pH fluctuations. Gametogenesis may be altered due to disruption of ionic balance in the adult fish. Embryonic development may be abnormal due to inadequate ion uptake or effects of increased dissolved heavy metal concentrations or interference with hatching processes.

The laboratory studies initiated in the DFO LRTAP program fall into three basic categories: 1) alterations in acid-base or ionic balances at low pH and resultant cardiovascular or respiratory responses; 2) alterations in egg and larval development at low pH; and 3) behavioral alterations imposed by low pH or behavioral responses to spatial pH gradients. Most of the laboratory studies are intended to either provide relevant information for closely linked intensive field programs or to provide further elucidation on the effects of low pH on physiological processes. The studies by Dr. Peterson, Dr. Haya, and by Drs. Scherer and Klaverkamp are linked closely with extensive field studies being performed at their respective institutions. In fact several other laboratory studies have been included in descriptions of the intensive fisheries studies because of their close linkage to these programs. Such studies as those on ionic balance, cardiovascular physiology, and hatching mechanisms are designed to provide new basic information on how low pH affects fish.

All three of the above categories of research are valid approaches. Disruption of ionic balance can have far-reaching effects on fish, resulting in decreased fecundity, growth rates and survival. Studies on embryonic development and physiology attack various aspects of recruitment failure. Behavioral alterations, such as avoidance responses, may be important in relation to basic migratory movements associated with spawning or feeding patterns of fish.

Project # C.1.1

PROJECT TITLE

Mechanisms of Toxic Action of Acid to Fish: Cardiovascular/Respiratory and Ionic Regulatory Systems.

PRINCIPAL DFO INVESTIGATOR'S NAME

Dr. Michael A. Giles

ADDRESS AND TELEPHONE NUMBER

Freshwater Institute
501 University Crescent
Winnipeg, Manitoba R3T 2N6

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

T. Hara)
S. Brown) Freshwater Institute
R. Evans)

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	3	3	3
b) Operating and Maintenance (\$000.)	25.5	25.5	25.5
c) Capital (\$000.)	9.5	43	12

ANTICIPATED DURATION OF THE PROJECT

To end of FY 1983/84.

OBJECTIVES OF THE PROJECT

1. To determine the actions and interactions of hydrogen ion and carbon dioxide upon cardiovascular/respiratory function and blood electrolyte regulation in fish with emphasis upon the dose-response relationships.
2. To investigate the physiological and biochemical mechanisms which result in these responses to acid/CO₂ stress.
3. To inter-relate the results of these studies with the results of neuro-endocrinological and histopathological investigations (Hara, Brown, Evans) on the same stock of fish to provide a more comprehensive statement on the mechanism by which acid adversely influences basic physiological functions in fish.

METHOD

- 1980/81
- a) Installation of a water acidification/degassification system to provide water of controlled pH and carbon dioxide/oxygen concentration.
 - b) Estimation of acid tolerance of laboratory-reared fish stocks using conventional bioassay techniques.

Project # C.1.1

- 1981/82 a) Measurement of the effects of acute and chronic exposure upon basic CURT parameters and blood plasma electrolyte concentrations over pH range 4.0 to 6.0
- b) Determine the time-course of acid-induced plasma electrolyte changes.
- c) Measurement of the effects of acute acid exposure upon kidney function in relation to electrolyte regulation.
- 1982/84 a) Measurement of effects of carbon dioxide upon acid-induced disruption in electrolyte regulation.
- b) Investigate the mechanisms involved in the disruption of electrolyte regulation (ie. enzyme involved in ionic transport, distribution of blood in respiratory and osmoregulatory epithelia). These studies will require the use of radio-tracers to measure electrolyte flux rates and cannot be performed without a gamma counter (\$43K capital 1982/83).

All the studies performed in this project will be conducted in vivo using free-swimming and/or surgically-treated rainbow trout.

PERFORMANCE INDICATORS

Project # C.1.2

PROJECT TITLE

Acid stress on fish neuro/endocrine systems.

PRINCIPAL DFO INVESTIGATOR'S NAME

Dr. T.J. Hara
S.B. Brown
R.E. Evans

ADDRESS AND TELEPHONE NUMBER

Department of Fisheries and Oceans
Freshwater Institute
501 University Crescent
Winnipeg, Manitoba R3T 2N6
(204) 269-7379

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Dr. J.G. Eales
Department of Zoology, University of Manitoba

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	2.5	2.5	2.5
b) Operating and Maintenance (\$000.)	25 (21 <u>a</u> base)	25 (21 <u>a</u> base)	25 (21 <u>a</u> base)
c) Capital (\$000.)			

ANTICIPATED DURATION OF THE PROJECT

1981-1984

OBJECTIVES OF THE PROJECT

To investigate effects of acid stress, and consequently heavy metals which are mobilized by acid, on the following neurohumoral systems regulating electrolyte metabolism and reproductive development in fish:

- 1) hypothalamo-pituitary-adrenal
- 2) pituitary-thyroidal, and
- 3) pituitary-gonadal

METHODS

Fish at different stages will be acutely and chronically exposed to various levels of acid stress and the following neural and endocrine functions examined:

1. Hypothalamo-pituitary, thyroid, adrenal and gonadal histology to identify pathological changes in these glands.

Project # C.1.2

2. Dynamics of plasma hormones - corticosteroids, thyroid hormones (T_4 and T_3 and their conversion), sex steroids - using radioimmunoassay procedures.
3. Treatment of fish with appropriately labelled hormone or precursor to determine production and degradation rates under acid stress (if time permits).
4. Measurements of related variables such as plasma protein, electrolytes, glucose and iodide levels.
5. Sensory neural inputs to hypothalamo-pituitary system and associated fish behaviour such as feeding, spawning and migration.

ANTICIPATED RESULTS

1. Identification of the direct effects of acid stress on the described neuro-/endocrine functions.
2. Integration of these effects with those of ionic-osmotic regulation and cardiovascular-respiratory systems.
3. Identification of an endocrinological sensitivity profile to estimate the degrees of stress in previously acidified aquatic systems.
4. Provide basis for investigations of the interactions between acid and increased heavy metal concentrations which are associated with acidification.

PERFORMANCE INDICATORS

Publication in primary journals.

Project # C.1.3PROJECT TITLE

Effects of acid waters on locomotor responses of fish and invertebrates.

PRINCIPAL DFO INVESTIGATOR'S NAME

Dr. E. Scherer

ADDRESS AND TELEPHONE NUMBER

Department of Fisheries and Oceans
 Freshwater Institute
 501 University Crescent
 Winnipeg, Manitoba R3T 2N6
 Tel: (204) 269-7379

COOPERATING AGENCIES AND INVESTIGATORS

(If Applicable)

Department of Fisheries and Oceans
 Dr. D.W. Schindler
 Dr. M. Giles
 Mr. J.F. Flannagan

DFO RESOURCES ASSIGNED

	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	2	2	2
b) Operating and Maintenance (\$000.)	18 (<u>a</u> base)	19 (<u>a</u> base)	18 (<u>a</u> base)
c) Capital (\$000.)	5 (<u>a</u> base)	5 (<u>a</u> base)	5 (<u>a</u> base)

ANTICIPATED DURATION OF THE PROJECT

- a) set-up and initiate experiments: 4/81 to 8/81
 b) conclusive experiments, results, publications: 8/81 to 3/85

OBJECTIVES OF THE PROJECT

To determine effects of acid waters on spatial distribution and abundance of selected freshwater organisms, by investigating preference/avoidance responses, effects on swimming performance and locomotor activity of fish, and on drift behaviour of invertebrates.

METHODS

A combination of laboratory and field experiments is used. Recording of locomotor activity of rainbow trout (Salmo gairdneri), lake whitefish (Coregonus clupeaformis), and brook trout (Salvelinus fontinalis)* in field cages** and lab aquaria, studies on preference/avoidance responses and maximum sustained swimming speeds of these species in existing lab set-ups with subsequent field checks; analysis of drift behaviour of selected stream dwelling invertebrates in laboratory stream channels.

* Add walleye (Stizostedion vitreum vitreum) - see Scherer 1971, J.F.R.B. 28: 1303-1307 and Arctic charr (Salvelinus alpinus).

** One battery-operated automatic field apparatus for monitoring locomotor activity of fish is ready for use (e.g. ELA).

Project # C.1.3ANTICIPATED RESULTS

Above methods have been successfully applied internationally to assess ecological effects of a number of organic and inorganic chemical compounds; comparable data on effects of acidified waters are very scarce. Results will determine effects of acidification on responses directly underlying spatial distribution and abundance, namely selection and maintenance of habitat by freshwater organisms, with special attention to possible mitigative adaptation mechanisms under chronic exposure.

PERFORMANCE INDICATORS

Project # C.1.4PROJECT TITLE: Laboratory studies on early development of fish at low pH.PRINCIPAL DFO INVESTIGATOR'S NAME: R.H. PetersonADDRESS AND TELEPHONE NUMBER: Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B. EOG 2X0

Telephone No.: (506)-529-8854

COOPERATING AGENCIES AND INVESTIGATORS:
(if Applicable)

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
-------------------------------	---------	---------	---------

- | | | | |
|---------------------------------------|--|--|--|
| a) Person Years | | | |
| b) Operating and Maintenance (\$000.) | | | |
| c) Capital (\$000.) | | | |

ANTICIPATED DURATION OF THE PROJECT: OpenOBJECTIVES OF THE PROJECT

Hatched salmonid alevins have a requirement for exogenous Ca^{++} , Na^{+} , and K^{+} (and possibly other ions) with accumulation increasing exponentially during yolk absorption. Preliminary results indicate that this accumulation is reduced at low pH. Further research will focus on sites of uptake, how low pH reduces accumulation, the effect of the ion deficiency on the viability of resultant fry, and comparative aspects (species differences etc.). The effects of ambient ion concentration on accumulation will also be investigated.

METHODS

Ambient pH will be controlled by pH-stat apparatus in a continuous-flow system. Ambient concentrations of ions will be regulated by standard dosing procedures. Total ions will be measured by standard atomic absorption spectroscopy on ion chromatography. In vivo measurements will be made with micro-ion selective electrodes.

ANTICIPATED RESULTS:

These studies will provide knowledge of the mechanisms whereby low pH affects the early development of fish.

PERFORMANCE INDICATORS:

Peterson, R.H., P.G. Daye, and J.L. Metcalfe. 1980. Inhibition of Atlantic salmon hatching at low pH. Can. J. Fish. Aquat. Sci. 37: 770-774.

_____. 1980. The effects of low pH on hatching in Atlantic salmon eggs. In Proc. Int. Conf. Ecol. Impact. Acid Precip., Norway, 1980, SNSF Project, P. 328.

Project #C.1.4PERFORMANCE INDICATORS: (Cont'd)

Daye, P.G. 1980. Effects of ambient pH in fish: an annotated bibliography.
Can. Tech. Rep. Fish. Aquat. Scie. 950, 28 p.

Peterson, R.H., P.G. Daye, G.L. Lacroix, and E.T. Garside. 1981. Reproduction
in fish experiencing acid and metal stress. Presented at Amer. Fish. Soc.
Symp, August, 1981.

Future primary Publications

Project # C.1.5

PROJECT TITLE: Development of analytical techniques

PRINCIPAL DFO INVESTIGATOR'S NAME: Dr. S. Ray

ADDRESS AND TELEPHONE NUMBER : Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B. E0G 2X0

Telephone No.: (506)-529-8854

COOPERATING AGENCIES AND INVESTIGATORS:
(if Applicable)

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
a) Person Years	0.5	0.5	0.5
b) Operating and Maintenance (\$000.)	15	10.5	10
c) Capital (\$000.)	0	0	0

ANTICIPATED DURATION OF THE PROJECT: 3 years.

OBJECTIVES OF THE PROJECT

Adapt or develop (as necessary) analytical techniques for the determination of aluminum, and for determination of strong and weak acidity. Analysis of Al in animal tissues is still uncertain. N.B.S. standards do not yet exist.

METHODS

Routine techniques (as yet unknown) for the determination of aluminum and forms of acidity will be developed and tested on water samples from the Westfield River study area.

ANTICIPATED RESULTS:

Improved methods of Al determination in fish tissues.

PERFORMANCE INDICATORS:

Primary publications

Project # C.1.6PROJECT TITLE: Effect of humic acid on Aluminum toxicity.PRINCIPAL DFO INVESTIGATOR'S NAME: Dr. S. RayADDRESS AND TELEPHONE NUMBER: Department of Fisheries and Oceans
Biological Station
St. Andrews, N.B., EOG 2X0

Telephone No.: (506)-529-8854

COOPERATING AGENCIES AND INVESTIGATORS:
(if Applicable)

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
a) Person Years	-	-	-
b) Operating and Maintenance (\$000.)	0	30	0
c) Capital (\$000.)	0	0	-

ANTICIPATED DURATION OF THE PROJECT: 1 Year.OBJECTIVES OF THE PROJECT

To determine the effect of humic substances on the toxicity of Aluminum to juvenile Atlantic salmon.

METHODS

Standard toxicity dosing and bioassay procedures will be utilized to test the toxicity of aluminum, in varying concentrations of humic acids, to juvenile Atlantic salmon. Humic-aluminum chemical interactions will also be studied. Complexation of other trace elements, like Cu and Zn, with humic and fulvic acids are known to reduce toxicity of the trace elements. Effects of complexation of aluminum with humic acid have not been extensively studied. These interactions will be studied under varying pH conditions to determine the stability of the complexes and subsequent toxicity to fish. The total Aluminum content will be determined by Atomic Absorption. Extensive survey of the literature will be conducted to determine and devise suitable methods for determining the complexed form.

ANTICIPATED RESULTS:

Knowledge of the toxicity of Al to Atlantic salmon, as affected by various concentrations of humic acid.

PERFORMANCE INDICATORS:

Primary publications

Project # C.1.7

PROJECT TITLE: Studies on reproduction of Atlantic salmon in an acid stream

PRINCIPAL DFO INVESTIGATOR'S NAME: Mr. H.C. Freeman

ADDRESS AND TELEPHONE NUMBER: Fisheries Environmental Research, FES
Department of Fisheries and Oceans
P.O. Box 550
Halifax, N.S. B3J 2S7

Telephone No.: (902)-426-6291

COOPERATING AGENCIES AND INVESTIGATORS DFO Mersey Hatchery
(if Applicable)

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
a) Person Years	0.5	0.5	0.5 (existing M/Y)
b) Operating and Maintenance (\$000.)	15	10.5	10
c) Capital (\$000.)	0	0	0

ANTICIPATED DURATION OF THE PROJECT: 3 years

OBJECTIVES OF THE PROJECT:

Determine effects of low ambient pH on gametogenesis in adult Atlantic salmon.

METHODS:

Sexually maturing Atlantic salmon will be held at controlled pH levels, and will also be sampled from the Westfield River until initiation of spawning. Effects of liming and aluminum will also be investigated. Steroid hormone metabolism, blood calcium levels, and egg number, size and fertility will be investigated.

ANTICIPATED RESULTS:

Determination of effects of low pH and aluminum on steroid hormone metabolism, gonad maturation, and reproduction.

PERFORMANCE INDICATORS:

Primary publications

Project #C.1.8

PROJECT TITLE: Biochemical toxicology of acid pH to aquatic fauna.PRINCIPAL DFO INVESTIGATOR'S NAME: Dr. K. Haya

ADDRESS AND TELEPHONE NUMBER: Department of Fisheries and Oceans
 Biological Station
 St. Andres, N.B. EOG 2K0

Telephone No. (506) - 529-8854

COOPERATING AGENCIES AND INVESTIGATOR: Drs. R.L. Saunders, R.H. Peterson
 (If Applicable)

<u>DFO RESOURCES ASSIGNED</u>	1981/82	1982/83	1983/84
a) Person Years	0.5	0.5	0.5 (existing M/Y)
b) Operating and Maintenance (\$000)	20.0	20.0	20.0
c) Capital (\$000)	0.0	0.0	0.0

ANTICIPATED DURATION OF THE PROJECT: 3 yearsOBJECTIVES OF THE PROJECT:

Develop biochemical indices of sublethal pH stress in aquatic fauna from acidic streams. Provide aid in assessment of overall health of aquatic communities in acidic environments.

METHODS:

1) Further studies to examine the role of chorionase on hatching success of various fish species in streams of low pH are being conducted; 2) a biochemical parameter considered potentially useful as an indicator of pollutant stress is adenylate energy charge (AEC) - a measure of the metabolic energy available for cellular metabolism. The following experiments will assess the potential of AEC as an indicator of sublethal stress in aquatic fauna to acidic habitats: (a) AEC during laboratory exposure or salmon parr to acid pH; (b) comparison of AEC in samples of fauna from acidic and non-acidic freshwater bodies; (c) AEC of Salmo salar during the smoltification process in laboratory controlled variations in pH; (d) AEC of smolts leaving the Westfield study area and other acid and non-acidic streams.

Project #C.1.8ANTICIPATED RESULTS:

pH activity profiles of chorionase and AEC. Activity profiles of chorionase and AEC for fauna from streams with differing ambient pH.

PERFORMANCE INDICATORS:

Primary publications

Haya, K., and B. A. Waiwood. 1981. Acid pH and chorionase activity on Atlantic salmon (Salmo salar) eggs. Bull. Environm. Contam.

Project #C.1.9PROJECT TITLE:

Sub-lethal ecotoxicology of aluminum and its complexes for Atlantic salmon and brook trout with respect to acid precipitation.

PRINCIPAL DFO INVESTIGATOR'S NAME: Y. Vigneault

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Champlain Harbour Station
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Tel: (418) 694-3478

COOPERATING AGENCIES & INVESTIGATORS:

1. Eco-Recherche, Inc.
121 boulevard Hymus
Pointe Claire, Quebec (contractor)
2. Dr. C. Schofield
Cornell Univ.
Ithaca, New York (consulting adviser)

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	--	--	--
b) Operating and Maintenance (\$000)	68.6	--	--
c) Capital (\$000)	--	--	--

ANTICIPATED DURATION OF PROJECT: 22 weeks

OBJECTIVES OF THE PROJECT:

To determine lethal and sub-lethal levels of aluminum at different pH and alkalinities and, within that context, the most toxic aluminum complexes for the two salmonids. To compare the sensitivity of both species to aluminum.

METHODS:

The fish will be maintained in solutions made of deionized water, cations (Ca, Mg, Na, K) and inorganic ($\text{Al}(\text{OH})_3$ or AlPO_4) or organic aluminum. Each solution prepared will be monitored for the following parameters: pH, alkalinity, hardness, conductivity, sulfates, nitrates, chlorine, total or organic aluminum following a model from INRS-Eau.

Test 1: Lethal Toxicity

The sensitivity of young (age of) salmon and trout is compared in continuous flow tests lasting seven days. Six tests are performed simultaneously (5 experimentals and one control). All tests will be replicated.

Each test will use a different concentration of aluminum and different levels of pH (4.5 or 5.5) and alkalinity (10-13 or 30-35 mg/l). Each bio-assay is performed with at least 10 fish maintained in a 30 l polypropylene tank where the solution is renewed by proportional pumps.

Test 2: Sub-lethal effects

The system is made up of two cylindrical polypropylene tanks each of 30 l capacity, connected at their bases by a tube of 7.5 cm diameter. Water flow is unidirectional from one tank to the other, and aluminum additions are made into the interconnecting tube. Ten salmon age 1+ are maintained in the system. After an initial acclimation period, number of fish in each tank (one with, one without aluminum additions) is counted every 15 seconds and means are calculated.

Test 3: Preference test

Using the same system as Test 2, distribution of fish in the two tanks subjected to different physico-chemical conditions (Al, pH, alkalinity) will be observed.

ANTICIPATED RESULTS:

- See objectives

PERFORMING INDICATORS:

A final report will be received from the contractor. If suitable this data will be published in the primary literature and possibly in the Fisheries and Oceans Technical Report Series.

VI Project Descriptions

2. MITIGATION PROGRAM COMPONENT

Mitigation Program Component

BACKGROUND

Evidence collected in Nova Scotia indicates that the most dramatic impact of acidification thus far is in the extirpation of at least 11 Atlantic salmon runs. The Department of Fisheries and Oceans, as the agency responsible for fish habitat protection in the Maritimes, is anxious to reverse this trend as soon as possible so as to prevent the loss of additional salmon stocks. The Nova Scotia rivers in which the Atlantic salmon stocks have gone extinct since 1950 are: Tusket (Main), Barrington, Clyde, Roseway, Jordan, Sable, Broad, Nine Mile, Salmon (Lawrencetown) and Larrys River. In addition, chemical, angling and electroseining data indicate that the salmon stocks of several other rivers, notably Middle (Chester), East (Chester), Ingram, Sackville, and Tangier, are on the verge of extinction, and unless the trend is reversed these stocks will also be lost over the next 1-5 years. Also, the Atlantic salmon stocks in West (Sheet Harbour), Liscomb, and Isaacs Harbour Rivers show significant declines beginning about 1960. All of the above rivers are chemically monitored on a monthly basis, and all had mean pH levels of 5.0 or less during 1980. In contrast, 4 rivers (Medway, Gold, Port Dufferin and Moser) in the pH range of 5.1 - 5.3 during 1980 (and for which we have angling data back to 1936) show no significant trend to date in annual angling returns.

Chemical data from the Halifax County lakes (Gorham, 1957) and Nova Scotia rivers (Thomas, 1960) indicate that for Nova Scotia's lakes and rivers in the Maguma-granite zone the average rate of fall in pH has been 0.017 units per year since 1955. At this rate of acidification it requires 20 years for a system to decline by 0.35 pH units, which our angling and electroseining data, and physiological investigations indicate is the difference between Atlantic salmon survival at pH 5.0 and extinction at pH 4.7.

One of the principal features of Atlantic salmon biology is the unique genetic characteristics of each river stock. The loss of a native salmon run is irreversible. Restoring a river's salmon run with non-native fish is very difficult and expensive, and frequently unsuccessful. It has become apparent to the Department of Fisheries and Oceans that because of North America's present deep concern over the cost of energy, the continental problem of acid pollution will almost certainly not be rectified in less than 20 years; and in the short term will probably get worse. Therefore, unless local corrective measures are taken we must anticipate a continuing loss of Atlantic salmon stocks.

One possible measure which has been considered is the collection of adult salmon broodstock and use of a hatchery facility to rear the fish through their freshwater phase before restocking as smolts back into their native rivers. The objection to this approach (other than hatchery construction costs) is that the very small gene pools that would be involved and the artificial selection imposed by hatchery conditions would likely result, after a few generations, in a marked genetic divergence from the native wild stock. Evidence for such divergence is available from the Mactaquac Hatchery rearing program in New Brunswick.

The economics of completely mitigating the effects of acidification on Atlantic salmon by liming are still speculative, though excellent results have been obtained in Norway and Sweden, and with other salmonid species in New York and Ontario as well as in Scandinavia. The Nova Scotian situation differs from the above regions in two significant aspects; the river drainage areas are on average smaller in Nova Scotia, and the rivers are "brown water" systems. Smaller rivers tend to be more susceptible to acidification because of lower geological diversity, and faster flow-throughs which give less time for natural deacidification processes. Rapid flow-through systems are also less amenable to restoration by current lake liming techniques; most of the lakes limed in Scandinavia, Ontario and New York have mean residence times in excess of one year, but most Nova Scotia lakes have mean residence times of the order of six months. The "brown water" is a result of drainage from peaty deposits. Bogs and heaths are very common in southwest Nova Scotia because of the shallowness of the soils, poorly developed drainage (legacies of glaciation) and low permeability of the bedrock. Such areas release humic acids (weak organic acids) which contribute to the acidity and cause the brown coloration of most surface waters in this region. One potential advantage, however, is the ability of humic acids to chelate (and thus detoxify) metals (Al, Mg, etc.) mobilized by acid precipitation.

The liming program undertaken by the Province of Ontario is one of lake rehabilitation because of the lake oriented nature of their sport fishery. The situation in Atlantic Canada is different because of the importance of anadromous fish (especially salmon) to the angling and commercial fisheries. In Nova Scotia, the Atlantic salmon in this freshwater phase inhabits rivers, not lakes. In the Maritimes, the mitigation effort must emphasize the rehabilitation of river habitats.

In the Maritime Provinces, the Federal Department of Fisheries and Oceans is responsible for all freshwater fisheries management. The Department is, therefore, obliged to examine methods whereby the Atlantic salmon stocks presently on the verge of extinction can be preserved for the future. The most practical method of achieving this appears to be the use of lime to create deacidified refuge in small tributaries so that a nucleus of native stock can be preserved for restocking the entire river after acid pollution is brought under control. First priority for this genetic preservation attempt is extended to the Middle, East, Ingram, Sackville and Tangier River, where evidence suggests that salvageable remnants of the native stocks may still be present.

Project # D.1.1

PROJECT TITLE

Pilot study of the practicality of using lime and/or limestone to create de-acidified refuges for Atlantic salmon survival.

PRINCIPAL DFO INVESTIGATOR'S NAME

W.D. Watt

ADDRESS AND TELEPHONE NUMBER

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902-426-3606

COOPERATING AGENCIES AND INVESTIGATORS

Dr. G.F. Farmer
Mr. W.J. White
Various Consultants

<u>DFO RESOURCES ASSIGNED</u>	<u>1981/82</u>	<u>1982/83</u>	<u>1983/84</u>
a) Person Years	3	3	3
b) Operating and Maintenance (\$000.)	125	125	125
c) Capital (\$000.)	20	20	20

ANTICIPATED DURATION OF THE PROJECT

Five (5) years.

OBJECTIVES OF THE PROJECT

In 1980, a decision was made to proceed with a pilot study on the practicality of creating de-acidified refuges for salmon survival.

It is intended that various forms of lime and limestone (quick lime, slaked lime and dolomitic and calcite limestone, finely ground and as gravel) locally available should be tested for neutralizing capability, rates of de-acidification in various lake types (high and low flushing rates, acidities, and aluminum and humic concentrations). Various delivery mechanisms will also be tested including spreading on ice, from boats, and by air, and careful comparisons made of costs and effectiveness.

Project # D.1.1METHODS

1. Select pilot liming sites, preferably in priority river systems.
2. Where practicable select adjacent control sites.
3. Survey chemistry and biology, where possible collecting one year of pre-liming data.
4. Treat lakes with lime or ground limestone and/or stream with limestone gravel.
5. Stock with juvenile fish if required.
6. Monitor post-liming biology and chemistry.

Chemical monitoring includes pH, acidity, alkalinity, colour, turbidity, conductivity, hardness, Ca^{++} , Mg^{++} , Na^+ , K^+ , SO_4 and total Al, Mn, Fe and Zn.

Biological and limnological monitoring includes (where practicable) photoplankton, zooplankton, macrobenthos, chlorophyll, temperature and oxygen profiles and fish (growth rates, etc.).

Treatment sites will be chosen for their compactness, accessibility for liming and monitoring, physical quality and quantity of the salmon habitat that will be protected by the treatment, and priority and acidity of the river system.

ANTICIPATED RESULTS

1. Assessment of potential effectiveness of de-acidified refuges for Atlantic salmon preservation.
2. Cost information on the various options for de-acidification.
3. Information on relative effectiveness for de-acidification purposes of several local varieties of limestone and lime products.
4. Information on relative effectiveness of different application systems including a comparison of lakes vs. stream treatment.

PERFORMANCE INDICATORS

Annual progress reports, technical reports and publications.

ADDENDUM

NOTE: This project was added to the program plan at the last moment. It is complimentary to those projects that comprise the national "Survey and Inventory of Sensitive Aquatic Systems to LRTAP".

Project # B.1.10

PROJECT TITLE

Baseline snow pack and water quality data collection and associated laboratory studies for British Columbia watercourses with regard to the proposed Hat Creek coalfired generating plant (net - 2,000 MW).

PRINCIPAL DFO INVESTIGATORS' NAMES

M.D. Nassichuk/S. Samis

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COOPERATING AGENCIES AND INVESTIGATORS

(If applicable)

International Pacific Salmon Fisheries Commission
Cultus Lake Laboratory
Sardis, British Columbia

(604) 858-4612 - Dr. J. Servizi

DFO RESOURCES ASSIGNED

1981/82

1982/83

1983/84

- a) Person Years
- b) Operating and Maintenance
(\$000.)
- c) Capital (\$000.)

ANTICIPATED DURATION OF THE PROJECT

Remainder of fiscal year 1981/82 (ie. to March 31, 1982) following which time the need to conduct further studies will be examined.

OBJECTIVES OF THE PROJECT

To increase baseline snow pack and water quality data with emphasis directed at determining the sensitivity of lower order B.C. streams during snowmelt, and throughout the year.

METHOD

Collect snow pack samples from selected areas, and water samples from selected watercourses in B.C. for analysis for the following parameters:

buffering capacity (titration curves)
pH
alkalinity
hardness (Ca^{+2} , Mg^{+2})
sulphates
metals (total and extractable)
conductivity

Project # B.1.10Timing of Sampling

- Snowpack will be sampled prior to snow melt; water quality sampling during early spring freshet (two times per week, minimum, for selected streams of alkalinities less than 300 $\mu\text{g/L}$).
- Remaining sites sampled twice monthly in spring.

ANTICIPATED RESULTS

To provide baseline snowpack data and water chemistry data on a range of B.C. watercourses to determine their sensitivity to increased acid deposition.

PERFORMANCE INDICATORS

Project just beginning.