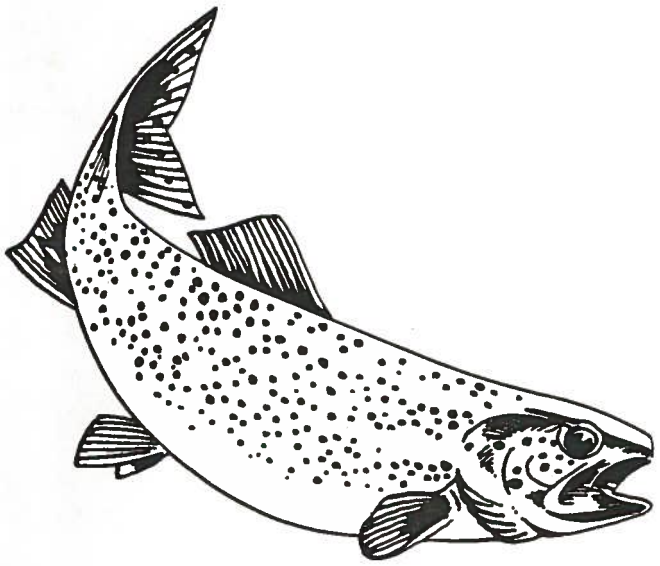
J C. MacLeod

Department of Fisheries and Oceans

NATIONAL PROGRAM

Project Summaries and Progress Achieved

February 1984



ACID RAIN

Canada

NOTE: Additional copies of this document can be obtained free of charge (while they last) by contacting:

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INDEX TO DEPARTMENT OF FISHERIES AND OCEANS

LRTAP PROJECT INFORMATION FORMS

I. Overview of Program Progress Since 1980

II. Aquatic and Biological Program

1 OVERVIEW

DEPARTMENT OF FISHERIES AND OCEANS NATIONAL PROGRAM ON THE LONG RANGE TRANSPORT OF AIR POLLUTANTS (ACID RAIN)

OVERVIEW OF PROGRAM PROGRESS SINCE 1980

INTRODUCTION

The following pages contain summaries of projects that have been undertaken under the auspices of DFO's national program on the Long Range Transport of Air Pollutants (more commonly referred to as LRTAP or "acid rain").

These summaries have been prepared at this time to provide documentation for DFO's input into a review by the Royal Society of Canada of the entire Federal program on "acid rain". This review is scheduled to be conducted in Toronto on February 21 and 22, 1984.

BACKGROUND

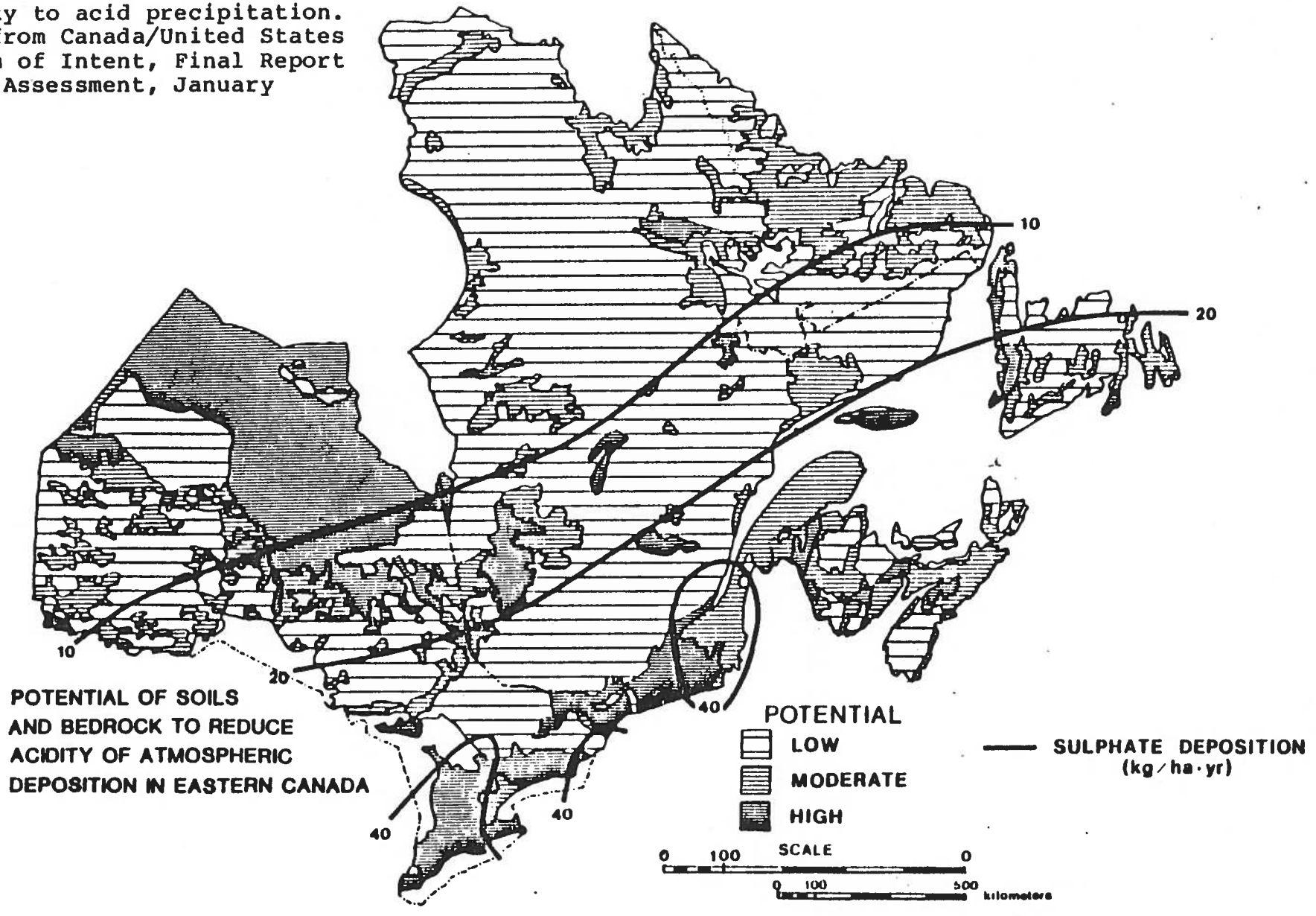
In July 1980 the Cabinet Committee on Economic Development approved resources until March, 1984 for an expanded and accelerated departmental program to deal with the threat of "acid rain" to Canadian fisheries resources. As we approach completion of the fourth year of the program, it is timely to report on the general progress.

Acid rain in Canada has eliminated all fish from hundreds of lakes in Ontario and eliminated at least ten runs of Atlantic salmon in Nova Scotia and has the potential for serious impacts in Newfoundland and Quebec.

Acid rain is caused from the short and long range transport and transformation of oxides of sulphur and nitrogen released during the burning of fossil fuels in electric power generation, industrial processes and transportation. Over half of Canada's acid rain originates in the United States.

The first casualties of acid rain are sensitive lakes and rivers located in areas containing noncalcareous bedrock and thin soils. Most of Eastern Canada fits this description (see Figure 1) and therefore most freshwater systems and especially fish are potentially susceptible to being affected by acid rain.

FIGURE 1: Map of Eastern Canada indicating sensitivity of aquatic resources to impact from acid preciptation. Areas with a "low potential" to reduce acidity are considered to have a high sensitivity to acid precipitation. (adapted from Canada/United States Memorandum of Intent, Final Report on Impact Assessment, January 1983).



World attention was drawn to the acid rain problem by the Scandinavians in 1972. Their aquatic systems are sensitive to acid input for the same reasons as those in Canada. Sweden claims that so far acid rain has affected 18,000 of its 75,000 lakes, 4,000 of them so seriously that most life, including all fish, have vanished. In Norway, experts estimate there are fish population damages in 33,000 km^2 and that fish populations are virtually extinct in 13,000 km^2 of this area. The losses are estimated to have started before 1940 and have been particularly rapid since 1960. Included in the area of impact are seven major rivers that have lost their Atlantic salmon populations. Presently the acidity of precipitation over large parts of south eastern Canada is very close to what is being observed in southern Sweden and Norway.

Canada cannot solve its acid rain problem alone. The only cure for acid rain is a bilateral air pollutant treaty for reduced emissions between Canada and the United States. Recognizing this fact both countries signed a Memorandum of Intent (MOI) in August 1980 indicating their determination to undertake the necessary steps to correct the acid rain problem. The designated lead agencies in negotiating the proposed treaty are Environment Canada and the Department of External Affairs. Other federal agencies also involved in the MOI process are the Department of Fisheries and Oceans, Health and Welfare Canada, Agriculture Canada, and the Department of Energy, Mines, and Resources. Several provincial environment and fishery agencies (most notably Ontario) have also been involved in the documentation of various aspects of the acid rain issue. These documents were jointly written with representatives from a variety of U.S. agencies and were intended to form the basis for bilateral negotiations. They were officially released by the Minister of the Environment on February 21, 1983. Since the release of these documents there has been little, if any progress towards the realization of the proposed bilateral treaty.

DFO PROGRAM HIGHLIGHTS

In November 1980, Treasury Board approved additional resources for acid rain research as part of a general "omnibus" submission. Since that time a number of significant highlights in the program have been achieved:

- the Experimental Lakes Area of Northern Ontario (Western Region, PFF) has expanded its unique program of whole lake acidification and is attempting to determine mechanisms of acidification and the effect

on fish and all other levels of the food chain,

- the Algoma Area Forested Watershed Program in Central Ontario (Ontario Region, PFF) has been initiated as a cooperative study with Environment Canada. By monitoring all chemical inputs and outputs in the 4-Lake Watershed, biological changes will be related to the acidification process,
- the Westfield River Study (Scotia-Fundy Region, Atlantic Fisheries) is determining how acid related stresses (pH, metals, food chain) affect Atlantic salmon in a seriously acid stressed river in south western Nova Scotia,
- since the Fall of 1980 DFO's National Inventory and Survey (N.I.S.) has documented acidification damage to water and biota in over 1,000 lakes located in areas sensitive to acid rain in eastern Canada; a number of Pacific salmon streams in potentially sensitive areas of British Columbia have also been surveyed,
- the mitigation component of the program (Scotia-Fundy Region, Atlantic Fisheries) has involved experimental neutralization of a number of acid-stressed lakes and rivers in Nova Scotia through the addition of "lime products",
- the economics program has produced several reports providing methodology and data to allow estimates of the socio-economic costs of damage to certain Canadian fisheries from acid rain,
- the communications program has produced and distributed a variety of public information items (brochures, fact sheets, posters, bumper stickers, displays, and magazine articles directed at fishing interest groups) in Canada and the United States.

PROGRAM GOAL AND OBJECTIVES

The goal of the Department's acid rain program is:

- to protect freshwater and anadromous fisheries resources threatened by acid precipitation and related pollutants, and

- ensure the long term maintenance of social and economic benefits associated with the fisheries resources.

In support of the above goal statement four major objectives were adopted.

Objective 1 - develop measures to support national and bilateral controls on emissions.

DFO's chosen strategies to address this objective include:

a) the production of significant scientific documentation on the effects of acid rain to fisheries
b) improved fishery agency cooperation

In support of 1a, DFO has contributed significant support to Environment Canada and External Affairs through the MOI process by providing information documenting the magnitude or potential magnitude of damage. Highlights of these accomplishments include the following:

- studies in Nova Scotia have shown that acid rain has destroyed Atlantic salmon stocks in 9 rivers with an additional 14 rivers endangered over the next 5 to 20 years,
- work at ELA has shown that severe damage to aquatic food chains begins when acidity values (measured as pH) are only slightly below 6.0,
- DFO's lake and river surveys (N.I.S.) have confirmed the existence of thousands of sensitive systems all over eastern Canada.

These data have been particularly useful in assessing the urgency and need for emission controls because they indicate causality between acid rain and biotic damage and because they show the problem is not localized in Canada but widescale over thousands of square kilometers.

Much of the information collected and synthesized for MOI reports has been circumstantial. The U.S. team has pointed this out on numerous occasions and is arguing on the need to prove causality before implementing expensive abatement programs. There is little "proof" of damage to forests but there are some indications of the potential for damage. Therefore much of the success in convincing the U.S. that our environment is being

damaged now and that controls are needed now is dependent on our ability to quantify damage to aquatic systems and in particular to fish that inhabit these systems.

In support of objective 1b, DFO and the United States Fish and Wildlife Service (USFWS) jointly sponsored an international symposium organized by the American Fisheries Society on "Acid Rain and Fisheries" on the campus of Cornell University in August 1981. A published hard cover book of the proceedings is now available. In 1982 DFO personnel were invited and participated in an international workshop on "liming", jointly sponsored by several U.S. government agencies including USFWS and a number of industries who contribute to the acid rain problem. These proceedings have also been published. Several DFO personnel were also invited and subsequently assisted in evaluating the U.S. Environmental Protection Agency's Critical Assessment Document (CAD) on acidic deposition effects. In the summer of 1983 DFO sponsored a special American Fisheries Society symposium on "Mitigation Techniques for Acidified Surface Waters". The proceedings are scheduled for publication in the AFS's journal entitled Fisheries.

Objective 2 - preserve genetically valuable fish stocks over the interim period while awaiting the implementation of effective emission controls, and rehabilitate fisheries that have been destroyed by acidification.

The strategies adopted in support of this objective include the "liming" of a number of acid-stressed rivers and lakes in Nova Scotia, and the stocking of larger more pH resistant hatchery reared Fall fingerlings instead of younger Spring smolts. The results to date have confirmed that this interim approach will be difficult to conduct on a large scale and will be very costly. Although extensive data are not yet available it appears technologically possible but not cost effective to restore extinct salmon runs in Nova Scotia rivers. Preventing the inevitable loss of any more salmon runs appears possible but the cost of doing this, using present methods, will probably exceed the dollar value of the fishery.

Objective 3 - assess the economic and social costs associated with the deterioration of the fishery resource.

A key overall strategy in promoting the development of effective national and bilateral control programs is the documentation of real economic and social costs. The urgency of the

need for controls will be emphasized from quantitative estimates of the costs of current and projected damage. Progress in this area has been hampered by a serious lack of applicable data and methodology. In the last two years new approaches have been developed which should allow the quantification of some fisheries losses.

Objective 4 - to make the general public in Canada and the United States fully aware of the inherent dangers to the fishery resource from acid rain as a means of generating acceptance and support for programs being undertaken at taxpayer's expense.

DFO's strategy in support of this objective has been to target special fishery interest groups with a variety of public information items. Polls have shown that public awareness and concern for the problem is very high in Canada, less so in the United States. The popular press in Canada has convinced the public that our fishery resource is being devastated by acid rain. Public expectation is that government will take necessary action to rectify the trend.

Concern for the issue is growing rapidly in the United States. A number of large and respected environmental interest groups have organized themselves to block any attempts to weaken existing "clean air" legislation presently being debated in Congress. An effective information program targeted at fishing interests in support of these efforts could play a key role in this process.

POSSIBLE FUTURE STRATEGIES

Since 1980 the focus of DFO's "acid rain" program has been on the deposition of strong acids in precipitation because it was perceived as the problem of greatest immediate consequence to Canada's fisheries resources.

It has also been clear for some time now that fisheries managers in the future will also have to be concerned with an evergrowing list of other contaminants in precipitation which pose serious, and as yet unevaluated risks for the resource. Included in the list of atmospheric pollutants other then acidifying substances are: heavy metals (including mercury, zinc, cadmium, selenium, etc.) and organic contaminants (including pesticides, polyaromatic hydrocarbons or PAH's, PCB's, benzopyrenes etc.). These types of atmospheric contamination have implications for all freshwaters in Canada, including the Great

Lakes, irrespective of their ability to "buffer" acids. A further consideration is that these contaminants pose a human health problem for people who consume affected fish in addition to having adverse effects on the fish themselves. Therefore it appears inevitable that this aspect of atmospheric pollution will be an area of increasing concern for this Department.

ASSESSMENT OF PROBLEM: SCIENTIFIC AND POLITICAL

The acid rain research program has provided convincing evidence that this is a real issue for this Department. Canada's freshwater and anadromous fishery resource has already been impacted and new evidence collected from the last three years of our expanded program indicates more damage will result unless the deposition of acidifying substances is reduced. Our studies have also suggested that some Pacific coast salmon streams are susceptible to damage from "acid rain".

At present our limited understanding of the processes resulting in acidification and the loss of fish prevents us from being able to quantify the rate at which particular resources can be expected to be affected. This uncertainty in itself is very disturbing and it is critical we develop a capability to make these estimates.

The MOI was signed by the Carter administration and called for a cooperative technical documentation of all aspects of the problem as the basis for negotiation of a bilateral air pollutant treaty. However the Reagan Administration has demonstrated a reluctance to support environmental protection on a variety of issues, including acid rain. In spite of overwhelming evidence to the contrary it is still their contention that not enough is known about the problem to warrant any significant changes in present policy.

In early February 1983, Canada and the U.S. agreed to a common working document on acid rain effects (both aquatic and terrestrial) as part of the MOI process. However the two countries could not agree on a common report summary and therefore there are two different interpretations of what the data imply in terms of the need for stricter emission reductions. These facts suggest that a bilateral agreement on permissible emissions of acidifying substances appears very unlikely in the foreseeable future.

The lack of any real progress in negotiating a bilateral agreement leading to reduced air pollutant depositions has serious long and short term implications for this Department.

Unless the Government of Canada can continue to provide to the bilateral process better quantified estimates of the increasing seriousness of this issue it is unlikely that an effective air pollutant treaty will ever be realized. Environment Canada is presently very heavily dependent on Fisheries and Oceans in providing data on effects and damage to the aquatic biota. Negotiations have indicated that changes in water quality must be related to biota and especially fish to be convincing that important problems exist.

The Minister of Fisheries and Oceans has a responsibility to conserve, protect, and enhance Canada's fisheries resources that are presently being affected by acid rain. His responsibility is even more acute in those parts of Eastern Canada where DFO has management responsibility for the freshwater and anadromous fishery and where damage is already occurring. The conditions which have led to the devastation of freshwaters in large areas of Scandinavia are all present in eastern Canada.

Our lack of knowledge of complex acidification processes and historical acid depositions in both areas does not allow us to explain, as yet, why Canada's fisheries have been substantially less affected than those in Scandinavia. This uncertainty is itself very unsettling.

In some areas of Sweden the devastation to fisheries has been so complete that the government has embarked on a $50 million dollar annual rehabilitation and restoration "liming" program. Their reluctance to initiate this "palliative" is emphasized by their continuing long term goal which is to negotiate an air pollution reduction treaty with the major European emittors of sulphur dioxide. Norway has also recently initiated experimental liming programs for their affected surface waters.

If eastern Canada were faced with fisheries impacts on a similar scale as has occurred in Sweden, our preliminary experimental results indicate that annual costs for mitigation would be substantially larger than $50 million annually.

PROGRAM RESOURCES

DFO's national program on acid rain has grown steadily since the fall of 1980 when special resources were committed to this issue. Table 1 indicates that the present commitment in the 1983-84 FY is 58 PY's and in excess of $4.77 million.

Table 1

The resource utilization in the acid rain program for the past four years is indicated in the following table. DFO received approval in late 1980 for a four year accelerated program on atmospheric pollutants as part of a general "omnibus" submission. The resources awarded amounted to approximately three million dollars and 16 person years, allocated annually, and were used to supplement an ongoing program. These additional resources are scheduled to terminate in March 1984.

TOTAL RESOURCES UTILIZED

		P/Y	$000. Estimated Salary	$000. O&M	$000. CAP.
1.	**FOR FISCAL YEAR 1980/81**				
1.	Scientific	31.65	822.5	941.5	507.
2.	Mitigation	1.5	39.	12.	0
3.	Socio-Economic	.5	13.	30.	0
4.	Communications	.1	3.	72.	0
5.	Program Management	1.1	29.	33.	0
	TOTALS	34.85	906.5	1,088.5	507.
2.	**FOR FISCAL YEAR 1981/82**				
1.	Scientific	42.25	1,182.8	2,365.5	289.
2.	Mitigation	4.0	112.0	125.0	20.
3.	Socio-Economic	.8	22.4	85.0	0
4.	Communications	.25	7.0	95.0	0
5.	Program Management	1.10	31.0	65.0	0
	TOTALS	48.4	1,355.2	2,735.5	309.
3.	**FOR FISCAL YEAR 1982/83**				
1.	Scientific	48.6	1,452.5	2,250.5	233.5
2.	Mitigation	4.0	120.0	125.0	20.0
3.	Socio-Economic	1.0	30.0	100.0	0
4.	Communications	.25	7.5	95.0	0
5.	Program Management	1.15	40.0	65.0	0
	TOTALS	55.0	1,650.0	2,635.5	253.5

Table 1 (cont'd)

TOTAL RESOURCES UTILIZED

		P/Y	$000. Estimated Salary	$000. O&M	$000. CAP.
4.	**FOR FISCAL YEAR 1983/84**				
1.	Scientific	51.7	1,654.4	2,064.	235.
2.	Mitigation	4.0	128.	143.	10.
3.	Socio-Economic	1.0	32.	200.	0
4.	Communications	.25	8.	95.	0
5.	Program Management	1.15	36.8	165.	0
	TOTALS	58.1	1,859.2	2,667.	245.

CONCLUSIONS

1. There will be a significant loss of Canada's fisheries resources to future generations unless an effective bilateral air pollution treaty is concluded with the United States.

2. Positive action will be possible only through a commitment of the government to a) continued scientific and socio-economic studies b) a highly visible public awareness campaign in the United States and Canada and c) continued political pressure from Canada for air pollution reductions by means of a bilateral air treaty.

John M. Cooley
Acid Rain Program Manager
February, 1984

II AQUATIC AND BIOLOGICAL PROGRAM

PACIFIC REGION

PROJECT INFORMATION FORM

1. Discipline:

Aquatic / Fisheries

2. Project Number: |.|

3. Agency and Department:

Department of Fisheries and Oceans

4. Project Title:

Surface Water and Snowpack Baseline Chemistry Monitoring of Pacific Salmon Watercourses in B. C. and the Yukon.

5. Principal Investigator(s) (include addresses):

S. Samis
Water Quality Unit
Habitat Management Division
(1090 West Pender, Vancouver
Telephone (606) 666-1209)

Contract Biologist (Ms L. Pella)

6. Cooperating Agencies and Investigators:

Dr. J. A. Servizi, International Pacific Salmon Fisheries Commission

7. Project Duration: Ongoing - Projected completion 5 years (1988)
Commenced December, 1981

8. Resources (show PYs, capital and non-salary O&M by year):

P/Y = 0
Contract Biologist salary + O & M = 30K/year

9. Service or Agency Objectives:

To evaluate the capacity of Pacific Salmon Habitat to withstand acidic deposition.

10. Project Objectives:

1. Establish for the Pacific Region through comprehensive surface water chemistry monitoring, the sensitivity of low order salmon streams to acidification. These data will provide a benchmark against which long term trends in acidification and buffering capacity will be assessed.

10. Project Objectives (continued)

2. Sample selected snowpack areas to characterize meltwater chemistry in conjunction with surface water monitoring data.

3. Monitor seasonal changes in surface water chemistry, for sensitive Pacific Salmon streams.

4. Document through semi-continuous sampling at melt, pH and alkalinity trends for selected streams.

5. Document fish utilization in poorly buffered systems particularly with reference to juvenile salmon rearing/ distribution and adult salmon spawning.

11. Physiographic Region and Province(s) in Which Research Conducted

British Columbia: a) North Coast including Skeena River watershed; Queen Charlotte Island
b) South Coast including Vancouver Island
c) Fraser River drainage: streams in the Hat Creek area and in key urban areas.

Yukon Territory: Pacific Salmon streams of interest.

12. Ecosystem Types Included in Research (where applicable):

At the watershed level.

13. Purpose or Hypotheses to be Examined:

a). To examine the extent to which Pacific Region salmon streams are sensitive to acid inputs seasonally and geographically.

b) To provide scientifically defensible data upon which departmental positions can be based concerning development having the potential to impact salmon habitats.

14. Study Design/Methodology (include lab and data analyses to be employed):

a) Surface water sampling and analysis conducted in accordance with methodology established through LRTAP (Research and Monitoring Coordinating Committee).
b) Snowpack is sampled with a plexiglass core sampler producing one "composite" per site which is kept frozen in plastic, lidded containers until analysis.
c) Water chemistry variables included are: pH, alkalinity, conductivity, hardness; total, extractable and dissolved metals (ICAP scan).
d) Chemical analytical quality control exercises have been carried out (Round robin). Gran titration methods used as required.
e) Corroborative "field" pH testing conducted.
f) Qualitative fish distribution and abundance carried out using conventional fish capture techniques such as minnow trapping and beach seining.

15. Results and Conclusions to Date:

Pacific Salmon streams throughout B. C. and in parts of the Yukon have been characterized with regard to buffering capacity, as follows:

a) those less than 200 meq.L^{-1} and;

b) those less than 40 meq.L^{-1}.

16. Anticipated Outputs:

a) Baseline sensitivity assessments of selected Pacific Salmon streams near the Hat Creek proposed coal-fired generating station to be published this year as a departmental technical report.

b) Data reports on ongoing surface water and snowpack sampling to be published.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

a) Timing of funding and P/Y allocation decisions have been awkward with respect to snowmelt sample timing.

b) To date the lack of P/Y allocations to the Pacific Region program has required support be provided from the Fisheries Employment Bridging Assistance Program (FEBAP) and A-Base allocations. Program coordination is of necessity, funded via a contract biologist out of program O & M.

c) In 1983/84 a new cost recovery system was implemented at the DFO/DOE chemistry laboratory necessitating reimbursement for analyses through program O & M.

WESTERN REGION

PROJECT INFORMATION FORM

1. Discipline:

Aquatic/Fisheries

2. Project Number: 2.1

3. Agency and Department:

Department of Fisheries and Oceans

4. Project Title:

Experimental Limnology

5. Principal Investigator(s) (include addresses):

D.W. Schindler)
D.F. Malley)
K.H. Mills)
R.H. Hesslein) all Freshwater Institute, Winnipeg
R.W. Newbury)
G.J. Brunskill)

6. Cooperating Agencies and Investigators:

- Lamont-Doherty Geological Observatory
- Canadian Department of Environment - AES
- Canadian Department of Environment - Water Survey
- University of Manitoba
- University of Winnipeg
- Ontario Ministry of Environment (Ron Hall, J. Marshall)

7. Project Duration:

Since 1976. Future beyond March 1984 unknown

8. Resources (show PYs, capital and non-salary O&M by year):

1984-85:	A-base			Acid Rain		
	PY	Cap	O&M	PY	Cap	O&M
	12.6	0	125	13.4	70	364

9. Service or Agency Objectives:

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.

10. Project Objectives:

To test specific hypothesis about lake acidification which can only be answered by ecosystem-level experimentation.

Project # 2.1

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Precambrian Shield, northwestern Ontario

12. Ecosystem Types Included in Research (where applicable):

Lake
Boreal forest (water and chemical yields to lakes)
Wetlands

13. Purpose or Hypotheses to be Examined:

Several key hypotheses in the acidification argument, including:

In lakes

1) Effects of acidification on production, respiration and nutrient cycling.
2) " " " on metal & radionuclide mobilization from lake sediments.
3) " " " on key populations of organisms, and how their changes affect ecosystem structure, organization and function.
4) Effects of acidification on alkalinity via bicarbonate decreases, cation mobilization, etc.
5) An ecosystem-level comparison of sulfuric and nitric acids, their relative contributions to acidification, and the ecosystem-level mechanisms responsible for differences.
6) Effects of chronic, low-level acid inputs on ultra-sensitive lakes.
7) Effects of aluminum plus acid vs. acid alone on whole-ecosystem responses.
8) Effects of neutral salts of sulfate on acidification.
9) A calibration of paleoecological methods in lakes with known acidification histories.
10) A 50% reduction in sulfuric acid input will allow a partial recovery of an acidified lake.

In wetlands Effects of acid precipitation on key wetland functions, such as sulfate reduction, denitrification, and binding of cations and trace metals which are discharged to nearby waters. Effects of acidification on wetland vegetation.

14. Study Design/Methodology (include lab and data analyses to be employed):

Controlled addition of acid or acid and aluminum to whole ecosystems, coupled with detailed nutrient and metabolism studies and detailed studies of key organisms in ecosystem organization. These are compared with long-term background studies to detect effects outside the normally expected range.

Project # 3.1

15. Results and Conclusions to Date: Some examples:

Acidification to pH 5 has no detrimental effects on production, decomposition or nutrient cycling in lakes. These are all poor indicators of acid stress on lakes.
Lake sediments can account for 50-100% of the metal concentration normally associated with watershed acidification.
Many organisms are more sensitive to acidification than previously known. Examples are Mysis and Pimephales, which disappear at a pH of ~5.8.
Bioturbation makes the onset of acidification appear to be much earlier in the sediment record than it actually happens.
Redundancies in the food web render losses of some species fairly unimportant to upper trophic levels. In other cases, no replacement organisms are available.
Nitric acid has relatively little effect on lake or wetland acidification, due to the high efficiency of denitrification.
Ammonium is a very important source of acidity to lakes. Both biological uptake and nitrification are involved in its exchange for H^+.
Sulfate reduction and denitrification occur at high rates at pH values of 4 and lower, contrary to popular belief.
Sulfate reduction in epilimnion and hypolimnion sediments is an important source of acid neutralizing capacity in lakes. This ability is retained even under extremely acid conditions, indicating that there are internal mechanisms which should assist in return of alkalinity once sources are reduced.

16. Anticipated Outputs:

Information useful for ecosystem-level management decisions. Publications which will increase our knowledge of ecosystem-level processes as they relate to acid precipitation. A list of publications is attached.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

Funding has been more than adequate. The fact that many personnel are on contract or term positions has been a major handicap - in some parts of the project the continuous replacement/retraining as "soft money" personnel move to more stable positions has prevented effective work. The long-term nature of ecosystem-level studies requires more continuity.

I am concerned about the inattention to LRTAP pollutants other than acidification. Much of our current expertise could be diverted to trace metal and trace organic work. Once the "acid rain" program ends, I'm afraid that the lack of a planned transition to other LRTAP problems will leave us starting over. The time to begin an orderly transition is now, and it should be part of the planning exercise.

Until 1983, lack of suitable computer facilities slowed larger data analyses. This problem has recently been rectified. Obsolete equipment, particularly in metals and production aspects remains a problem. Potential lack of service by Water Survey of Canada in 1984.

#2.1

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

Primary Publications

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France, R.L. 1982. Comment on Daphnia respiration in low pH water - re: the importance of carbon dioxide in laboratory acidification experiments. Hydrobiol. 94: 195-198.

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.

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Malley, D. F. 1980. Decreased survival and calcium uptake by the crayfish Orconectes virilis in low pH. Can. J. Fish. Aquat. Sci. 37(3): 364-372.

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PROJECT INFORMATION FORM

1. Discipline:

Aquatic/Fisheries

2. Project Number: 2.2

3. Agency and Department:

Department of Fisheries and Oceans

4. Project Title:

Ecotoxicology

5. Principal Investigator(s) (include addresses):

J.F. Klaverkamp)
T. Hara)
F.P. Healey) Freshwater Institute
S.G. Lawrence) 501 University Crescent
J.W.M. Rudd) Winnipeg, Manitoba R3T 2N6
E. Scherer)

6. Cooperating Agencies and Investigators:

ELA Project in NW Ontario; Hudson Bay Mining and Smelting (W. Fraser); Provincial governments of Manitoba and Saskatchewan; Technical Committee of Western Canada LRTAP; Ontario Ministry of Environment (P. Dillon); R. Wright

(see over)

7. Project Duration:

Project formally started on April 1, 1983

8. Resources (show PYs, capital and non-salary O&M by year):

	A-base			Acid Rain		
	PY	Cap	O&M	PY	Cap	O&M
1984-85	12.0	0	75	5.0	45	115

9. Service or Agency Objectives:

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.

10. Project Objectives:

1. To develop practical, meaningful and sensitive indicators of stress induced by acidification and associated heavy metals in algae, zooplankton, macro-invertebrates, and fish by investigating fundamental mechanisms and critical sites of deleterious actions produced by these chemicals.

(see over)

Project # 2.2

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Precambrian Shield areas in northwestern Ontario, southern Ontario, northwestern Manitoba, northeastern Saskatchewan, and the Adirondacks.

12. Ecosystem Types Included in Research (where applicable):

While much of the research involves laboratory exposures, under conditions simulating oligotrophic lakes in the Precambrian Shield, some investigations are conducted in collaboration with whole-ecosystem studies at ELA. Fish and other organisms from these lakes in northwestern Ontario (ELA), northern

(see over)

13. Purpose or Hypotheses to be Examined:

1. To investigate the role of microbial processes on mercury methylation and accumulation by fish, and to study the influence of other factors, such as reduced pH, algal nutrients, and selenium on these processes and mercury accumulation.
2. To investigate the role of microbial processes on nitrate and sulfate reduction as whole-lake buffering mechanisms and on methane production at reduced pH.
3. To investigate the fundamental toxicology of acid-metal interactions in algae.
4. To investigate the effects of acids and metals on zooplankton and their food webs at ELA.
5. To determine the effects of reduced pH on locomotor activity, avoidance/preference behavior, food extract attractance, and swimming performance in fish.
6. To investigate fundamental mechanisms and critical sites of action of acids/metals in fish with emphasis placed on developing sub-lethal stress indicators useful in evaluating the impact of these chemicals on animals in the natural environment.
7. To evaluate the practicality, meaning and sensitivity of these stress indicators by applying them to fish exposed to experimental acidification

(see over)

14. Study Design/Methodology (include lab and data analyses to be employed):

During the 70's, methodology development in biochemical, physiological and behavioral areas of aquatic toxicity testing was a major objective for many of the researchers in this recently formed Ecotoxicology Project. For example, a manual for the culture of freshwater invertebrates (Can. Spec. Publ. of Fish. Aquat. Sci. No. 54, S.G. Lawrence (ed.), 1981, 169 p.) describes culture conditions for 10 species of protozoa, mollusca or arthropoda. Twenty toxicity tests were developed using some of these invertebrates and freshwater fish (Can. Spec. Publ. of Fish. Aquat. Sci. No. 44, E. Scherer (ed.), 1979, 194 p.). Experience gained and methodology developed by these researchers during the past decade are utilized to design and conduct experiments relating to the first objective in section 10.

14.(cont'd) Project # 2.2

Other investigations pertaining to acid/metal toxicology use methods developed in other scientific areas, in other projects at FWI, or by designing new methods to address specific problems. For example, some studies, especially those in biochemistry and physiology, employ modified approaches and techniques developed for mammalian studies. Others, such as those conducted in whole lakes or in field microcosms, have been developed by ecologists and limnologists in other projects. Unique methodological advances, which have been used by other investigators in Canada and foreign countries, have been developed by Project personnel for use in acidification studies.

6. Cooperating Agencies and Investigators: (Cont'd.)

in Norway; and research colleagues in the Universities of Manitoba and Winnipeg (see no. 15 - Actual Outputs - section C), Cornell University, Syracuse University, and University of Amsterdam.

10. Project Objectives: (Cont'd.)

2. To investigate fundamental processes affecting the contamination by mercury and other toxic metals of fish impacted by experimental acidification at ELA or by base-metal smelter emissions in the Flin Flon, Manitoba area.
3. To investigate the role of microbial processes in buffering acid-impacted lakes in NW Ontario (ELA), southern Ontario, the Adirondacks and Scandanavia.

12. Ecosystem Types Included in Research (Cont'd.)

Manitoba and northern Saskatchewan are sampled and analyzed for effects produced by experimental acidification or base-metal smelter emissions. Biological, sediment and water samples from smelter-impacted areas are brought into the laboratory for analyses of contamination by mercury and other toxic trace elements.

13. Purpose or Hypotheses to be Examined (Cont'd.)

at the ELA or to base-metal smelter emissions in Flin Flon, Manitoba.

8. To investigate reproductive capability, egg development, and contamination by mercury and selenium in fish exposed to experimental acidification in whole-lakes at the ELA.
9. To assess the contamination of fisheries by mercury and other trace elements emitted to the atmosphere by the base-metal smelter in Flin Flon, Manitoba.
10. To evaluate resistance to metal toxicity and the role of the protein, metallothionein, in fish from lakes impacted by emissions from this smelter.

Project # 2.2

15. Results and Conclusions to Date:

A. Microbial Processes:

In investigations on mercury methylation and accumulation by fish, major findings include:

1. Reduction in pH reduced the rate of mercury methylation because of a pH-induced reduction of sediment porewater mercury concentration. A radiochemical method was developed to measure rates of mercury demethylation.

2. Addition of algal nutrients stimulated methylmercury production by bacteria resulting in an increase of fish mercury concentration.

3. Trace additions of selenium were found to reduce the rate of mercury bioaccumulation by fish. Selenium also reduces the toxicity of methylmercury in the fish consumer. (see attached pages)

16. Anticipated Outputs:

If sufficient funding is received for the proposed 5 year duration, research will continue to address those objectives listed in section 13. It is anticipated that resources will be shifted somewhat from laboratory research to field studies in order to provide greater emphasis on evaluating the sensitivity, practicality, and meaning of sub-lethal stress indicators on organisms impacted in the natural environment.

Results will be presented at conferences and meetings and they will be published in appropriate media, e.g. primary scientific journals, technical reports, conference proceedings, etc. Results will be used to support bilateral processes leading to reduced industrial emissions.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

1. Uncertainty in funding level and duration make it exceedingly difficult to plan and conduct the long-term fundamental research required to produce meaningful diagnostic indicators of acidification-related stress in organisms from the natural environment.
2. Travel restrictions for scientific conferences are very detrimental to information exchange, and they increase the likelihood of poorly coordinated and integrated approaches.
3. More resources are required in analytical chemistry for detecting trace amounts of mercury and other elements and for processing large numbers of biological samples.

#2.2

15. Results and Conclusions to Date: (cont'd.)

Investigations on microbial nitrate and sulfate reduction and on methane production at reduced pH provide evidence that:

1. Nitrate and sulfate reduction maintains pore-water pH in acidified lakes. This protects the bacteria from low pH enabling them to continue to be a source of renewable buffering in lakes. These activities were also found in Adirondack lakes acidified for several decades demonstrating that these bacteria could participate in the recovery of acidified lakes.

2. Organic matter decomposition (CO_2 and CH_4 production) was resistant to acidification because sediment microbial activity buffered pore-water pH and because bacteria were not affected by H^+ concentration until about pH 5.0.

B. Acid/Metal Toxicology in Algae:

Laboratory studies using inhibition of phosphorus uptake by a green alga (Scenedesmus quadricauda) demonstrate that inorganic metal complexes are not significant factors in the joint toxicity of acid and metals, and that there is a marked increase in Cd and Cu toxicity with increasing pH indicating competition for cellular binding sites between hydrogen ion and free metal cations. Studies on the pH dependence of metal inhibition of P uptake by this alga were extended to include the pH dependence of Cd uptake and of inhibition of ammonium uptake by several metals and the ameliorating effect of organic chelators on metal toxicity.

C. Zooplankton/Food Web Studies at the ELA

Cladoceran zooplankters in continuously-flowing impoundments incubated in L302S (=pH 6.0-6.3) declined in number by at least one order of magnitude when exposed to 1-3 µg Cd/L. Copepod growth cycles were interrupted or retarded. Seasonality effects may be linked with temperature and concentration of dissolved organic carbon. Aluminum added in concentrations up to 300 µg/L to waters of L302 (pH 6.3), L114 (pH 5.7) and L223 (pH 5.0) did not affect zooplankton numbers. Desmid populations in L114 exhibited increasing incidence of morphological aberration with increasing concentrations of aluminum (0-75 µg/L).

D. Fish and Macro-Invertebrates: Biochemical, Physiological, Behavioral, Ecological, and Toxicological Processes:

A biphasic locomotor activity response to lowered pH was shown to occur in lake whitefish (Coregonus clupeaformis); also, a biphasic preference/avoidance response to lowered pH was displayed by Arctic charr (Salvelinus alpinus); impaired attractance to food extract at pH lower than 5.5. Swimming performance of S. alpinus was impaired after 8 d exposure to pH 4.

#22

Investigations on fundamental mechanisms and critical sites of action of acids/metals in fish were conducted with emphasis on developing sub-lethal stress indicators useful in evaluating the impact of these chemicals on animals in the natural environment. Major findings include:

1. Exposure of rainbow trout to sulfuric acid at a pH of ≈5.2 for 21 d produced an increase in plasma cortisol, implying sustained interrenal cortisol release. Interrenal histology showed hyperplasia and elevated nuclear diameter at pH 4.7. Eight days of exposure to sulfuric acid at pH 4.7 also produced a significant increase in plasma cortisol.

2. At pH ≈4.7 the ratio of plasma T_4 (L-thyroxine) to T_3 (3,5,3'-triiodo-L-thyronine) increased in relation to the controls. Depending upon the experiment this was due to either a significant elevation in plasma T_4 or a decrease in plasma T_3. No histological changes were evident in the thyroid of acid-treated trout. Eight days of acid exposure (pH 4.7) were required to depress plasma T_3.

3. Coincidental with higher interrenal activity, plasma glucose was elevated in acid-treated fish (pH <5.2) after 4 d of exposure.

4. At pH values ranging from 4.5 to 5.5, rainbow trout also exhibited stress in cardiovascular/respiratory systems as evidenced by increased ventilatory and cardiac rates, increased hematocrit, increased hemoglobin concentrations, increased plasma phosphate, and decreased concentrations of plasma Ca, Mg, Na and Cl.

5. Investigations on olfactory and gustatory responses in Arctic charr with acid/CO_2 have shown that olfaction depends on ambient pH's, but acid itself does not stimulate; taste receptors are sensitive to acid/CO_2.

Investigations were conducted on fish exposed to experimental acidification in whole-lakes at the ELA. Major findings include:

1. The reproductive capability of adult white suckers seems relatively unaffected by acid when evaluated by plasma estrogen, phosphorprotein, calcium, and egg production in fish from Lakes 223 and 302. Reproduction capability of lake trout from Lake 223 is being evaluated using these parameters.

2. Histological and histochemical assessment of egg development of suckers to evaluate effects of acid stress in lab and ELA have so far not revealed differences between control and acidified lakes. These assessments are being extended to include lake trout.

3. Preliminary analyses show that lake trout from acidified Lake 223 develop elevated Hg in liver and decreased Se in muscle with decreased pH.

Investigations to determine the impact of metal smelter emissions on fish in the natural environment have also been conducted. These studies had the following objectives:

#2.2

1. To assess the contamination of fisheries by mercury and other trace elements emitted to the atmosphere by the metal smelter in Flin Flon, Manitoba, liver and muscle samples from about 300 fish (pike and suckers in 13 lakes) were analyzed for Hg, Se, Zn, Cu, Cd, As and Pb. The fish have been aged using 2 methods. Data are being collated and analyzed.

2. To evaluate the role of the protein, metallothionein, in protecting natural fish stocks from metal toxicity we found that suckers from a metal-contaminated lake near Flin Flon contained 2.2, 2.5, 2.9 and 4.3 times the metallothionein in kidney, liver, intestine and gill, respectively, when compared to suckers from a less contaminated lake. The suckers with elevated metallothionein levels were 2.3 times more resistant to cadmium toxicity.

The level of effort devoted directly to acidification-related research by members of this Project ranged from that of a minor interest to a full-time commitment. All output for is provided to indicate the productivity of the group. However, only those items indicate an asterisk pertain directly to the acidification-related hypotheses described in Section

A. Completed Publications:

Proj. #2.2

1. Published or In Press:

*Brown, S.B., J.G. Eales, R.E. Evans and T.J. Hara. 1983. Interrenal, thyroidal, and carbohydrate responses of rainbow trout (Salmo gairdneri) to environmental acidification. Can. J. Fish. Aquat. Sci. In press.

Donaldson, E.M. and E. Scherer. 1983. Methods to test and assess effects of chemicals on reproduction in fish, p. 365-404. In V.B. Vouk and P.J. Sheehan (eds.) Methods for Assessing the Effects of Chemicals on Reproductive Functions. John Wiley and Sons, Toronto.

*Duncan, D.A. and J.F. Klaverkamp. 1983. Tolerance and resistance to cadmium in white suckers previously exposed to cadmium, mercury, zinc or selenium. Can. J. Fish. Aquat. Sci. 40: 128-138.

Hara, T.J., S.B. Brown and R.E. Evans. 1983. Pollutants and chemoreception in aquatic organisms, p. 247-306. In J.O. Nriagu (ed.) Aquatic Toxicology. John Wiley and Sons, New York.

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Healey, F.P. 1983. Phosphate, p. 105-124. In B.A. Whitton and N.G. Carr (eds.) The Biology of Cyanobacteria. Blackwell Scientific, Oxford.

Healey, F.P. 1983. The effect of temperature and light intensity on the growth rate of Synura sphagnicola. J. Plankton Res. 5: 767-774.

*Kelly, C.A., J.W.M. Rudd, A. Furutani and D.W. Schindler. 1983. Effects of lake acidification on rates of organic matter decomposition in lake sediments. Limnol. Oceanogr. In press.

*Kelly, C.A., J.W.M. Rudd and D.W. Schindler. 1983. Epilimnetic sulfate reduction and its relationship to lake acidification. Limnol. Oceanogr. In press.

*Klaverkamp, J.F., D.A. Hodgins and A. Lutz. 1983. Selenite toxicity and mercury-selenium interactions in juvenile fish. Arch. Environ. Contam. Toxicol. 12: 405-413.

*Klaverkamp, J.F., W.A. Macdonald, W.R. Lillie and A. Lutz. 1983. Joint toxicity of mercury and selenium in salmonid eggs. Arch. Environ. Contam. Toxicol. 12: 415-419.

*Klaverkamp, J.F., W.A. Macdonald, D.A. Duncan and R. Wagemann. 1983. Metallothionein and acclimation to heavy metals in fish - a review. In J.O. Nriagu (ed.) Monitoring Contaminants Effects on Fish. John Wiley and Sons, Inc. Publishers, N.Y. In press.

*Klaverkamp, J.F., M.A. Turner, S.E. Harrison and R.H. Hesslein. 1983. Fates of metal radiotracers added to a whole lake: Accumulation in slimy sculpin and white sucker. Sci. Total Environ. 28: 119-128.

Marui, T., R.E. Evans, B. Zielinski and T.J. Hara. 1983. Gustatory responses of rainbow trout (Salmo gairdneri) palate to amino acids and derivatives. J. Comp. Physiol. In press.

McNicol, R.E., E. Scherer and E.J. Murkin. 1983. Quantitative field investigations of feeding and territorial behavior of young-of-the-year brook charr, Salvelinus fontinalis. J. Environ. Biol. Fish. In press.

Rudd, J.W.M., M.A. Turner, A. Furutani, A.L. Swick and B.E. Townsend. 1983. The English-Wabigoon River system: I. A synthesis of recent research with a view towards mercury amelioration. Can. J. Fish. Aquat. Sci. In press (Dec. issue).

Rudd, J.W.M. and M.A. Turner. 1983. The English-Wabigoon River system: II. Suppression of mercury and selenium bioaccumulation by suspended and bottom sediments. Can. J. Fish. Aquat. Sci. In press (Dec. issue).

Proj # 2.2

Rudd, J.W.M. and M.A. Turner. 1983. The English-Wabigoon River system: V. Mercury and selenium bioaccumulation as a function of aquatic primary production. Can. J. Fish. Aquat. Sci. In press (Dec. issue).

Turner, M.A. and J.W.M. Rudd. 1983. The English-Wabigoon River system: III: Selenium in lake enclosures: its geochemistry, bioaccumulation and ability to reduce mercury bioaccumulation. Can. J. Fish. Aquat. Sci. In press (Dec. issue).

Turner, M.A. and A.L. Swick. 1983. The English-Wabigoon River system: IV. Interaction between mercury and selenium accumulated from waterborne and dietary sources by northern pike (Esox lucius). Can. J. Fish. Aquat. Sci. In press (Dec. issue).

2. Under Review:

*Duncan, D.A. and J.F. Klaverkamp. 1983. Acclimation to cadmium toxicity in white suckers previously exposed to cadmium, mercury or zinc: Metal distribution in liver and gill methallothionein. Can. J. Fish. Aquat. Sci. PRC review.

Evans, R.E. and T.J. Hara. 1983. The characteristics of the electro-olfactogram (EOG): its loss and recovery following olfactory nerve section in rainbow trout (Salmo gairdneri). J. Comp. Physiol. Submitted.

*Furutani, A., J.W.M. Rudd and C.A. Kelly. 1983. A method for the measurement of adaptation of sediment microbial communities to environmental changes. Can. J. Microbiol. Submitted.

*Giles, M.A., H.S. Majewski and B. Hobden. 1983. Cardiovascular and osmoregulatory responses of rainbow trout (Salmo gairdneri) exposed to extended environmental acidification. Can. J. Fish. Aquat. Sci. Submitted.

Healey, F.P. 1983. The interaction of light and nutrient limitation of algal growth. J. Phycology. FHR review.

Hendzel, L.L. and F.P. Healey. 1983. Extraction of algal ATP and interpretation of measurements. Can. J. Fish. Aquat. Sci. Submitted.

*Jones, K.A. and S. Elliott. 1983. A method of quantifying the locomotor behavior of fish. FHR review.

Lawrence, S.G., D.F. Malley, W.J. Findlay and I.L. Delbaere. 1983. Determination of dry weight biomass of zooplankton species by estimation of volume. FHR review.

Leonhard, S.L. and S.G. Lawrence. 1983. Production of ephippial eggs in the absence of males in laboratory cultures of Daphnia magna. FHR review.

*Peterson, H.G., F.P. Healey and R. Wagemann. 1983. Metal toxicity to algae: A highly pH dependent phenomenon. Can. J. Fish. Aquat. Sci. Submitted.

*Rudd, J.W.M. and C.A. Kelly. 1983. Natural microbial mechanisms for recovery of acidified lakes. FHR review.

Scherer, E., R.E. McNicol and E.J. Murkin. 1983. Habitat selection and partitioning by brook charr, Salvelinus fontinalis (Mitchill) in a first-order Manitoba woodland stream. FHR review.

Wagemann, R., R. Hunt and J.F. Klaverkamp. 1983. Subcellular distribution of heavy metals in liver and kidney of a narwhal whale: An evaluation for the presence of metallothionein. Comp. Biochem. Physiol. PRC review.

3. Other:

Rudd, J.W.M., M.A. Turner, A. Furutani, J.F. Klaverkamp, B.E. Townsend and A. Swick. 1983. Factors controlling mercury bioaccumulation in aquatic ecosystesm. In R.J. Allan and T. Brydges (eds.) Mercury Pollution in the Wabigoon-English River System of Northwestern Ontario, and Possible Remedial Measures. In press.

Proj. #2.2

B. Presentations at Meetings:

Healey, F.P. 1983. Algal nutrition. Presented at the Workshop on Prairie Lake Restoration and Manipulation. N.W.R.I., Winnipeg, October 3-6.

Klaverkamp, J.F., W.A. Macdonald, L.J. Wesson and A. Lutz. 1983. Metallothionein and resistance to cadmium toxicity in white suckers impacted by atmospheric emissions from a base-metal smelter. Presented at the 10th Annual Aquatic Toxicity Workshop, Halifax, Nova Scotia, November 7-10.

Kling, H.J. and S.G. Lawrence. Seasonal succession in prairie lakes. Presented at Workshop on Prairie Lake Restoration and Manipulation. N.W.R.I., Winnipeg, October 3-6.

Leonhard, S.L. 1983. Publication of the Freshwater Institute Poster Session. Presente at the Warm Water Aquaculture Symposium, Laie, Hawaii, February.

Leonhard, S.L. and S.G. Lawrence. 1983. A note on the life history of Daphnia culturec in the laboratory to provide stocks for toxicity testing. Presented at the 10th Annual Aquatic Toxicity Workshop, Halifax, N.S., November 7-10.

McNicol, R.E. and E. Scherer. 1983. Field observations on feeding and territorial behaviour of young-of-the-year brook charr, Salvelinus fontinalis. Presented at th Fourth Biennial Conference "Ethology and Behavioral Ecology of Fishes", May 10-12.

C. Theses Supervision:

Five of the scientists in the Project serve as Adjunct Professors in Departments of Biology, Botany, Microbiology or Zoology at the Universities of Manitoba or Winnipeg. Consequently, they supervise graduate students and serve on their examining committees.

Completed theses:

*Awang, G.M. 1983. The effect of low pH on methanogenic fermentation in freshwater sediments. M.Sc. (Supervisor - S.G. Lawrence).

*Loewen, N. 1983. On the acetylene blockage method for measuring rates of bacterial nitrate reduction. M.Sc. (Supervisor - J.W.M. Rudd).

*Ramlal, P. 1983. Measurement of biological mercury methylation in littoral sediments o an acidified and a non-acidified lake. M.Sc. (Supervisor - J.W.M. Rudd).

Completed theses research; writing is in progress:

Guildford, S. On factors affecting phytoplankton growth in South Indian Lake. M.Sc. (Supervisor - F.P. Healey).

Zielinski, B. Differentiation of olfactory receptor neurons in rainbow trout. Ph.D. (Supervisor - T. Hara).

Ongoing theses research:

Brown, S. Acid-aluminum interactions on hypothalamic, thyroid and interrenal systems in fish. Ph.D. (Supervisor - T. Hara).

Sveinsson, T. Determination of specific chemosensory response patterns in fish. M.Sc. (Supervisor - T. Hara).

PROJECT INFORMATION FORM

1. Discipline: Aquatic/Fisheries

2. Project Number: 2.3

3. Agency and Department: Department of Fisheries and Oceans

4. Project Title: National Inventory Survey, NWT

5. Principal Investigator(s) (include addresses):

R. Hecky, FWI

6. Cooperating Agencies and Investigators:

ALUR

7. Project Duration: 1984-85, 1985-86

8. Resources (show PYs, capital and non-salary O&M by year):

	A-base			Acid Rain		
	PY	Cap	O&M	PY	O&M	Cap
1984-85	3	0	0	2	125	15
1985-86	3	0	0	2	125	15

This STUDY IS PROPOSED

9. Service or Agency Objectives:

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.

10. Project Objectives:

Definition of risk to NWT freshwater and anadromous freshwater fishery by acidification. Improved data base of chemical and biological status of NWT fishery.
To characterize NWT lakes and rivers for sensitivity by acid rain impact by chemical and biological survey sampling.
To expand the NIS data base to include NWT Shield lakes and rivers.

Project # 2.3

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Shield drainage basins in eastern Northwest Territories including sensitive areas of the High Arctic.

12. Ecosystem Types Included in Research (where applicable):

Lakes, rivers and their watersheds.

13. Purpose or Hypotheses to be Examined:

Canadian Shield drainage areas in the NWT contain thousands of lakes and rivers with a likely sensitivity to acid rain. Arctic charr and lake trout are the most important commercial, domestic and sporting components of the fishery. At least lake trout is known to be sensitive to acid conditions. The limited number of species at all levels of the food chain may make these systems more fragile than in temperate regions.

In view of the possibility of impact from "arctic haze", transboundary dealings with the Soviet Union and poorly established deposition rates in the NWT, we would like to document the chemical and biological status of the NWT freshwater and andronomous fish habitat to complete the national coverage of the NIS.

14. Study Design/Methodology (include lab and data analyses to be employed):

The survey of NWT watersheds would follow essentially the plan used in other NIS areas to assure compatability of data. Certain measurements or techniques may be changed based on the analyses of previous NIS data completed by ESSA Ltd. The program will consist of four phases:

1. Lakes and rivers will be chosen based on areal distribution, geologic characteristics and fisheries interest. Some information is available for these siting decisions from the Arctic Land Use Reconnnaissance (ALUR) and the Eastern Arctic Pipeline study. These studies provide data on some areas from as early as 1975. The survey will be planned

Project # 2.3

to include as many lakes and rivers as possible which have been studied under these programs. This will allow data checks and possible time trend analyses. The lack of alkalinity and dissolved inorganic carbon measurements in the ALUR data make it impossible to simply use that data for NIS purposes.

2. Chemical survey of NWT watersheds. This will be done by the best methodology derived from previous NIS work and improvements suggested by ESSA Ltd. and recent workshops on acid rain chemistry. All analyses will be done at the Freshwater Institute and samples preserved until all analyses are complete and checked.

3. Biological survey will be sited based on the results of the chemical survey and the information gathered under ALUR and EAPS. The survey will cover phytoplankton, zooplankton, zoobenthos, and fish. Significant changes may be made relative to the present NIS plans based on problems with the data exposed in preliminary investigations by ESSA Ltd.

4. Data reduction and analyses. Data will be added to the NIS data base and interpreted in conjunction with the previous analyses.

Expenditure of funds will not proceed at any stage without the completion of a detailed plan approved by FWI acid rain researchers as well as some of those involved in coordination of previous NIS work.

Project # 2.3

15. Results and Conclusions to Date:

Some data for time trend analyses available from ALUR and EAPS.

Several years chemical and biological data from lakes near Saqvaqjuac (Chesterfield Inlet, NWT). This data suggests an increase in sea salt corrected SO_4 (H.E. Welch, FWI).

16. Anticipated Outputs:

1. Time trend analyses vs previous data.
2. Sensitivity maps and fishery composition analyses for NWT.
3. Analyses of present relationships between chemical components and flora and fauna.
4. Comparison of high latitude regions to temperate ones.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

ONTARIO REGION

PROJECT INFORMATION FORM

1. Discipline: Aquatic 2. Project Number: 3.1

3. Agency and Department: Great Lakes Fisheries Research Branch,
Pacific and Freshwater Fisheries, Ontario Region
Fisheries and Oceans

4. Project Title: Large Scale Risk Assessment

5. Principal Investigator(s) (include addresses):

C. K. Minns - DFO, Burlington
with J. R. M. Kelso - DFO, Sault Ste. Marie
M. G. Johnson - DFO, Owen Sound

6. Cooperating Agencies and Investigators:

Ontario Ministry Natural Resources (G. Beggs, J. Maclean)
Ontario Ministry of Environment (W. Scheider)
Dept. of Environment (F. Elder, M. Thompson)
ESSA Ltd. (M. Jones, D. Marmorek, L. Greig)
Hough Stansbury & Michalski (M. Michalski, E. Hanna)
plus DFO - Regional LRTAP people.

7. Project Duration: 3 yrs. and continuing

8. Resources (show PYs, capital and non-salary O&M by year):

1981-82 50 K + 0.5 PY
1982-83 75 K + 0.5 PY
1983-84 60 K + 0.5 PY (+ 50 K from DSS)

9. Service or Agency Objectives: Protection and Conservation of Canada's Fisheries Resources

10. Project Objectives: To estimate the size of eastern Canada Inland fishery resources by region, fish community in units of #s and areas of lakes and potential yield. To estimate the amount of those resources currently affected by LRTAP. To predict the amount of those resources that might be lost or restored under a variety of future LRTAP regimes.

Project # 3.1

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

All of Canada east of the Manitoba - Ontario border, south of latitude 56.

12. Ecosystem Types Included in Research (where applicable):

Inland lakes and their drainage
Salmon rivers on the Atlantic coast

13. Purpose or Hypotheses to be Examined:

To provide realistic appraisal of the likely impact of various emission control strategies, such that bilateral negotiations aimed at controlling LRTAP can be concluded to Canada's satisfaction.

To apply extensively the results of the various intensive studies.

14. Study Design/Methodology (include lab and data analyses to be employed):

Analysis of regional survey and inventory data on the limnology and fisheries of lakes and rivers in eastern Canada (e.g. National Inventory Survey, OMNR Inventory/Sensitivity file).

Collation of counts and measures by which the size of the resource may be estimated.

Develop, test and apply static and dynamic simulation models of limnology and fish on a large scale (Province or Region).

Assess data and concept uncertainties in models so that:
- confidence intervals on predictions can be estimated; and
- research and data acquisition priorities can be identified.

Methodology is repeated iteratively so that new concepts, results and data can be incorporated in the estimation procedure.

15. Results and Conclusions to Date:

Minns (1981) published a preliminary estimate of the resource at risking Ontario.

Hough Stansbury and Michalski Ltd. completed a project to develop a methodology to predict the impact of LRTAP on sport fisheries in Ontario.
- A dynamic model based on the idea that there was an exhaustable cation reserve in the watershed soils, predicted lake alkalinity and pH.
- Potential fish yield was assumed to be a function of alkalinity.
- This model outlined a general approach, but had severe data and concept problems.

Project # 3.1

ESSA Ltd. conducted an Adaptive Environmental Assessment Workshop on estimating the impact on the fishery resources of eastern Canada.

- A lake alkalinity model was used that assumes that Acid Neutralizing Capacity of a watershed can be back calculated from current alkalinity and acid deposition.
- MEI was used to predict potential yield which was in turn modelled as an input/output process and inputs were affected by threshold pH/Aluminium values.
- This model produced a much stronger conceptual base, but highlighted: i) the lack of strong links between chemistry and fish survival; ii) the inability to predict potential yield; and iii) the lack of basic counts and measures data on lakes.

Regions undertook to obtain necessary counts and measures data.

DFO - OMNR jointly sought to look at watersheds with many lakes for calibration purposes i.e. representativeness of earlier surveys, sources of variability, unbiased sampling. (Mesoscale Watershed Study)

DFO - OMNR actively investigating methods to link lake parameter and measured or estimated fish production or yield.

National Inventory survey data from all regions analyzed to provide a broad overview and to look for interregional differences.

- Basic chemical relationships look the same in all regions.
- Metals like Aluminum show regional variation.
- Fish data is limited.
- Fish contaminant data revealed very little, except the difficulty of getting reliable measures.
- Other biotic survey data (benthos, zooplankton, phytoplankton) provided little insight into the LRTAP problem.
- Useful data (chemistry, fish) for modelling exercises.
- Gives good overview of the extent of LRTAP impact on lake chemistry in eastern Canada.

We have evolved a workable modelling framework by which estimates of impact can be made.

A third modelling excercise is underway with ESSA Ltd., the result of an unsolicited proposal.

There still needs to be a great effort on establishing the fundamental links in the aquatic chain: deposition - watershed - lake - fish - yield - dollars. A shift to a monitoring mode now would leave most of the basic questions unanswered.

Project # 3.1

16. Anticipated Outputs:

Spring 1984

An estimate of the potential impact of different LRTAP regimes on the fishery resources of eastern Canada and an appraisal of the sensitivity of these estimates to the uncertainties identified.

Beyond

Iterative improvements in the confidence of the estimate as new ideas, results and data are made available.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

No overall program direction/organization to ensure that obvious gaps are filled i.e. Freshet chemistry and fish survival/recruitment.

- Lake parameters and fish production.
- Potential vs. actual use of fishery resources.

Lack of basic resource inventory data.

- #s and areas of lakes.
- Fish species presence/absence.
- Less of a problem in Ontario but
- Unbiased surveys.

Interagency connections are too concerned with bureaucracy and not enough with getting together the best case for Canada.

Regional allocation of resources which are at variance with data collection and research priorities.

3.1

ONTARIO REGION DFO LRTAP PROGRAM PUBLICATIONS
(including projects 3.2, 3.3, 3.4)

Collins, R.H., J.R.M. Kelso, J.H. Lipsit and J.E. Moore, 1983. Phytoplankton production, as estimated by the C^{14} technique, and populations contributing to production 1980/81/82 in the Turkey Lakes, Ontario, watershed. Can. Tech. Rep. Fish. Aquat. Sci. No. 1191.

Department of Fisheries and Oceans. 1982. Acid precipitation in eastern Canada: an application of adaptive management to the problem of assessing and predicting impacts on an extensive basis. Results of a DFO modelling workshop. 145p.

Department of Fisheries and Oceans. 1982. An approach to assessing the effects of acid rain on Ontario's inland sport fisheries. Contract report by Hough, Stansbury and Michalski Ltd. 177p.

Dermott, R. 1982. The benthic fauna of poorly buffered lakes displaying a gradient of pH. IN. R.E. Johnson ed. Acid Rain/Fisheries Symp. Amer. Fish. Soc. Aug. 1981. 357p.

Gray, J. Historical water quality changes in Algoma lakes due to acidification. IAGLR 1982.

Gray, J. and J.R.M. Kelso. An examination of historical lake and stream chemistry in north-central Ontario. Can a case be made for acidification? CCFFR 1983.

Gray, J. and J.R.M. Kelso. 1983. An examination of historical lake and stream chemistry in north-central Ontario - can case histories document acidification? Can. Tech. Rep. Fish. Aquat. Sci. in press.

Johnson, M.G. 1982. Acid rain and fisheries - an overview. IN. R.E. Johnson ed. Acid Rain/Fisheries Symp. Amer.Fish. Soc. Aug. 1981. 357 p.

Johnson, M.G. 1981. And no fish swam: Acid rain in Canada. Queens Quarterly. 88:420-428.

Johnson, M.G. and L. Culp. Trends in time of heavy metals in the Turkey Lakes. 1982. IAGLR Conference.

Kelso, J.R.M. and C.K. Minns. 1982. Current status of lake acidification and its effect on the fishery resources of Canada. IN. R.E. Johnson ed. Acid Rain/Fisheries Symp. Amer. Fish. Soc. Aug. 1981. 357p.

Kelso, J.R.M. Symptoms of fish communities in acidic environments. Presented at Univ. Mich. Mar. 1982.

Kelso, J.R.M., R.J. Love, J.H. Lipsit and R. Dermott. 1981. Chemical and biological status of headwater lakes in the Sault Ste. Marie district, Ontario. IN. Proc. of the Conf. on the Effects of Acid Precipitation on Ecological Systems in the Great Lakes Region. F. D'itri ed.

Kelso, J.R.M. and J.M. Gunn. 1982. Additional information on the responses of fish communities to acidic waters in Ontario. Division of Environmental Chemistry, Amer. Chem. Soc., Las Vegas NV. March 1982.

Kelso, J.R.M. and J.M. Gunn. 1983. Responses of fish communities to acidic waters in Ontario. IN. G. Hendrey ed. Symposium Proc. Div. Env. Chem., Amer. Chem. Soc. p.105-115.

Minns, C.K. Assessing the potential impact of acid rain on lake/fish resources in eastern Canada. IAGLR. 1982.

Minns, C.K. 1981. Acid Rain: A preliminary estimate of the risk to Ontario's inland fisheries. Can. Man. Rep. of Fish and Aquatic Sci. No. MS1622.

Oliver, B.G. and J.R.M. Kelso. 1983. A role for sediments in retarding the acidification of headwater lakes. Water, Air and Soil Pollution 20:379-389.

PROJECT INFORMATION FORM

1. **Discipline:** Aquatic/Fisheries

2. **Project Number:** 3.2

3. **Agency and Department:** Department of Fisheries and Oceans

4. **Project Title:** Mesoscale/Monitoring - Mediation effects of a watershed on atmospheric deposition.

5. **Principal Investigator(s) (include addresses):**

Dr. John R.M. Kelso
Great Lakes Fisheries Research Br.
1219 Queen St. E.
Sault Ste. Marie, Ontario

Dr. Murray G. Johnson
Great Lakes Fisheries Research B
1180 20th Street East
Owen Sound, Ontario

6. **Cooperating Agencies and Investigators:** Ontario Ministry of the Environment
Ontario Ministry of Natural Resources

7. **Project Duration:** This is the second year. Presumed duration continuing.

8. **Resources (show PYs, capital and non-salary O&M by year):**

approx.	PY's	O&M	Capital
	3	110	15

9. **Service or Agency Objectives:** To protect fisheries resources threatened by atmospheric pollutants.

10. **Project Objectives:** 1) To test regional models developed by DFO to predict regional impacts upon fisheries.
2) To determine how effects of atmospheric deposition are mediated through a watershed.
3) To determine how these watershed features are reflected in the fishery in terms of community structure and body burdens of selected metals and anthropogenic organics.

Project # 3.2

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

"moderate" sulphate loading (30kg/ha/yr), Canadian Shield, central Ontario

12. Ecosystem Types Included in Research (where applicable):

All terrestrial and aquatic ecosystems within the watershed.

13. Purpose or Hypotheses to be Examined: In most cases models must be confined to the format imposed by available data. This project collects data to suit the model(s) and attempts to address weaknesses of existing models e.g. scaling a subset of lakes to reflect the population of lakes, relating fish community to lake type, determining the watershed contribution of alkalinity and enables an evaluation of the model. Further, data has often been restricted to surveys or intensive observation of few sites. The approach in this study is intermediate loading to predicting regional response.

Special attention is being paid to relating fish community to lake type (to enhance interpolation on a regional scale), characterizing alkalinity export from the terrestrial watershed and adding data that will enhance model prediction.

Further, the 4 watersheds lie in differing deposition areas, on different substrates and support widely differing fisheries enabling contrast of results.

14. Study Design/Methodology (include lab and data analyses to be employed):

- prior to lake sampling, the following lake/watershed characteristics were determined: lake area, lake order, drainage area, bedrock, terrain characteristics and forest type.
- in two watersheds half the lakes were sampled for chemistry and in the other two watersheds all lakes > 1 ha were sampled. Water collection was in the spring and fall.
- a standard lake survey was conducted on approx. 100 lakes from the 4 watersheds to determine fish community structure, catch rates, lake morphometry and chemical stratification.
- chloropyll analysis was conducted on all lakes to enable comparison of productivity.

Project # 3.2

- lake chemical characteristics measured include major ions, colour, DOC, nutrients and 6 trace metals.
- some 2000 whole fish are being examined for body burdens of Cu, Ni, Zn, Pb, As, Se and Hg from the 4 watersheds.
- some 300 fish are being analyzed from 2 watersheds for a spectrum of trace organic contaminants.
- "wet-only" and bulk precipitation collectors have been in place since Sept. 1982.
- approx. 18 terrestrial streams are being monitored for their alkalinity contribution to lakes.
- data is being used to augment the acid-sensitive lake data base maintained by Ontario, to aid in current contracts to determine the estimating capabilities of models and, once completely computerized will serve to test the model developed by DFO in 1982.

Project # 3.2

15. **Results and Conclusions to Date:** The watersheds differ greatly in fish species composition although they all drain from the Canadian Shield into L. Huron. More acidic lakes exist in the Mahzenazing watershed in Killarney Park with fewest in the Rapid R. system (Mississagi R. sub-unit). Deposition differs greatly among the watersheds.

These watersheds are ideally suited to any continued monitoring program that may be put in place by DFO/DOE.

A problem still existing for any regional assessment of fish loss is the prediction of fish yield (stock, production). Good catch data exists for these lakes but our predictive capability is still limited. We suggest this capability should be expanded using the data base developed.

16. **Anticipated Outputs:** primary literature, technical reports, symposia and conferences as appropriate.

17. **Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):**

If this study is to continue, funding must be at the level requested in the Treasury Board request as helicopter and contract costs are high.

The water chemistry analysis produced by OME has a turn-around time 1/3 of that of the DFO/DOE laboratory for LRTAP in Sault Ste. Marie.

PROJECT INFORMATION FORM

1. **Discipline:** Aquatic/Fisheries

2. **Project Number:** 3.3

3. **Agency and Department:** Department of Fisheries & Oceans

4. **Project Title:** Turkey Lakes Calibrated Watershed Study (DFO Contributior

5. **Principal Investigator(s) (include addresses):**

Dr. John R.M. Kelso
Great Lakes Fisheries Research Branch
1219 Queen St. E.
Sault Ste. Marie, Ontario P6A 5M7

6. **Cooperating Agencies and Investigators:** DOE: AES NWRI, NHRI, GLFRC, WSC; OMNR; universities: Laurentian Univ., U. of Quelph, U. of Waterloo. of the above, DFO/GLFRB, DOE/NWRI and DOE/GLFRC are the major contributors.

7. **Project Duration:** Commenced 1980; considered continuing.

8. **Resources (show PYs, capital and non-salary O&M by year):**

DFO only:	PY's	O&M	Capital	
	5.5	110	25	Approximate yearly average

9. **Service or Agency Objectives:** The watershed is being used to determine effects of atmospheric pollutants on the fishery resource and can be used to judge the efficacy of controls once they are in place.

10. **Project Objectives:** To link atmospheric contamination to biological effect; to guage the impact of "moderate" (≈30kg/ha/y) sulphate deposition upon a sensitive aquatic system; to serve as a guage against which deposition can be related to effect. On the part of all agencies, studies are directed toward determining processes as well as describing effects.

Project # 3.3

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

"moderate" sulphate loading (≈30 kg/ha/yr), Canadian Shield, central Ontario

12. Ecosystem Types Included in Research (where applicable):

All terrestrial and aquatic ecosystems within the watershed.

13. Purpose or Hypotheses to be Examined: The watershed is a "clear water" system composed of 4 lakes in a cascading system in a mixed hardwood forest. Terrain is moderately sensitive (silicate bedrock of basaltic composition). The fishery is a salmonid community of predominately brook trout.

The watershed and investigators participating provided an ideal opportunity to examine processes and to develop predictive geochemical and biological models reflecting the range of conditions in the watershed.

A further advantage to this approach is the potential value of long-term monitoring of the effectiveness of negotiated emission reductions. An extensive data base exists.

This approach therefore enables i) developing an understanding of the processes of acidification, ii) constructing the linkage between deposition and biological response, iii) monitoring change-through-time with/without controls as negotiated, and iv) through experimentation in a natural system a determination of the effects of episodic pH/metal alterations upon fish.

14. Study Design/Methodology (include lab and data analyses to be employed):

Basic responsibilities have been assumed by the principal investigating agencies as follows:
DFO - develop an understanding and evaluation of biological production in the watershed and the factors affecting that production. Current effort focus on determining community structure and measuring production at each trophic level. Future efforts will carry on these functions while, with DOE, test process hypotheses developed to explain phenomenon observed in the watershed e.g. episodic influences on fish survival/success.

Project # 3.3

DOE

NWRI - develop an understanding of the processes and mechanisms controlling short and long-term geochemical responses of lakes to atmospheric deposition. This includes the current effort to determine mass balances for the lakes and to describe the rapid changes during episodes of high flow.

GLFRC - develop biogeochemical process models which will predict forest production and water quality from forested catchments. Output from forested catchments serves as an input to aquatic system.

The Turkey Lakes Watershed Steering Committee maintains close scrutiny over scientific direction and progress and is responsible for research coordination.

The GLFRB has carried out mark-recapture experiments on the major fish species of each lake, conducted a capture program for stream resident fish, carried out routine collections of phytoplankton and zooplankton in each lake basin within the watershed and conducted community and biomass information of benthos throughout the lakes and streams of the watershed. These collections and experiments enable us to determine community structure and production for each trophic level within the biological system. Standard, documented assessment and population estimation techniques have been used in each instance.

Fish (age 0 brook trout) have been "corralled" in two headwater lakes from spring melt to early fall to examine survival and uptake of contaminants. Using an onshore static bioassay system, we have conducted a bioassay program using Turkey Lakes water to determine short-term toxicity to brook trout using sulphuric and nitric acids. Since high Pb levels have been found periodically within the watershed we have examined blood Pb levels, enzyme responses and Pb storage in various tissues of fish from 2 lakes in the watershed.

Since acidification may exacerbate water metal levels and some body burdens, we have examined metal concentrations in dated cores to determine metal loadings through time. Fish and selected fish tissues have been examined for trace metals and organics to determine body burdens carried by fish remote from emission sources.

As the history of aquatic systems is of great concern, chironomids have also been examined from dated sediment cores.

Project # 3.3

15. **Results and Conclusions to Date:** Most of the initial community structure and production measures are completed with many papers in press & several published.

Since there are no fish in the headwater lake (lowest pH and alkalinity) but caged fish survive, effort must be devoted to determining if the "no fish" situation results from acidification. Further, since the bioassays indicated that metals play a significant role with DOE, attention must be focused on factors (other than mineral acids) that perturb fisheries. Several approaches have been discussed (DOE-DFO) and could include the acidification of a catchment.

Major activities will therefore shift (but still include) from determining biological status to examining processes.

16. **Anticipated Outputs:** Technical reports, primary literature, symposia as appropriate.

17. **Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):**

1. These studies do not provide quick-fix answers but as per MOI are intensive studies, longer term studies of process and response. As such, resource allocation should be for the long term.
2. Initial expertise (1980-82) in lower trophic levels is no longer available in DFO and must be sought (and bought at times) from other agencies. Resources must be available (PY's or $) for this expertise.
3. Analytical support facilities should be increased in Sault Ste. Marie to shorten turn-around time.

PROJECT INFORMATION FORM

1. **Discipline:** Aquatic/Fisheries

2. **Project Number:** 3.4

3. **Agency and Department:** Department of Fisheries & Oceans

4. **Project Title:** Impact of Atmospheric Pollutants on Georgian Bay.

5. **Principal Investigator(s) (include addresses):**

M. G. Johnson,
Great Lakes Fisheries Research Branch,
Dept. Fisheries & Oceans,
1180 20th Street East, Box 969,
Owen Sound, Ontario.
N4K 6H6

6. **Cooperating Agencies and Investigators:**

Department of Environment (Chemical analyses, provision of precipitation chemistry data, field assistance from NRWI Technical Operations group.

7. **Project Duration:** 1980-1984 Phase I, 1984-1988 Phase II

8. **Resources (show PYs, capital and non-salary O&M by year):** (includes some A base)

1980-81	1.5 PY	35 OM	1982-83	1.5 PY	35 OM
1981-82	1.5 PY	35 OM	1983-84	1.5 PY	58.6 OM 14.0 C

9. **Service or Agency Objectives:**

To determine kind and degree of impact on environmental quality and aquatic resources by atmospheric pollutants by direct or indirect means to a selected area of the St. Lawrence Great Lakes.

10. **Project Objectives:**

1. Examine inputs from rivers and precipitation to bays of major ions, mineral acids, nutrients and heavy metals.
2. Describe and compare bays and inshore Georgian Bay using water and sediment chemistry, benthos, fish.
3. Obtain trend-in-time data on inputs using sediment cores and on ecological changes using fossil chironomids.
4. Assess impairment of habitat, especially as related to LRTAP issue.

Project # 3.4

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

St. Lawrence Great Lakes in Ontario.

12. Ecosystem Types Included in Research (where applicable):

Aquatic (bay and river habitats).

13. Purpose or Hypotheses to be Examined:

1. Do river and bay chemical data show loss of alkalinity, depressed pH, increased heavy metal concentrations as determined by monitoring, modelling (Hendrikson's alkalinity loss)?
2. Do sediment profiles in bays reveal increased metal loadings or other limnological changes?
3. Do chironomid associations in cores indicate ecological changes in bays?
4. Do contemporary benthic macroinvertebrate associations and spatial variations indicate impaired habitat in some bays?
5. Do tissue levels of metals in common fish species (yellow perch, bluntnose minnow or spottail shiner) and molluscs indicate enhanced exposure to heavy metals in some bays?

14. Study Design/Methodology (include lab and data analyses to be employed):

Field

1. Monitoring chemical characteristics of snow pack and river discharge in 1980-83.
2. Helicopter sampling of bay chemistry at times of spring melt in 1980 and 1981
3. Collection of surface sediments and benthos and sediment cores in 1980-83.
4. Collection of selected fish and unionid clams in 1980-83.

Project # 3.4

Laboratory

1. Analyses of snow, river water, bay water samples for major ions, metals, nutrients.
2. Analyses of surface sediments and core slices for ICP parameters plus Hg.
3. Analysis of pollen profiles (Dr. J. McAndrews, ROM).
4. Identification of chironomid head capsules from core slices.
5. Identification of Ekman macroinvertebrates.
6. Analyses of metals in unionid clams and fish.

Interpretation

1. River chemistry at freshet compared with snow chemistry.
2. Hendrikson model applied to river chemistry to estimate alkalinity loss and excess SO_4.
3. Loading rates of metals to bay sediments calculated from mass sedimentation rates and metal concentrations.
4. Bay chemistry at spring freshet compared with river inputs and Georgian Bay chemistry.
5. Bay chemistry compared re. summer vs. spring freshet.
6. Community analysis indices on benthic macroinvertebrates, discriminant analysis on sediment chemistry of bays, and discriminant function analysis to relate sediment and morphometric characteristics of bays to occurence of common benthic macroinvertebrate associations.
7. Heavy metals in biota compared with estimated effects of river drainage on bays.

Project # 3.4

15. Results and Conclusions to Date:

1. almost all rivers examined show very significant alkalinity loss and those rivers draining from the Sudbury area have considerable excess SO_4 as well as elevated metal concentrations.
2. depressed pH's and alkalinities are locally detectable at spring freshet time in bays, e.g. Collins Inlet, Beaverstone, Iroquois, McGregor bays.
3. elevated modern loading rates to sediments are found for Pb, Cd, Zn, Hg.
4. high metal levels were found in surface sediments in most bays, often (> 50%) in excess of "polluted" guidelines for Pb, Cd, Ni, Zn, Cu. Georgian Bay sediments show least metal enrichment.
5. Macroinvertebrates occurred in ten main community types; discriminant function analysis showed strongest influence by loss on ignition, percent silt, alkalinity and lead concentration in sediments.
6. numbers and diversity of chironomids in cores decreased toward the surface of cores.

16. Anticipated Outputs:

Manuscripts which deal with results above, plus

1. patterns in tissue levels of metals in fish and clams in relation to bay limnology.
2. chironomid species community composition through time in bay cores.

Phase II will compare/contrast habitat, especially spawning habitat, of selected walleye and yellow perch populations selected as stressed and unstressed populations. Possible study sites are Iroquois Bay, Collins Inlet - Beaverstone Bay and Shawanaga Inlet (most stressed) and Byng Inlet and Bayfield Inlet (least stressed).

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

1. Funds did not permit use of 210 Pb dating technique; rather, we had to use pollen techniques which are less satisfactory.

QUEBEC REGION

PROJECT INFORMATION FORM

PROJ # 4.1

1. Discipline:

Aquatic environment
Fisheries

2. Project number:

4.1

3. Agency and department:

Department of Fisheries and Oceans

4. Project title:

National inventory of Quebec salmon lakes and rivers

5. Principal investigator(s) (include addresses):

Claude Langlois and Yvan Vigneault
Department of Fisheries and Oceans
Fisheries Research Branch
Champlain Harbour Station
901 Cap Diamant
PO Box 15,500
Quebec City, Quebec
G1K 7Y7

6. Cooperating agencies and investigators:

Gilles Shooner Inc, Quebec City
Le Groupe Dryade, Quebec City
INRS-Eau, Quebec City

7. Project duration:

Start: May 1981
Finish: Indeterminate

8. Resources (show PYs, capital and non-salary O & M by year):

1981/82:	2.0 PY	200K O & M	50K Capital
1982/83:	1.5 PY	225K O & M	50K Capital
1983/84:	1.0 PY	100K O & M	35K Capital

PROJ #4.1

9. Service or agency objectives:

   A. Protect freshwater and anadromous fishes from the effects of acid precipitation;

   B. Ensure that fisheries resources are maintained in perpetuity for the benefit of society and the Canadian economy.

10. Project objectives:

   A. Assess the physico-chemical quality of salmon lakes and rivers located within Quebec;

   B. Acquire basic data on the biology (plankton, benthos, fish) of these waters and assess the effects of water quality on the lacustrine communities.

11. Physiographic region and province(s) in which research is conducted (eg St Lawrence Lowlands, Quebec):

   Laurentians, James Bay lowlands, Abitibi plateau, Mistassini hills.

12. Ecosystem types included in research (where applicable):

   Lakes and rivers.

13. Purpose or hypotheses to be examined:

   Hypotheses to be verified:

   1. The quality of the water in Quebec lakes and rivers is modified by acid precipitation;

   2. The biological communities are affected with respect to composition, structure, reproduction and/or survival by changes in the physico-chemical quality of the water;

   3. The survival and reproduction of fish populations are threatened by acid precipitation.

14. Study design/methodology (include lab and data analyses to be employed:

   A) Lake inventory:

   Physico-chemistry: 1981: 200 headwater lakes
   1982: 172 headwater lakes
   38 2nd level lakes
   17 3rd level lakes
   24 bog lakes

PROJ # 4.1

Physico-chemistry: - Wild lakes, free of all signs of human activity;
- Minimum length, 1 kilometer; minimum depth, 4 metres (except for bog lakes);
- Parameters measured: transparence, temperature, dissolved oxygen, conductivity, pH, true colour, gran alkalinity, total and disolved organic and inorganic carbon, calcium, magnesium, nitrates, sulfates, potassium, sodium, chlorides, aluminum, iron, manganese, cadmium, nickel, zinc, copper, and lead.

Biology: 1981: 38 lakes, uniformly distributed over the study area;
1982: 54 lakes, uniformly distributed over the study area.

Phytoplankton: - 5-metre water column, 3 stations;

Zooplankton: - Wisconsin net (64-μ dia);
- Vertical tow
- Stations

Benthos: - Eckman dredge;
- Transect - 3 stations at 1, 4 and 8 metres;

Sediments: - With Eckman dredge;
- Chemical analysis for metals;

Fish: - Experimental nets, 2 stations;
- Seine, if possible;
- Length, weight, age, sex;
- Fish flesh for chemical analysis.

B) Inventory of salmon rivers:

Physico-chemistry: 1981/82: 24 rivers (Upper and Mid North Shore); monthly sampling;
1982/83: 22 rivers (Upper, Mid and Lower North Shore); bimonthly sampling (once every two months);

The parameters measured will be the same as those for the lake inventory.

Biology: 1983/84: - 2 rivers (Godbout and Sainte-Marguerite)
- Inventory of parr by electrofishing; 10 100-m^2 stations per river;
- Benthos sampling (surbur net);
- Visual observation of spawners;
- Sport fishing statistics from Ministère du Loisir, de la Chasse et de la Pêche.

PROJ #4.1

15. Results and conclusions to date:

The physico-chemistry of the lakes in the Outaouais, Abitibi/James Bay and Mauricie regions is greatly modified by Long-Range Transportation of Airborne Pollutants. While certain effects on the biology are already observable, biological data are not sufficiently abundant to allow us to draw conclusions with regard to the effects of acid precipitation on fish in Quebec. Our priority should be to collect temporal series of biological data in high risk areas. Seasonal pH and alkalinity fluctuations in salmon rivers on the North Shore have proven to be particularly large in spring. This situation, which is directly related to spring thawing, suggests a serious threat to the survival of Atlantic salmon in these rivers. Spring hatching can be considerably disrupted by springtime acid shock. At present, biological data on the salmon populations are insufficient to permit correlation with water quality changes.

16. Anticipated outputs:

The full results of the Quebec National Inventory will be published in a series of technical reports:

1. Langlois, C, Y Vigneault, L Désilets, A Nadeau et M Lachance. 1983. Evaluation des effets de l'acidification sur la physico-chimie et la biologie des lacs du bouclier canadien (Québec). Rapp tech can sci halieut aquat No : xii - 129 p. (gone to press)

2. Langlois, C, A Lemay, J Ouzilleau et Y Vigneault. 1984. Qualité physico-chimique de 251 lacs du bouclier canadien (Québec). Rapp tech sci halieut aquat No vii - 65 p. (in preparation)

3. Nadeau, A, C Desjardins, et Y Vigneault. 1983. Teneurs en métaux et en ions majeurs des chairs de poissons de trente-deux lacs du Québec. Rapp man can sci halieut aquat No vii - 50 p. (gone to press)

17. Identify problems encountered (eg funding limitations, unexpected constraints, jurisdictional, data availability, etc):

The most serious problem we have encountered is related to the fisheries jurisdictional dispute that has been going on between Ottawa and Quebec City for the last two years. In 1983, we experienced major difficulties in obtaining a permit from the Ministère du Loisir, de la Chasse et de la Pêche du Québec to fish for scientific purposes in the lakes and rivers selected.

PROJECT INFORMATION FORM

PROJ #4.2

1. Discipline:

Aquatic environment
Fisheries

2. Project number:

4.2

3. Agency and department:

Department of Fisheries and Oceans

4. Project title:

4.1 Fish inventory of Lac Laflamme

4.2 Exploratory study of the Arctic char habitat

5. Principal investigator(s) (include addresses):

5.1 Mr Ghislain Verreault
Mr Claude Langlois
Fisheries and Oceans

5.2 Mr Roger Lejeune
Mr Bruno P Harvey
Mr Yvan Vigneault
Fisheries and Oceans

6. Cooperating agencies and investigators:

6.1 Environment Canada
6.2 Nil

7. Project duration:

7.1 Start: August 1982
Finish: December 1983

7.2 Start: May 1983
Finish: Indeterminate

8. Resources (show PYs, capital and non-salary O & M by year):

8.1	1982/83:	0.1 PY	10K O & M	8.2	1983/84:	0.2 PY	25K O & M
	1983/84:	0.1 PY	13K O & M		1984/85:	-	-

PROJ 4.2

9. Service or agency objectives:

A. Protect freshwater and anadromous fishes from the effects of acid precipitation;

B. Ensure that fisheries resources are maintained in perpetuity for the benefit of society and the Canadian economy.

10. Project objectives:

10.1 Acquire basic data on the main characteristics of the brook trout population in Lac Laflamme: reproduction, fecundity, dynamics, growth rate, age structures, etc.

10.2 Acquire basic data on the distribution of Arctic char in southern Quebec as it relates to acid precipitation.

11. Physiographic region and province(s) in which research is conducted (eg St Lawrence Lowlands, Quebec):

11.1 Laurentians

11.2 Laurentians, Appalachians (Notre Dame Mountains)

12. Ecosystem types included in research (where applicable):

Lakes

13. Purpose or hypotheses to be examined:

13.1 Under the joint study (Environment Canada, Fisheries and Oceans, Laval University, and INRS-Eau) conducted in the Lac Laflamme experimental drainage basin, the Department of Fisheries and Oceans is mandated to study the lake's ichthyological fauna. Lac Laflamme, located in the Parc des Laurentides, has been selected for study of the effect of atmospheric pollutants on the boreal forest aquatic ecosystem.

13.2 Arctic char (Salvelinus alpinus) has a fairly unusual distribution in Quebec. The species is particularly abundant in New Quebec, but a number of endemic populations are present on the North Shore and in the Gaspé, the Outaouais, and the Parc des Laurentides. Continuation of the project in 1984/85 on other lakes and in New Quebec would make it possible to more accurately determine the current distribution of Arctic char stocks and attempt to determine the extent of their resistance to acidification.

14. Study design/methodology (include lab and data analyses to be employed):

14.1 A) Study of fecundity and reproduction (fall 1982):

- location of spawning grounds;
- study of behaviour of spawners;
- counting of spawners; extent of activity in spawning grounds;
- identification of spawning site substrate;
- capture of spawners;
- measurement of total and fork length;
- measurement of total weight and gonad weight;
- identification of sex;
- assessment of gonad maturation;
- collection of gonads for fecundity measurement;
- collection of otoliths for age determination.

B) Study of population dynamics and structure (summer 1983):

- capture-tagging-recapture;
- measurement of length, weight, scale age;
- selection of mathematical models (Peterson, Chapman, Bailey, Schnabel) for calculation of the following parameters: growth rate, mortality rate, survival rate by age group, condition factor, growth, population age structure.

14.2 During the summer of 1983, 12 lakes were selected in four regions of Quebec: Gaspé, North Shore, Outaouais, and Laurentians. A physico-chemical and biological inventory was carried out on the lakes selected. The biological communities (fish, plankton, benthos) were studied in relation to the physico-chemistry of the waters.

15. Results and conclusions to date:

15.1 More than 150 nests were observed in the lake's two major spawning sites; the total number of fish is in the order of 2,000. High mortality involving 400 to 500 adults in the spring of 1981 resulted in a considerable drop in observable recruitment of age 1 individuals in 1983.

15.2 The lakes were selected on the basis of presumed presence of Arctic char. They proved to be little affected by acidification, and it would appear that the deep lakes inhabited by Arctic char are better buffered against acidification. Char were captured in only seven of the 12 lakes selected.

16. Anticipated outputs:

The results of these studies will be published in technical reports which are currently in preparation.

PROJ #4.2

7. Identify problems encountered (eg funding limitations, unexpected constraints, jurisdictional, data availability, etc):

17.1 No problems encountered.

17.2 We experienced major difficulties in obtaining scientific fishing permits from the Ministère du Loisir, de la Chasse et de la Pêche du Québec. These difficulties would appear to be due to the fisheries jurisdictional dispute between Ottawa and Quebec City that has continued over the last two years.

PROJECT INFORMATION FORM

PROJ # 4.3

1. Discipline:

Aquatic environment

2. Project number:

4.3

3. Agency and department:

Department of Fisheries and Oceans

4. Project title:

Development of a prediction model based on the relationship between hydrobiological factors associated with a drainage sub-basin and the survival of Atlantic salmon (Unsolicited proposal)

5. Principal investigator(s) (include addresses):

Gilles Shooner Inc
40, rue Racine
Loretteville, Quebec
G2B 1C6

Delegated scientific officer: Mr Yvan Vigneault
Fisheries and Oceans

6. Cooperating agencies and investigators:

Eco-Recherche Inc, Pointe-Claire
Bio-Conseil Inc, Quebec City
INRS-Eau, Quebec City

7. Project duration:

Start: March 1982
Finish: March 1985 (?)

8. Resources (show PYs, capital and non-salary O & M by year):

1981/82:	0 PY	6K O & M
1982/83:	0.1 PY	33K O & M
1983/84:	0.2 PY	100K O & M
1984/85:	0.2 PY	70K O & M

Proj #4.3

9. Service or agency objectives:

   A. Protect freshwater and anadromous fishes from the effects of acid precipitation;

   B. Ensure that fisheries resources are maintained in perpetuity for the benefit of society and the Canadian economy.

10. Project objectives:

   A. Assess the tolerance for acid deposition of a salmon river drainage basin on the North Shore;

   B. Assess the impact of acidification on Atlantic salmon spawning sites;

   C. Develop a prediction model relating Atlantic salmon survival to acid precipitation.

11. Physiographic region and province(s) in which research is conducted (eg St Lawrence Lowlands, Quebec):

   Laurentians (Upper North Shore)

12. Ecosystem types included in research (where applicable):

   River, coniferous forest

13. Purpose or hypotheses to be examined:

   Hypotheses to be verified:

   1. Springtime increase in river acidity is due to acid precipitation;

   2. The ability to buffer acid deposition in the rivers of the North Shore is very limited and this limitation threatens the long-term survival of Atlantic salmon.

   3. Large temporal variations in water quantity in spawning sites could be the direct cause of egg and fry mortality.

14. Study design/methodology (include lab and data analyses to be employed:

   A. Study of precipitation:

   - quantity and physico-chemical quality of inputs over basin;
   - quantity and physico-chemical quality of inputs under forest cover;
   - quantity and quality of ground snow.

PROJ # 4.3

B. Study of receiving water

- basin physiography (maps);
- meteorology (snow gauge, recording rain gauge, thermograph);
- surface hydrology (water level station);
- underground hydrology (lysimeter);
- soils (leaching at various pH's);
- vegetation (inventory);
- geology (inventory).

C. Physico-chemical quality of surface waters:

- longitudinal profile on Rivière Cassette (tributary of Rivière des Escoumins)
  - seasonal sampling at six stations;
- temporal evolution on Rivière Cassette
  - weekly sampling at one station (spring: 3 times a week)
- Rivière des Escoumins: monthly sampling at one station (semimonthly in March, April, and May).

D. Salmon egg bio-accumulation and mortality:

- incubation on-site: 20,000 eggs in hatchery troughs
  4,500 eggs in Vibert boxes
- monthly observation of mortality rate (weekly observation from March to June);
- determination of metal and major ion accumulation in eggs, at same intervals.

E. Dynamics of Al and Mn transfer in salmon eggs:

- laboratory exposure of eggs to different pH, Al and Mn conditions for a two-week period;
- experiments with the three following stages: green eggs, eyed eggs, and sac fry.

F. Assessment of basin tolerance and the relative importance of the various biotic and abiotic components:

- calculation of transfers and balance;
- stochastic modelling.

G. Assessment of salmon tolerance by means of an ecotoxicological approach:

- comparative extrapolation based on preceding calculations and data available in Nova Scotia and Scandinavia.

15. Results and conclusions to date:

A study conducted over the spring of 1982 has made it possible to more clearly ascertain the influence of springtime hydrometeorological conditions on daily variations in the

PROJ #4.3

physico-chemical quality of waters in the sector upstream of the Rivière des Escoumins. During March and April 1982, surface water samples were taken on a daily basis at three stations located on tributaries with small drainage areas. Statistical analysis of the interrelationships between the stations for the chemical parameters measured (including sulfates, alkalinity, pH, and aluminum) showed that the spring thaw phenomenon is apparent at all stations, although to differing degrees. Stations on the main section of the river showed similar behaviour, while the tributaries with small drainage basins were subject to much greater water quality fluctuations. Moreover, the specific conditions which were prevalent in the small tributaries are difficult to extrapolate from the information collected in the main section of the same water course since they are much more closely related to events of an episodic nature associated with snow thawing. Some of the conditions observed, including fluctuations in pH, alkalinity, and aluminum, suggest a potential risk, on a more or less long-term basis, for salmonids, particularly in tributaries with small drainage areas.

16. Anticipated outputs:

The study results will be published in the form of technical reports. The following articles have already been published:

Brouard, D, M Lachance, C Langlois. 1983. Qualité physico-chimique printanière des eaux de surface et des précipitations au secteur amont de la rivière des Escoumins. Can Tech Rep Fish Aquat Sci No 1228, vii - 39 p.

Van Coillie, R, D Brouard, M Lachance et Y Vigneault. 1982. Effets physico-chimiques des précipitations acides sur quatre rivières à saumons. Eau du Québec, Vol 15, No 4, pp 384-393.

Brouard, D, M Lachance, G Shooner et R van Coillie. 1982. Sensibilité à l'acidification de quatre rivières à saumons de la Côte-Nord du Saint-Laurent (Québec). Rapp techn can sci halieut aquat No 1109F, v - 56 pp.

Lachance, M, D Brouard, R van Coillie et JD Dutil. 1982. Physico-chimie des eaux de la rivière Sainte-Marguerite en période de fonte. Submitted for publication in Water Pollution Research Journal of Canada.

17. Identify problems encountered (eg funding limitations, unexpected constraints, jurisdictional, data availability, etc):

This project is the result of an unsolicited proposal submitted by Gilles Shooner Inc. The funds allocated for the study by the Department of Supply and Services are limited to 1983/84. Although the project is scheduled to run until March 1985, the financial restrictions threaten its survival in 1984/85.

PROJECT INFORMATION FORM

PROJ #4.4

1. Discipline:

Aquatic environment
Fisheries

2. Project number:

4.4

3. Agency and department:

Department of Fisheries and Oceans (DFO)
Environment Canada/Canadian Wildlife Service (CWS)

4. Project title:

Development of a model based on planktonic organisms to describe the effects of certain environmental factors on trophic relations in Quebec lakes (Unsolicited proposal)

5. Principal investigator(s) (include addresses):

Dr Gregory F Pope
IEC BEAK Consultants Ltd
400-3333 Cavendish Boulevard
Montreal, Quebec
H4B 2M5

Delegated scientific officer: Mr Claude Langlois
Fisheries and Oceans

6. Cooperating agencies and investigators:

Nil

7. Project duration:

Start: May 1983
Finish: July 1984

8. Resources (show PYs, capital and non-salary O & M by year):

1983/84:	0.4 PY	175K O & M
1984/85:	0.1 PY	25K O & M

PROJ #4.4

9. Service or agency objectives:

A. Protect freshwater and anadromous fishes from the effects of acid precipitation;

B. Ensure that fisheries resources are maintained in perpetuity for the benefit of society and the Canadian economy.

10. Project objectives:

A. Assess the effect of acid precipitation on trophic relations in Quebec lakes;

B. Develop a model based on planktonic organisms for assessing the degree of lake acidification;

C. Identify the indirect effects of acidification on fish.

11. Physiographic region and province(s) in which research is conducted (eg St Lawrence Lowlands, Quebec):

Laurentians, Caniapiscau plateau, and Labrador trough

12. Ecosystem types included in research (where applicable):

Lakes and ponds

13. Purpose or hypotheses to be examined:

Hypotheses to be verified:

1. Lake acidification modifies the structure and composition of the lacustrine communities.

2. The changes in the lacustrine communities are due as much to disruption of trophic relations as to the direct toxicity of acidity.

3. Adverse physico-chemical conditions can indirectly affect fish by modifying predator/prey relationships.

4. The communities living in acid lakes are similar to those living in fishless non-acid lakes.

14. Study design/methodology (include lab and data analyses to be employed:

Phase 1: Model development

a) Bibliographical review of predator/prey models;

b) Review of the effects of acid precipitation on aquatic environments;

Proj #4.4

c) Preparation of models for:

- oligotrophization (pH 6.0 to 5.4)
- fish extinction (pH 5.4 to 4.5)
- sterilization (pH 4.5 to 3.0)

Phase II: Field inventory:

a) - 50 lakes: single visit during the summer of 1983 (Outaouais, Sept-Iles, Gagnon, Shefferville);

- 8 lakes: three visits during the summer of 1983 (Outaouais);

- physico-chemistry of the lakes selected was known (1981 or 1982 DFO or CWS inventories);

- lakes of several categories:
  - deep or shallow;
  - headwater or lower level;
  - acid or non-acid;
  - in area of light or heavy atmospheric acid deposition;

b) phytoplankton: 5-metre water column; 3 stations;

c) zooplankton: Wisconsin net; vertical tow; 3 stations;

d) benthos: Eckman or Ponar dredge; 2 transects at three depths each (1, 4 and 8 metres); epibenthos by suction-dome sampler, benthos net (non-quantitative);

e) fish: 2 gill nets in series at 2 stations on the lake; 2 minnow traps; electrofishing and seine;

f) physico-chemistry:
- pH, temperature and O_2 for all lakes;
- all usual parameters (major ions and metals, cations, etc) for the 8 lakes visited 3 times.

Phase III - Application of models for Quebec

- Identification of indicator species;

- Identification of diagnostic factors.

15. Results and conclusions to date:

The pH of the lakes sampled ranges from 3.0 to 8.5. A total of 17 lakes were fishless, and most of them had a pH $<$ 6.0. Annual and seasonal variability of lake pH is very high, while alkalinity and sulfates are much more stable; this temporal variability likely has an influence on the composition and structure of the planktonic communities. Among the factors that control the diversity of fish in Quebec lakes, acidification, biogeographical isolation, winterkill, and habitat diversity should be noted. According to some predator/prey models (Zaret, 1980), the abundance of cladocera, which are very sensitive to acid precipitation, is conditioned by and at the same time conditions the abundance of fish and copepods in lakes.

PROJ #4.4

6. Anticipated outputs:

A preliminary report will be available in June 1984.

7. Identify problems encountered (eg funding limitations, unexpected constraints, jurisdictional, data availability, etc):

No specific problems have been encountered to date.

PROJECT INFORMATION FORM

PROJ # 4.5

1. Discipline:

Aquatic environment
Fisheries

2. Project number:

4.5

3. Agency and department:

Department of Fisheries and Oceans

4. Project title:

Study of the influence of acidification on egg mortality in brook trout (Salvelinus fontinalis) (Unsolicited proposal)

5. Principal investigator(s) (include addresses):

Mr Jacques Leclerc
Bio-Conseil Inc
105 Côte de la Montagne
Suite 501
Quebec City, Quebec
G1K 4E4

Delegated scientific officer: Mr Claude Langlois
Fisheries and Oceans

6. Cooperating agencies and investigators:

Ministère du Loisir, de la Chasse et de la Pêche du Québec

7. Project duration:

Start: September 1981
Finish: September 1983

8. Resources (show PYs, capital and non-salary O & M by year):

1981/82:	0 PY	30K O & M
1982/83:	0.2 PY	55K O & M
1983/84:	0.2 PY	12K O & M

PROJ #4.5

9. Service or agency objectives:

A. Protect freshwater and anadromous fishes from the effects of acid precipitation;

B. Ensure that fisheries resources are maintained in perpetuity for the benefit of society and the Canadian economy.

10. Project objectives:

A. Assess the effect of acid precipitation on water quality in brook trout spawning sites;

B. Assess the effect of temporal variations in water physico-chemistry on the survival of brook trout eggs;

C. Assess the susceptibility of the species at different development stages.

11. Physiographic region and province(s) in which research is conducted (eg St Lawrence Lowlands, Quebec):

Laurentians (Portneuf and Charlevoix)

12. Ecosystem types included in research (where applicable):

Lakes

13. Purpose or hypotheses to be examined:

Hypotheses to be verified:

1. Atmospheric acid deposition modifies the physico-chemical composition of water in brook trout spawning sites in Quebec.

2. Deterioration of water quality in spawning sites can result in increased egg mortality rates or development or growth anomalies.

3. The major impact of acid deposition is felt in the spring thaw period when the eggs are hatching.

14. Study design/methodology (include lab and data analyses to be employed:

Eggs were incubated in Whitlock-Vilbert boxes in natural brook trout spawning sites. The experimental sites are characterized by surface water having a summer pH of less than 5.00 (alkalinity < 20 μeq/l), while surface water summer pH in the control sites is greater than 6.00 (alkalinity > 80 μeq/l). The egg mortality rate was recorded throughout the incubation period (September to April), and surface water physico-chemical analyses were conducted concurrently.

PROJ #4.5

The first part of the study was conducted in 1981-1982 in the Portneuf reserve. Results showed a relationship between pH and (1) the concentration of the sum of heavy metals (Fe, Cu, Zn, Pb, Ni, and Mn) and (2) the egg mortality rate. The second part of the study was conducted in 1982-1983 in cooperation with the Ministère du Loisir, de la Chasse et de la Pêche in the ZEC des Martres. By determination of malate dehydrogenase and total proteins in the dead eggs, it was possible to estimate the approximate date of mortality (1 week) within monthly observation periods.

In addition, isoelectric focusing of membrane and cytoplasmic proteins made it possible to detect intracellular differences between eggs and fry subjected to acid conditions and those incubated in control environments. Tissue concentrations of Na and Cl ions and metals (Al, Fe, Cd, Cu, and Zn) were measured in eggs from acid sites and control sites.

15. Results and conclusions to date:

Abiotic egg mortality (when biotic egg mortality due to saprolegniales is eliminated) is about 15% in control sites but rises to 100% in acid sites. From nearly zero during the embryonic stages, the mortality rate rises to 30% at the start of incubation and reaches 100% at the time of hatching for pH 4.8. Development takes place more rapidly at pH 6.8 than at pH 4.8. Tissue sodium concentration is lower in acid sites than in control sites, while copper concentration is clearly higher in acid sites at the time of hatching. Abiotic mortality in acid sites would appear to be mainly due to hydrogen ions.

16. Anticipated outputs:

The results of the study are contained in:

Leclerc, J, Y Chagnon, P Dulude et C Langlois. 1984. Influence de l'acidification sur la survie et le développement des oeufs et des alevins vésiculés d'omble de fontaine au Québec. Rapp techn can sci halieut aquat No (in preparation).

17. Identify problems encountered (eg funding limitations, unexpected constraints, jurisdictional, data availability, etc):

The problems encountered in connection with this study were mainly technical in nature:

A. Infinite precautions required during handling of eggs;

B. Difficulty in harvesting Vibert boxes under the ice in winter.

PROJECT INFORMATION FORM

PROJ #4.6

1. Discipline:

Aquatic environment
Fisheries

2. Project number:

4.6

3. Agency and department:

Department of Fisheries and Oceans

4. Project title:

Aluminum ecotoxicology for Atlantic salmon and brook trout

5. Principal investigator(s) (include addresses):

Dr Raymond VanCoillie
Eco-Recherche Inc
121 Hymus Boulevard
Pointe-Claire, Quebec
H2R 1E6

Delegated scientific officer: Mr Yvan Vigneault
Fisheries and Oceans

6. Cooperating agencies and investigators:

INRS-Eau, Quebec City

7. Project duration:

Start: August 1981
Finish: October 1983

8. Resources (show PYs, capital and non-salary O & M by year):

1981/82:	0 PY	65K O & M
1982/83:	0.2 PY	35K O & M
1983/84:	0.2 PY	2K O & M

PROJ #4.6

9. Service or agency objectives:

   A. Protect freshwater and anadromous fishes from the effects of acid precipitation;

   B. Ensure that fisheries resources are maintained in perpetuity for the benefit of society and the Canadian economy.

10. Project objectives:

   A. Determine the lethal concentrations of aluminum at different pH's for salmon and brook trout;

   B. Determine the sub-lethal concentrations of aluminum which can affect the behaviour of the species;

   C. Study the toxicity of the different aluminum species and the influence of humic acids.

11. Physiographic region and province(s) in which research is conducted (eg St Lawrence Lowlands, Quebec):

   Laurentians (North Shore)

12. Ecosystem types included in research (where applicable):

   Rivers

13. Purpose or hypotheses to be examined:

   Hypotheses to be verified:

   1. Aluminum toxicity for fish varies according to pH and water hardness;

   2. Atlantic salmon and brook trout do not have the same tolerance for high aluminum concentrations;

   3. The different aluminum species present in the water influence toxicity for fish.

14. Study design/methodology (include lab and data analyses to be employed:

   The study was conducted entirely in the laboratory. The researchers used deionized water to which were added major cations (Ca, Mg, Na, K) and inorganic aluminum ($Al(OH_3)$ or $AlPO_4$) or organic aluminum, as called for by the tests. For each solution that was prepared, the following parameters were controlled and analysed: pH, alkalinity, hardness, conductivity, sulfates, nitrates, chlorides, and total or organic aluminum.

PROJ #4.6

Test 1: Lethal toxicity

Age 1 salmon and brook trout are compared for sensitivity by subjecting them in turn to 7-day dynamic (continuous flow) tests performed in duplicate (five concentrations and one control) for different concentrations of organic and inorganic aluminum at pH's of 4.5 or 5.5 and alkalinities of 10-13 mg/l or 30-35 mg/l. These bioassays are conducted in 30-l polypropylene basins with a minimum of 10 organisms per basin. Solution renewal is carried out by means of proportional diluters.

Test 2: Sub-lethal effect

The test setup consists of two cylindrical 30-l polypropylene basins linked by 7.5-cm openings at their bases. Water flow is unidirectional and aluminum is added on the target side at the level of the central tube. Ten trout, age 2, are placed in the system. After a pre-adaptation period, the number of fish in each basin (one with aluminum, the other without) is counted every 15 seconds. Means are then calculated.

Test 3: Preference test

With the above test setup, the distribution of specimens in the two basins will be observed under different physico-chemical conditions (Al, pH and alkalinity).

Aluminum species

Using the method developed by Campbell et al (1982*), we determined total Al, total dissolved Al, dissolved non-labile Al, dissolved labile Al, and particulate Al in water samples taken during the bioassays mentioned above.

* Campbell, PGC, Bisson, M, Boivert, J, Bougie, R, Tessier, A, et Villeneuve, JP. 1982. Méthodologie analytique pour déterminer la spéciation de l'aluminium dans les eaux lacustres en voie d'acidification. Rapport scientifique INRS-Eau (Institut national de la recherche scientifique), Université du Québec, pour Environnement Canada, No 145: 113 p - annexes.

5. Results and conclusions to date:

Aluminum has proven to be clearly more toxic for Atlantic salmon than for brook trout. For Atlantic salmon, it is more deadly at pH 4.6 than at pH 5.5, but the opposite is true for brook trout. In very soft water, the toxic effect of aluminum in enhanced. In the presence of organic matter, the lethal toxicity of aluminum is considerably attenuated. For total concentrations below 300 µg/l, the aluminum is almost totallly dissolved at pH's of 4.6 and 5.5 and most of it is in labile, and likely bio-exchangeable, form.

PROJ # 4.6

16. Anticipated outputs:

The results of this study are to be published as follows:

Van Coillie, R, C Thellen, PGC Campbell et Y Vigneault. 1983. Effets toxiques de l'aluminium chez les salmonidés en relation avec des conditions physico-chimiques acides. Rapp techn can sci halieut et aquat no ix - 84 p. (gone to press)

Van Coillie, R, D Brouard, M Lachance et G Shooner. 1982. Possibilités écotoxicologiques des précipitations acides pour le saumon dans quatre rivières de la Côte-Nord du St-Laurent. Submitted for publication in Eau du Québec.

17. Identify problems encountered (eg funding limitations, unexpected constraints, jurisdictional, data availability, etc):

The major problems encountered were technical in nature:

- difficulty in maintaining conditions stable for synthetic water employed (pH, Al, etc);

- difficulty in obtaining natural organic matter in order to test synergy between Al and humic matter.

SCOTIA-FUNDY REGION

PROJECT INFORMATION FORM

1. Discipline: Aquatic/Fisheries 2. Project Number: 5.1

3. Agency and Department: Department of Fisheries and Oceans, Fisheries Research Branch, Scotia-Fundy Region

4. Project Title: Westfield River Project: I. Long-term monitoring of Atlantic salmon populations, other fisheries resources and aquatic systems.

5. Principal Investigator(s) (include addresses):

Dr. Gilles L. Lacroix
Fisheries and Environmental Sciences
Department of Fisheries and Oceans,
Biological Station, St. Andrews, N.B.
EOG 2X0

6. Cooperating Agencies and Investigators:

Contracting agencies as required

7. Project Duration: 1982-83 to 1988-89

8. Resources (show PYs, capital and non-salary O&M by year):

	PYs	$K Capital	$K O&M
1982-83	1.0	30.0	80.0
1983-84	1.0	5.0	100.0

9. Service or Agency Objectives:

To document damage to the well-being of fisheries resources caused by acid precipitation and related pollutants and to protect freshwater and anadromous fisheries resources being threatened and ensure their long-term maintenance.

10. Project Objectives:

To monitor the effects of continued acid inputs from precipitation (or a decrease thereof) on the chemistry of coloured, humic waters and the resulting effects on freshwater and anadromous fisheries resources, particularly Atlantic salmon.

Project # 5.1

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Atlantic drainage systems, headwaters, southwest Nova Scotia

12. Ecosystem Types Included in Research (where applicable):

Coastal rivers and tributary streams subject to bog drainage; Coloured, humic waters.

13. Purpose or Hypotheses to be Examined:

A. Estimate numbers of migrating and resident fishes in the Westfield River to assess escapement, reproductive success and productivity as influenced by stream acidity and to generate data for evaluating the contribution by the different fish species to and export from the nutrient base within the stream ecosystem, hence the significance of the potential change to key ecosystem functions.

B. Continue monitoring precipitation and stream water chemistry in the Westfield drainage and in other streams where comparative studies are underway in support of the studies of fish populations and, construct and compare annual nutrient and major ion mass balances in three sub-drainage areas of the Westfield basin both to assess the responses of water chemistry to precipitation and to evaluate changes in fisheries resources and ecosystem processes.

14. Study Design/Methodology (include lab and data analyses to be employed):

A. A fish counting fence allowing for capture of upstream and downstream migrants will be operated on the Westfield River as in 1982 and 1983 during the ice-free period (April-December) for the duration of the project. This will allow for continued monitoring of the status of anadromous fish populations which use the Westfield River and its headwater tributaries for spawning and as nursery areas. All species captured at the fence are counted, measured, weighed, aged, and sexed (when possible) and both Atlantic salmon adults and smolts are tagged. These data will provide accurate annual estimates of the numbers of spawners and, using fecundity data appropriate for these stocks, of potential egg deposition by Atlantic salmon and alewives. The production of salmon smolts and juvenile alewives will also be determined from data obtained at the counting

fence and hence, the reproductive success of these anadromous species.

The counting fence will also provide information on freshwater fish species residing in the Westfield system and on their movements (e.g., white sucker, brook trout, yellow perch, brown bullhead and creek chub). The production of American eel in the system will also be determined; an eel weir will be used to monitor downstream movements of adult eels in the Westfield River since the counting fence is inadequate to assess eel movements.

The densities and other parameters of juvenile Atlantic salmon and resident freshwater fishes will continue to be estimated as during 1983-84 in three areas of the Westfield River(pH<5.0), in a more acidic tributary (pH<4.7) of the Westfield and in a less acidic nearby river (pH>6.0). Population density estimates for all species of fish will be conducted using electrofishing gear by the removal method (calculations based on catch-depletion data) in areas of 500+ m^2 enclosed with stop-nets at each site on seven occasions annually (February, April, June, July, August, October, December). All fish are to be measured, weighed, aged, sexed (when possible), branded and returned alive to the stream after each estimate. The rates of disappearance (mortality + emigration), growth rates, biomass and production are to be calculated for each age-class and species for each interval and for the year. These estimates will be compared in relation to physical and chemical characteristics at each study site.

In addition, general electrofishing surveys in streams and trap netting surveys in lakes of the Westfield drainage are to be conducted during period of annual pH minima and maxima in these waters to determine species distribution in the system, the importance of temporal and spatial variations in water chemistry on this distribution and the potential utilization of refuge areas. Fish movements to a known possible refuge area (a small lake of pH>6.0 joined by a thoroughfare to the main lake of pH<5.0 at the head of the Westfield River) will be examined in future years by operating a fish counting fence in the thoroughfare.

B. Permanent discharge gauging stations on the Westfield River and its two main tributaries and three precipitation gauges (propane-heated tipping bucket type with recorders) are located in the Westfield drainage area and will continue to be operated as in 1982 and 1983. Weekly monitoring of stream-water chemistry of the Westfield and the two tributaries will also be continued with more frequent sampling during the study of specific precipitation episodes. Precipitation, which in the past was collected weekly, will be collected on an event basis using two automated wet precipitation collectors starting in 1984. Samples are to be analyzed for the following parameters: pH, conductivity, dissolved organic carbon (<0.45 µm), total phosphate (Stannous Chloride Method), ammonium (Phenate Method), nitrate-nitrite (Cadmium Reduction), metals (Na, K, Ca and Mg, using Perkin-Elmer 403 A.A.S.), chloride (Mercuric Nitrate Titration Method), alkalinity (Gran Titration Method), acidity (Electrometric Titration Method), and heavy metals (total extractable Al and Fe). Sulphate will be analyzed using an Ion Chromatograph starting in 1984 because of problems encountered during previous years when using the turbidimetric and colourimetric methods in coloured, humic waters.

Annual balances between inputs from precipitation and outputs in stream flow will be calculated and compared for the three sub-drainage areas of the Westfield basin; A first-order stream draining bog areas, a record-order stream draining two small lakes, and a third-order stream draining seven lakes and including the other two

#5.1

sub-drainage areas. Such comparisons will better define the natural and anthropogenic components of acidity in the Westfield River and the response of coloured, humic waters to acid loading from precipitation.

15. Results and Conclusions to Date: Fisheries data obtained at the fish counting fence on the Westfield River for the April-December period in 1982 and 1983 indicate: low numbers of mature adult salmon migrating to headwater areas with a large proportion of the run consisting of strays from the salmon enhancement program on the Medway River; low salmon smolt production; high escapement and reproductive success of the alewife making it the most abundant anadromous species in the system. Comparative surveys of fish density in the Westfield River, its more acidic tributaries and in other less acidic Nova Scotia streams indicate: extremely low densities of yearling salmon in the Westfield; absence of all juvenile salmon stages from major tributaries of the Westfield; increased importance of eel populations in the fish biomass of the most acidic streams. Continuous gauging and weekly chemistry data for precipitation and the Westfield River and its two main tributaries are available for 1982 and 1983; preliminary mass balances for major ions in these waters indicate acidification of surface waters in response to acid loadings in precipitation and also from drainage of bog areas.

16. Anticipated Outputs: The findings will be published in an appropriate medium and will be used to support the bilateral process leading to reduced emissions. The monitoring program described will allow for a continued comprehensive evaluation of the reproductive success and productivity of fishes in the Westfield System, and identification of stages, periods and extent of mortality in relation to both episodic and annually increasing (or decreasing if and when emissions are reduced) acidity in the system. The data will allow for development of quantitative procedures for predicting changes in fish populations in response to changes in water chemistry. The Westfield is a tributary of the Medway River and the findings will also be of use to management of the Medway salmon enhancement program as it provides information on movements of salmon studied in this program which return to the Westfield, and on the likelihood of enhancement success in four tributaries of the Medway. The Westfield acid rain study is also of strategic importance as the findings in this study will complement these of the nearby Kejimkujik Calibrated Watershed Study.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

Lack of long-term security for program; It is important to continue the studies initiated on the fish populations of the Westfield River since only 2 years of research effort have been expended to date, yet 4 years are required just to monitor the salmon population through one generation; it is also imperative to continue the monitoring through the initial period of reduced emissions, when such are negotiated. Lack of personnel resources for program; Additional person-years are required to complete a timely analysis and reporting of the mass of information being generated by this monitoring program.

APPENDIX: List of publications resulting from work related to the Westfield Project. #5.1

A. Primary Publications:

Peterson, R.H., and D.J. Martin-Robichaud. 1983. Embryonic movements of Atlantic salmon as influenced by pH, temperature, and development. J. Fish. Aquat. Sci. 40: 777-782.

Saunders, R.L., E.G. Henderson, C.E. Johnston, and J.G. Eales. 1983. Effects of low environmental pH on smolting of Atlantic salmon (Salmo salar). Can. J. Fish. Aquat. Sci. 40: 1203-1211.

Waiwood, B.A., and K. Haya. 1983. Levels of chorionase activity during embryonic development of Salmo salar under acidic conditions. Bull. Environm. Contam. Toxicol. 30: 511-515.

Peterson, R.H., and D.J. Martin-Robichaud. 1982. Water uptake by Atlantic salmon ova as affected by low pH. Trans. Am. Fish. Soc. 111: 772-774.

Haya, K., and B.A. Waiwood. 1981. Acid pH and chorionase activity of Atlantic salmon (Salmo salar) eggs. Bull. Environm. Contam. Toxicol. 27: 7-12.

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.

Freeman, H.C., G.B. Sangalang, G. Burns, and M.C. McEnemy. 1983. The blood hormone levels in sexually mature Atlantic salmon (Salmo salar) in the Westfield River (pH 4.7) and Medway River (pH 5.6), Nova Scotia. Science of the Total Environment. (in press)

*Lacroix, G.L., D.J. Gordon, and D.J. Johnston. Survival, growth and electrolyte balance of post-emergent Atlantic salmon (Salmo salar) reared in acidic and limestone-treated river water. (in preparation)

Schom, C.B. Genetic control or resistance to low pH in Atlantic salmon at the family and stock level. (submitted)

Peterson, R.H., D.J. Gordon, and D.J. Johnston. Distribution of mayfly nymphs and caddisfly larvae in some streams of eastern Canada as related to stream pH. (in preparation)

Peterson, R.H. The influence of varying pH and some inorganic cations on the perivitelline potential of Atlantic salmon (Salmo salar) eggs. (submitted)

Peterson, R.H., J.L. Metcalfe, and S. Ray. Uptake of cadmium by Atlantic salmon (Salmo salar) eggs and alevins as influenced by acidic conditions. (in preparation)

B. Proceedings of Conferences, Symposia:

Peterson, R.H., P.G. Daye, G.L. Lacroix, and E.T. Garside. 1982. Reproduction in fish experiencing acid and metal stress. IN: Acid Rain and Fisheries, Proc. of an Int. Symp. on Acidic Precipitation and Fishery Impacts. (R. Johnen, ed.)

Peterson, R.H., P.G. Daye, and J.L. Metcalfe. 1980. The effects of low pH on hatching of Atlantic salmon eggs. IN: Proc. Int. Conf. Ecol. Acid Precipitation, Norway 1980, SNSF Project.

*Lacroix, G.L. Survival of Atlantic salmon eggs and alevins as related to the water chemistry of redd interstitial water in acidic Nova Scotian streams. (submitted)

Freeman, H.C., G.B. Sangalang, M.C. McEnemy, G. Burns, and T. Goff. 1983. Studies on the effect of a low pH river on weight gain, sexual maturation, androgen production, and reproduction in the Atlantic salmon (Salmo salar). Int. Conf. Exp. Sea, C.M.1983/M:19.

Saunders, R.L., E.B. Henderson, P.R. Harmon, and C.E. Johnston. 1981. Influence of low environmental pH on smolting of Atlantic salmon. Int. Conf. Exp. Sea, C.M.1981/M:30, 15 p.

Technical Reports

1983 Workshop on Acid Rain (Peterson, R.H., H.H.V. Hord, eds.) 1983. Can. Tech. Rep. Fish. Aquat. Sci. No. 1213, 79 p.

Johnston, C.E., R.L. Saunders, E.B. Henderson, P.R. Harmon, and K. Davidson. Chronic effects of low pH on some physiological aspects of the parr-smolt transformation in Atlantic salmon. Can. Tech. Rep. Fish. Aquat. Sci. (in preparation)

DeGraeve, G.M., and R.H. Peterson. 1982. Hydrologic and land-use surveys of the Westfield watershed. Can. Tech. Rep. Fish. Aquat. Sci. No. 1095, 11 p.

Zitko, V. 1982. Computer programs for evaluation of acid/base titrations. Can. Tech. Rep. Fish. Aquat. Sci. No. 1102, 20 p.

Other

"Workshop on acid rain", Westfield River, N.S. Project Reports, 1981-82. Department of Fisheries and Oceans, 1982, 127 p.

PROJECT INFORMATION FORM

1. Discipline: Aquatic/Fisheries 2. Project Number: 5.2

3. Agency and Department: Department of Fisheries and Oceans
Fisheries Research Branch, Scotia-Fundy Region

4. Project Title: Westfield River Project: II. Short-term studies (cause-effect) of acidification on Atlantic salmon, other fishes and their habitat.

5. Principal Investigator(s) (include addresses):

Dr. Gilles L. Lacroix
Fisheries and Environmental Sciences
Department of Fisheries and Oceans
Biological Station,
St. Andrews, New Brunswick
EOG 2XO

6. Cooperating Agencies and Investigators:

Contracting agencies as required.

7. Project Duration: 1981-82 to 1986-87

8. Resources (show PYs, capital and non-salary O&M by year):

	PYs	$K Capital	$K O&M
1981-82	-	-	-
1982-83	2.0	30.0	80.0
1983-84	2.0	5.0	100.0

9. Service or Agency Objectives:

To document damage to the well being of fisheries resources caused by acid precipitation and related pollutants and to protect freshwater and anadromous fisheries resources being threatened and ensure their long-term maintenance.

10. Project Objectives: To provide a firm understanding of the mode of impact and a detailed description of responses for fish populations and habitat in relation to acidification in coloured, humic waters representative of systems with important Atlantic salmon stocks.

Project # 5.2

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Atlantic drainage systems headwaters, southwest Nova Scotia. Associated laboratory analyses at St. Andrews Biological Station.

12. Ecosystem Types Included in Research (where applicable):

Coastal rivers and tributary streams subject to bog drainage; Coloured, humic waters.

13. Purpose or Hypotheses to be Examined:

A. Conduct in situ experiments to determine the fate of Atlantic salmon fry/parr from emergence for the first year of stream life and of other species and life cycle stages as affected by stream acidity; to quantify the sensitivity of fish species and life stages to acidic, coloured waters with elevated aluminum concentrations; and to evaluate the applicability of laboratory bioassay measurements of fish sensitivity to field population responses.

B. Conduct comparative analyses of fish plasma ion concentrations in relation to seasonal and episodic changes in river pH in the Westfield River and other Nova Scotia rivers with different chemical characteristics to identify periods and conditions (pH and ionic composition of water) affecting different stages and species of fish; and to identify possible indicators of stress related to acidification and possible mechanism(s) of effect.

C. Complete and integrate studies of the effects of stream acidity on ecosystem processes, trophic relationships and fish-food habits and hence, salmon production in the Westfield River to evaluate mechanisms for the decline of fish populations with acidification such as the potential importance of decreased food availability and/or nutritional value; to evaluate the response of fish populations in relation to charges in habitat; and to evaluate the significance of the possible loss of fish populations from the ecosystem.

14. Study Design/Methodology (include lab and data analyses to be employed):

A. Preliminary streamside experiments using Westfield River water have indicated that the mortality of salmon fry during the initial period of exogenous feeding, 15-25 days after emergence from redds, can be high enough (~70%) to severely limit salmon recruitment in the river. Although the intensity of spawning by Atlantic salmon is still adequate to maintain the population, the densities of older parr (1+ and older) and the production of smolts are extremely low.

An intensive study will be conducted during 1984/85 in a secondary channel of the Westfield River to assess the survival, dispersion and possible emigration, feeding habits, and physiological condition of underyearlings throughout the first year. Fry from eggs fertilized and incubated in the Westfield River will be introduced to a suitable natural rearing channel (500 m^2) bounded by barriers with traps. Densities will be determined regularly to estimate survival and to identify

Project # 5.2

periods of mortality. Traps will be operated continuously to monitor movements; other fish species and potential predators are to be prevented access to the area. Fry are to be sampled periodically to determine food habits and for tissue and plasma ion analyses to determine their physiological condition and to provide insight into the possible mechanism of pH effect on survival.

Such an experiment should provide: immediate invaluable information towards answering one of the major and most pressing questions regarding the fate of Atlantic salmon during the freshwater stages of its life cycle in relation to chemical conditions in the Westfield River.

In subsequent years, similar in situ experiments in rearing channels or in stream-side tanks, using Westfield River water, will be conducted to quantify the effects of river acidity on critical life cycle stages of other native fish species and to determine the effects on fish of altering some of the chemical characteristics (e.g., aluminum species, calcium concentration) of Westfield water.

B. Plasma Na^+ and Cl^- concentrations have been used in laboratory experiments and some field situations as indicators of acid-related stress in some fish species and plasma Ca^{++} concentrations have also been used as indicators of possible reproductive impairment.

As part of continuing studies on the Westfield River to determine the effects of stream acidity on anadromous fishes. A comparative study of plasma ion concentrations in maturing and migrating Atlantic salmon and alewives will be conducted in the Westfield River (pH<5.0), the Medway River (pH ca. 5.4) and LaHave River (pH>6.0). The Westfield has a fish counting fence and both other rivers have fishways with facilities which allow for the safe capture, handling, sampling and release of the salmon. Plasma Na^+, K^+, and Cl^- concentrations will be analyzed to assess acid-related stress. Plasma Ca^{++} concentrations in maturing fish will also be analyzed to assess possible impairment of normal maturation process (oogenesis) and, if warranted, egg quality will be examined in relation to altered Ca^{++} metabolism in maturing females.

Blood samples (<1 cc required) will be collected using standard handling and sampling techniques by caudal venapuncture from 10 (depending upon availability) maturing salmon of each sex captured in each river during the early run (June) and from similar numbers of ripe salmon captured before spawning (October) and spent salmon (November). Blood samples will also be collected from at least 10 maturing (May-June), 10 ripe (June-July) and 10 spent (July-August) alewives of each sex during their spawning migration in the same three rivers. Blood hematocrit will be measured and plasma samples will be analyzed for Na^+, K^+, Ca^{++} (Ion Chromatograph) and Cl^- (Cotlove Chloridometer). These may also be compared for maturing white suckers (April-May) and brook trout (September-November) as well as for Atlantic salmon parr from several rivers of different pH on a seasonal basis and during spisodes of pH depression in the rivers.

The study should point out the intensity and type of sublethal acid effects, the pH levels and periods of concern, and the stages and species affected.

C. Comparative studies of seasonal periphyton species composition and primary production (^{14}C uptake method), benthic invertebrate species composition and total production, and of juvenile salmon food habits and production are being completed during 1983-84 in the Westfield River (pH<5.0) and other Nova Scotia rivers of different pH.

Further identification of the trophic relationships and pathways for flow of nutrients will be required. This will be accomplished through a continued analysis

(Cont'd, see over)

#5.2

(Study Design)(Cont'd):

of existing samples and data collected from 1982-84 and by further studies in situ. Analyses of dissolved (<0.45 µm) and fine particulate (0.45-365 µm) organic matter in water samples will be continued, and a seasonal evaluation of coarse particulate organic matter (>365 µm) will be made using stream-drift samplers. Collection and estimation of allochthonous organic matter inputs (e.g., leaf litter) will also be made using appropriate litter traps. The evaluation of inputs and outputs of biomass represented by anadromous and catadromous fish populations will be continued at the counting fence on the Westfield River.

Carbon and nitrogen analyses (Perkin-Elmer 240C CHN Analyzer) will be performed on the different fractions of organic matter, on benthic invertebrates of different feeding strategies and those representing major fish-food items, and on migratory fish species representing significant biomass inputs to and outputs from the system as well as on fish species such as juvenile salmon. Other major ions may also be analyzed (Ion Chromatograph) for some samples of representative fish-food items and important fish species.

This information, together with that obtained from studies conducted between 1982 and 1984 will be used to construct models and budgets for carbon (and possibly other major ions) relating to allochthonous, autotrophic, and heterotrophic components of an acidified stream ecosystem.

Project # 5.2

15. Results and Conclusions to Date: The hatching success of Atlantic salmon eggs was found to be correlated with pH of the redd interstitial water in the Westfield River and other tributaries of the Medway River. The successful emergence of salmon fry from natural redds in the Westfield was confirmed. Streamside experiments have demonstrated very high (ca. 70%) mortality and growth retardation of newly feeding salmon fry in Westfield River water (pH 5.0), and this mortality could be eliminated by raising the river water to pH 6.0 by passing it through limestone. Densities of the yearling salmon in the Westfield are extremely low in relation to fry densities of the previous fall, so that either a n excessively high overwinter mortality of fry or a massive migration of fry from the area possibly occurs. (See over)

Total annual benthic invertebrate production in the Westfield was similar to that in a nearby river of pH>6.0. There was less diversity of organisms in the diet of juvenile salmon in the Westfield than in the higher pH river, yet the numbers of items consumed by fish were similar in both rivers.

Projects which have been funded in the Westfield program and which have been concluded within the past year have produced the following results:

1. Results of survey of 20 Nova Scotian streams indicate that Ephemeroptera diversity is directly related to stream pH according to the regression: number of mayfly genera present = -6.4 + 2.2 pH ($r = 0.82$). No gastropods were sampled from streams of pH $\leq$5.2 nor were sphaeridae sampled from streams with pH $\leq$4.7.

2. Metamorphosis of Atlantic salmon parr to the marine smolt stage fails at pH levels less than 4.9, as revealed by various physiological parameters associated with smoltification.

3. The activity of enzyme associated with breakdown of the Atlantic salmon egg capsule during hatching (chorionase) in eggs incubated at pH 4.5 is reduced to one-third of that in eggs incubated at pH 6.8. As a result, hatching is slower and with higher-associated mortality at low pH.

4. Levels of testosterone and 11-keto-testerone are lower in sexually mature salmon from the Westfield River (pH ca. 5.0) than in salmon from the Medway River (pH ca. 5.5).

16. Anticipated Outputs:

The findings will be published on an appropriate medium and will be used to support the bilateral process leading to reduced emissions. Anticipated outputs are defined under items 13 and 14.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

Lack of personnel resources for program; Some of the studies described herein cannot be continued without additional person-years being granted to this project.

PROJECT INFORMATION FORM

1. Discipline: Aquatic/Fisheries 2. Project Number: 5.3

3. Agency and Department: Department of Fisheries and Oceans
Fisheries Research Branch, Scotia-Fundy Region

4. Project Title: Determination of pH levels which are avoided/selected by Atlantic salmon and other fish species.

5. Principal Investigator(s) (include addresses):

Richard H. Peterson
Biological Station
St. Andrews, New Brunswick
E0G 2X0

6. Cooperating Agencies and Investigators:

Uno Paim, University of New Brunswick,
Fredericton, N.B.

7. Project Duration:

Initiated 1983-84, to terminate in 1986-87

8. Resources (show PYs, capital and non-salary O&M by year):

1983-84: 0.3 PY, 0 Capital, 5,000 O&M

9. Service or Agency Objectives:

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.

10. Project Objectives:

To determine what pH levels are avoided or selected by various freshwater fish species. Ultimately to determine sensory mechanisms which enable fish to sense pH.

Project # 5.3

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Laboratory experiments, New Brunswick
St. Andrews Biological Station

12. Ecosystem Types Included in Research (where applicable):

N/A

13. Purpose or Hypotheses to be Examined:

Hypotheses to be tested:

1) that fish, when presented with continuous pH gradient, will confine themselves to a restricted region(s) of the gradient;
2) that species differences exist with respect to regions of a pH gradient selected;
3) that selected pH ranges are alterable by adaptation to differing ambient pH levels, or presence of other dissolved substances (Ca^{++}, humic acids);
4) that a specific sensory modality is utilized in discriminating pH in a gradient.

Purpose: To determine, under controlled laboratory conditions, if pH is a directive factor with respect to fish distribution.

14. Study Design/Methodology (include lab and data analyses to be employed):

The apparatus to be used will permit establishment of a linear pH gradient. Water entering one end of the gradient apparatus will have been acidified to the lowest pH required and will have been air-equilibrated to purge it of CO_2 generated by acidification. Sulfuric acid will be used to lower pH in the first experiments, but other acids may be used later.

Project # 5.3

The gradient apparatus is partially divided into seven compartments by baffles. As the acidified water passes into each compartment, the pH is raised with base added under feedback control from a titrimeter assembly. The water in each compartment will be aerated to ensure adequate mixing. Delivery of base and aeration will be situated such that thorough mixing will occur before the water passes to the next compartment. Sodium hydroxide will be used as the base in initial experiments. Control experiments will be performed with equivalent sodium sulfate gradients established in the apparatus.

Gradients with pH extremes of 4.5 to 6.5 will be initially employed.

The number of fish utilized in each experiment will be varied to determine an optimum number. It has been found in work with temperature gradients that groups of salmonids yield better results than single fish.

Project # 5-3

15. Results and Conclusions to Date:

To date effort on this project has been concerned with construction and improvement of the gradient apparatus. Particular care has been taken to develop an apparatus which will not create gradients of CO_2 supersaturation - a fault which has plagued earlier published work on responses of fish to pH gradients.

16. Anticipated Outputs:

I anticipate that the results will be worthy of publication in a primary journal. Results obtained will be useful in understanding or interpreting movements of natural fish populations in relation to episodes of low pH or in relation to naturally occurring gradients within a drainage basin.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

N/A

PROJECT INFORMATION FORM

1. Discipline: Aquatic/Fisheries 2. Project Number: 5.4

3. Agency and Department: Department of Fisheries and Oceans
Fisheries Research Branch, Scotia-Fundy Region

4. Project Title: The Relationship between the Interaction of Toxic Elements, Acid Rain and Humic Acids, and the Uptake and Sublethal Effects in Salmonidae.

5. Principal Investigator(s) (include addresses):

H.C. Freeman and J.F. Uthe
Fisheries and Environmental Sciences
Halifax Fisheries Research Laboratory
Department of Fisheries and Oceans
P.O. Box 550,
Halifax, N.S. B3J 2S7

6. Cooperating Agencies and Investigators:

T. Goff, Mersey Hatchery
Department of Fisheries and Oceans
P.O. Box 86, Milton, N.S. B0T 1P0

7. Project Duration:
To be Initiated in Fiscal 1984/85 to 1987/88

8. Resources (show PYs, capital and non-salary O&M by year):

P.Y. 2.0	
O&M	125K
CAP.	30K

9. Service or Agency Objectives:

Develop the scientific basis for demonstrating the adverse effects of acid rain on the Atlantic salmon and other salmonids in watersheds of low buffering capacity.

10. Project Objectives: To obtain data that will demonstrate and give scientific explanations of how acid rain is affecting the physiology and reproduction of Atlantic salmon and other economically important salmonids, thus contributing to their declining populations.

Project # 5.4

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Southwestern Nova Scotia

12. Ecosystem Types Included in Research (where applicable):

Many western Nova Scotia rivers are highly unbuffered, due to metamorphic sandstones, slates and granitic formations in their watersheds. The pH of these waters has been shown to be decreasing over time both generally and episodically during and after rainfall from storms approaching from the continental United States.

13. Purpose or Hypotheses to be Examined:

Acid precipitation is, in itself, dangerous and furthermore, capable of solubilizing other toxic substances such as trace elements and humic acids from the surrounding soils and bedrock. We intend to determine the relationship between acidic waters, humic acids and a variety of trace elements, in particular, mercury, cadmium and aluminum and study the effect of this interaction on the uptake and sublethal toxicology of these elements. Effects on steroid hormone metabolism and reproduction will be investigated. Facilities at the Mersey Hatchery will be used to assess egg viability to the latest stage possible. A multi-year study will be needed to separate out the natural and acidic effects due to the annual differences in rainfall and acidification in the area.

14. Study Design/Methodology (include lab and data analyses to be employed):

This project is designed to investigate the effects of acid precipitation on the levels of humic acids and toxic elements in the Westfield River, Nova Scotia. The project will be made up of a field component and a laboratory one. The laboratory component will be made up of a study of the effect of pH and sulfate on the interaction between humic acids and certain toxic elements, notably cadmium, mercury and aluminum using a combination of polarography and size exclusion-atomic absorption spectrophotometry. The selection of cadmium and mercury is based on the acute and chronic effects of low levels of cadmium on reproduction in brook trout (Salvelinus fontinalis) (Sangalang and Freeman 1974) and the occurrence of high levels of mercury in eels from rivers in southwestern Nova Scotia coupled with the observation that only 50% of the

total mercury in these eels can be accounted for by methyl mercury. Since fish do not appear to demethylate methyl mercury, it is postulated that these eels are exposed to relatively high levels of inorganic mercury resulting from acid leaching in the area (Freeman and Horne 1972).

Following the development of an understanding of the humic acid-metal-pH interactions, attempts will be made to determine concentrations of bound and unbound metals in the waters of the Westfield River. The effect of humic acids on the uptake and toxicology of these metals will be assessed via laboratory exposure of salmonids followed by in vitro studies of hormonal metabolism and reproduction in these animals. The initial metals to be studied are mercury and cadmium but, time and money permitting, the study will be extended to include aluminum and calcium (as a sparing agent on the toxicological effects of the other two toxic metals).

The field experiments will include holding salmon in cages in the Westfield and a control river over the course of sexual maturation. Periodically, blood samples and growth parameters will be monitored during maturation and at the end of maturation. The viability of the eggs will be assessed along with the capacities of the reproductive organs and the interrenals to synthesize and metabolize steroid hormones which are involved in reproduction, stress responses and osmoregulation.

Project # 5.4

15. Results and Conclusions to Date:

We have shown that both wild and caged salmon held in the Westfield River have irregular sexual maturation and reduced egg viability. Caged salmon held in the Westfield had reduced feeding and growth compared to control salmon held in the more neutral Medway River. Eggs from the Westfield River fish had a mortality exceeding 90%. To date the relative contributions of acid waters and increased presence of other toxic materials due to the acidic water has not been determined.

16. Anticipated Outputs:

In addition to the usual route of dissemination of scientific information through the literature and an increased understanding of the mechanism of the toxic actions of acid rain, the information generated will have applicability in building a case for the limitation of the input of sulfur and nitrogen oxides to the atmosphere, especially upwind of those areas in which the aquatic conditions are conducive to severe impaction.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

There is a need for administrators and managers to recognize that the procurement of valid scientific information is not to be limited by temporal constraints.

#5.4

References

1. Freeman, H.C., and J.F. Uthe. 1979. Effects of cadmium on aquatic animals in "Effects of cadmium in the Canadian environment". National Research Council of Canada, Publication No. NRCC 16473, 68-79 p.

2. Freeman, H.C., and G.B. Sangalang. 1977. Changes in steroid hormone metabolism as a sensitive method of monitoring pollutants and contaminants. E.P.S. Technical Report, No. EPS-5-AR-77-1.

3. Freeman, H.C., and D.A. Horne. 1972. Mercury in Canadian seals. ICES Report, C.M.1972/N:9.

4. Sangalang, G.B., and H.C. Freeman. 1974. Effects of sublethal cadmium on maturation and testosterone and 11-keto-testosterone production *in vivo* in brook trout. Biology of Reproduction *11*: 429-435.

5. Uthe, J.F., H.C. Freeman and A. McIntyre. 1980. The selection of sublethal testing procedures for assessment of chemical toxics in the aquatic environment and experiences in the use of steroid hormone metabolism. Can. Tech. Rep. Fish. Aquat. Sci. No. 975, 231-242.

PROJECT INFORMATION FORM

1. **Discipline:**
Aquatic Fisheries

2. **Project Number:** 6.1

3. **Agency and Department:** Department of Fisheries and Oceans

4. **Project Title:**
Assessing and monitoring the impact of acid precipitation on Maritime fish habitat.

5. **Principal Investigator(s) (include addresses):**
W.D. Watt
Fisheries Research Branch
P.O. Box 550
Halifax, N.S.
B3J 2S7

6. **Cooperating Agencies and Investigators:**

7. **Project Duration:** 1977 - continuing

8. **Resources (show PYs, capital and non-salary O&M by year):**

	1977	1978	1979	1980	1981	1982	1983
PY	0.5	0.5	0.5	1	2	2	2
Cap.	1	1	1	2	7	7	0
O&M	5	5	5	10	20	40	50

9. **Service or Agency Objectives:**
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. (Fisheries and Oceans).

10. **Project Objectives:**
To ascertain what chemical changes have occurred in the Maritimes as a result of acid precipitation, relationships with other environmental factors, rates of change, and the impacts on fishery resources.

Project # 6.1

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Initial surveys were conducted throughout Nova Scotia, New Brunswick and Prince Edward Island. Research is presently concentrated on the Atlantic Upland of N.S.

12. Ecosystem Types Included in Research (where applicable):

Lakes and rivers.

13. Purpose or Hypotheses to be Examined:

1. Freshwater fish habitat in the Maritimes is being acidified.
2. Acidification is having a deleterious impact on fish habitat.
3. The rates of acidification and degree of impact vary in response to local geology, soil types, land usage and pollution sources.

14. Study Design/Methodology (include lab and data analyses to be employed):

1. Survey all river systems in the Maritimes and combine with other available water quality data to ascertain the extent of the acidification threat and the relationships with other environmental factors.
2. Compare present water chemistry with records from the past to ascertain the rates of change and to relate the chemical changes to quantifiable changes in the fishery resource.
3. Examining geographical distributions of freshwater fish in Nova Scotia to ascertain whether species are disappearing from the former ranges indicated in earlier biogeographical studies. Seek to relate any significant shifts to chemical and other environmental factors.

Project # 6.1

4. Chemical and biological monitoring of N.S. rivers flowing through the Atlantic Upland where some historic salmon rivers are now barren, and the severely impacted remnant runs to a dozen others appear to be on the verge of extinction.

Project # 6.1

15. Results and Conclusions to Date:

Freshwater fish habitat has been acidified, especially in the Atlantic Upland area of N.S. The average rate of pH decline (in susceptible rivers and lakes) since the mid 1950's has been 0.017 units/year. Atlantic salmon angling data provide an indication of the time trend of the impact of acidification on this species.

Watt, W.D., D. Scott, and S. Ray. 1979. Acidification and other chemical changes in Halifax County lakes after 21 years. Limnol. Oceanogr. 24: 1154-1161.

Watt, W.D. 1981. Present and potential effects of acid precipitation on the Atlantic salmon in Eastern Canada. In Acid Rain and the Atlantic salmon. Proceedings of a conference held November 22-23, 1980. Int. Atl. Salmon Found. Spec. Pub. Ser. 10: 39-45.

Watt, W.D., C.D. Scott and W.J. White. 1983. Evidence of acidification of some Nova Scotian rivers and its impact on Atlantic salmon, Salmo salar. Can. J. Fish. Aquat. Sci. 40: 462-473.

16. Anticipated Outputs:

1. Comparison of present biogeographic distributions of N.S. lake fish species with studies from the 1950's.
2. Impact of seasonal variation and episodic events on river species, especially juvenile salmon.
3. Response of remnant juvenile salmon populations to annual variations and trends in acid precipitation loading.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

An unexpected reorganization of D.O.E.'s Water Quality Branch and changes in the interpretation of D.S.S. procurement regulations have forced us to change chemical laboratories twice for our analytical services.

PROJECT INFORMATION FORM

1. **Discipline:**
Aquatic/Fisheries

2. **Project Number:** 6.2

3. **Agency and Department:** Department of Fisheries and Oceans

4. **Project Title:**
Investigation of the practicality of using lime and/or limestone to create de-acidified refuges for Atlantic salmon survival.

5. **Principal Investigator(s) (include addresses):**
W.D. Watt, J.W. White, and G. Farmer
Fisheries Research Branch
P.O. Box 550
Halifax, N.S.
B3J 2S7

6. **Cooperating Agencies and Investigators:**

7. **Project Duration:** 1981-88

8. **Resources (show PYs, capital and non-salary O&M by year):**

	1981	1982	1983
PY	2	2	2
Cap.	13	13	10
O&M	100	90	90

9. **Service or Agency Objectives:**
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 (Fisheries and Oceans).

10. **Project Objectives:**
It is intended that various forms of locally available lime and limestone should be tested for neutralizing capacity and rates of deacidification in lakes and rivers. Various delivery mechanisms will also be tested, and careful comparisons made of cost and effectiveness. The duration of the deacidification effectiveness in lakes and rivers will be monitored and related to environmental factors. Examine the nature and limitations of detoxification of aluminum by pH elevation. This will be followed by a demonstration project in a small acidified N.S. salmon river.

Project # 6.2

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Atlantic Upland, N.S.

12. Ecosystem Types Included in Research (where applicable):

Lake and river systems.

13. Purpose or Hypotheses to be Examined:

Evidence collected in Nova Scotia indicates that the most dramatic impact of acidification thus far is in the expirpation of at least 10 Atlantic salmon runs. The Department of Fisheries and Oceans, as the agency responsible for fish habitat protection in the Maritimes, is anxious to halt this trend as soon as possible.

One of the principle features of Atlantic salmon biology is the unique genetic characteristics of each river stock. Ths loss of a native salmon run is irreversible.

The technical and economic practicality of mitigating the effects of acidification on Atlantic salmon by liming are still speculative, though promising results have been obtained in Norway and Sweden, and with other salmonid species in New York and Ontario as well as in Scandanavia.

The Department of Fisheries and Oceans is 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 de-acidified refuges 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.

14. Study Design/Methodology (include lab and data analyses to be employed):

Three methods of limestone application were initially considered, based on personal communications and review of previously published accounts of experience in Sweden (Grahn and Hultberg, 1975), the United States (Pearson and McDonnell, 1975) and Canada (Schieder et al, 1975 and Dillon et al, 1977); use of a silo to lime the river as it flows past the site, use of crushed limestone gravel in the river bed, and use of powdered limestone to neutralize headwater lakes. Possible use of various other mechanical devices and wells was tentatively rejected because of the high probability of their being jammed or blocked by ice during the four months of freezing conditions typical of most Nova Scotian winters. The maximum limestone requirement occurs during the winter months when discharges tend to be high and pH is at its lowest level.

Project # 6.2

The silo concept was initially rejected because of the difficulty of designing a dosing apparatus with a three order-of-magnitude response range, and because of the potential breakdowns which would be unavoidable in a wilderness situation where winter power failures of one to four days duration are not infrequent. Possible failure of the liming apparatus, especially during the low-pH winter period, would almost certainly result in a major fish kill.

Procedures:

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^{+}, $SO_4^{=}$, Cl^{-} 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.

Project # 6.2

15. Results and Conclusions to Date:

1. Instream limestone gravel can be utilized to raise the pH's of moderately acidified (mean pH 4.8-5) Atlantic salmon rivers to acceptable levels during the sensitive early feeding stage in May-June.
2. Instream limestone gravel cannot provide year-round pH control because under winter and early spring conditions, the quantities of gravel that would theoretically be required to achieve the necessary pH elevation are impractically large.
3. Headwater lake liming using a calcitic limestone dose of 3X acidity can provide effective pH control for approximately one year.
4. For pH control during the May-June period, headwater lake liming would be a more economical approach than instream limestone gravel, but it would also be more vulnerable to interruptions in annual treatments.

16. Anticipated Outputs:

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.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

Occasional warm mid-winter depressions cause heavy rainfalls on frozen soils, producing rapid surface runoff. The runoff acidity may actually be higher than that of the precipitation if partial freezing concentrates the acid. In lakes under ice cover, mixing is minimal and an inverse thermal stratification prevails. The runoff water enters the streams and lakes near 0°C and it spreads in a surface layer 0.5-1.5 meters thick immediately under the ice. Unfortunately, it is this low-pH surface water that is discharged to the salmon habitat in the rivers by the natural surface outlets. In Nova Scotia, snow melt-water, which is a commonly identified cause of episodic pH depression, is considerably lower in acidity than rain.

NEWFOUNDLAND REGION

PROJECT INFORMATION FORM

1. Discipline: Project Number: 7.1

Aquatic/Fisheries

3. Agency and Department:

Department of Fisheries and Oceans

4. Project Title:

a) Headwater Lakes Survey of Insular Newfoundland.

b) Intensive Lake Survey of South Coast of Insular Newfoundland.

5. Principal Investigator(s) (include addresses):

Mr. David A. Scruton
Mr. H. Bain
Fisheries and Oceans
Newfoundland Region
P.O. Box 5667
St. John's, Newfoundland
A1C 5X1
(709) 772-4485

6. Cooperating Agencies and Investigators:

Consultants: 1) Dobrocky Seatech (Nfld.) Ltd. (field data collection, water chemistry)

2) Ocean Chem Ltd. (water chemistry 1983/84)

3) Beak Consultants Ltd. (zooplankton and phytoplankton identification and enumeration)

4) McLaren Plansearch Ltd. (benthic identifications and enumerations.

5) Dr. H. Duthie, U. of Waterloo (statistical assessment of phytoplankton assembleges).

6) Dr. J.H.C. Carter, U. of Waterloo (statistical assessment of crustacean zooplankton).

#7.1

7. Project Duration:

a) April 1981-March 1982

b) April 1983-March 1984

8. Resources (show PYs, capital and non-salary O&M by year):

	1981/82	1982/83	1983/84
a) Person years	1.0	0.5	2.0
b) Operating and Maintenance ($000)	347	39	121
c) Capital ($000)	-	-	41.5

9. Service or Agency Objectives:

To protect freshwater and anadromous fisheries resources threatened by acid precipiation and related pollutants and ensure the long term maintenance of the social and economic benefits associated with the fisheries resources.

10. Project Objectives:

a) - To determine the chemical status and sensitivity of headwater lakes in insular Newfoundland in relation to acid deposition.

- To establish a data base for water chemistry and biota to permit temporal assessment of the effects of acid deposition and for use in future monitoring programs.

- To provide data for a regional assessment of lake and biota status in relation to anthropogenic acidification (NIS synthesis).

- To establish background levels of heavy metals in fish tissue in relation to lake chemistry and its determinants.

b) - To more clearly define the chemical status of headwater lakes in south coastal region, an area of highest deposition and extreme sensitivity.

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

a) Insular Newfoundland
b) South Coast of Insular Newfoundland

12. Ecosystem Types Included in Research (where applicable):

Headwater lakes ranging from highly alkaline to oligotrophic to dystrophic.

13. Purpose or Hypotheses to be Examined:

To obtain a comprehensive and reliable data base on freshwater chemistry and biota for lakes in a region that previously had a limited and geographically restricted data base.

#7.1

14. Study Design/Methodology (include lab and data analyses to be employed):

One hundred and nine (109) remote lakes were visited by aircraft. Detailed bathymetry was obtained on 12 preselected lakes. A water sample was obtained for detailed analysis (pH, conductivity, alkalinity, major ions, nutrients, trace metals). Plankton samples (zoo- and nanno-) were obtained and subsequently identified and enumerated. Grab samples (up to 5) of sediments were obtained from lakes with soft substrates. Macrobenthos were removed from the grabs and subsequently identified and enumerated. Fish were collected by gill net from the lakes for age, growth and tissue analysis. Mercury, aluminum, manganese, selenium, cadmium, nickel, and total lipid content were determined in fish tissue in length stratified subsamples.

Lake sensitivity was established by nationally accepted criteria. Lake status was examined by models developed by Henriksen, Dillon, and others.

Assessment of planktonic community structure in relation to morphometric and chemical variables using principle component ordination, factor analysis, stepwise multiple regression, and canonical correlation is ongoing. (Complete by March 1984)

Assessment of fish and benthic data has not been initiated.

15. Results and Conclusions to Date:

a) One hundred and nine (109) headwater lakes, ranging in size from 21 to 2519 ha were surveyed from August 16 to October 18, 1981. Water chemistry was highly variable between lakes with bedrock geology, input of marine aerosols and atmospheric deposition the dominant features controlling variability in chemical parameters. Lake pH varied from 4.90 to 8.39 with ten (10) lakes having a pH of less than 5.50. Ninety-three (93) lakes had alkalinities of less than 200 $\mu eq\ L^{-1}$, indicating moderate to high sensitivity to acidification. Excess sulphate values ranged from 5.7 to 91.4 $\mu eq\ L^{-1}$ (mean of 34.5) and these levels are less than those reported for lakes experiencing moderate to high atmospheric loadings. Study lakes were highly coloured (mean of 48 TCU) which correlates to high natural acidity and also complicates assessment of anthropogenic acidification. Sensitive lakes demonstrated a sulphate domonance over bicarbonate and an alkalinity deficiency relative to major cations. Models developed by Henriksen suggest that acidification in five (5) lakes can be related to mineral acids (sulphate deposition) while in twelve (12) lakes natural organic acidity is a major contributing factor. Aluminum and manganese levels in lake water varied from 0 to 430 mgL^{-1} (mean of 112) and from 0 to 52 mgL^{-1} (mean of 13) respectively, reflecting values that are less than those reported for acidified fresh waters. A total of one thousand two hundred and sixteen (1216) fish were netted from eighty-one (81) lakes. Species captured were brook trout ouananiche or landlocked Atlantic salmon, anadromous Atlantic salmon and brown trout. Catch per unit of effort was correlated to lake pH and surface area while fish presence/absence was related to lake pH. It was estimated that a potential annual fish

#7.1

production of one million kg (in standing waters) and 73,900 anadromous salmon (in river systems) is associated with regions at high risk to acidification. Trace metals including mercury, aluminum, manganese, cadmium, arsenic, selenium, nickel, and zinc were determined in tissue collected from nine hundred and sixty-five (965) fish. Mercury levels ranged from 0.02 to 1.3 ppm with seventy-two (72) specimens exceeding 0.5 ppm. Aluminum and manganese in fish tissue ranged from 0 to 4.6 ppm and 0 to 3.9 ppm, respectively. Other metals were largely in low to undetectable quantities.

(b) Evaluation of study results is ongoing. Preliminary examination of data suggests that the region's (south coast) fresh waters are even more sensitive than originally thought and that smaller water bodies (< 10 ha) are particularly vulnerable.

Study results will be used to select a smaller set of lakes for use in a long term chemical and biological monitoring program. Lakes selected will will be those demonstrating extreme sensitivity to acid precipitation and some alteration of chemical status (i.e. Transition Lakes of Henri ksen's Nomograph). Water chemistry, fish, plankton, and possibly benthos will be monitored, with emphasis on seasonal dynamics and monitoring of acid sensitive taxa. Initial sampling (year 1) will be intensive to illucidate seasonal dynamics and to determine optimum sampling strategies in subsequent years.

Water chemistry monitoring will look at both long term and episodic alterations. Labile aluminum levels will be determined using methods developed by WQB in Moncton. Organic contributions will be considered. Monitoring of fish populations may include population estimation (spring), year class structure, possibly growth and feeding, and also Hg levels in fish tissue. Field investigations may be supported by laboratory experiments (flow-through bioassays) to investigate responses of different species, populations, and life stages to acidic environments. Monitoring of plankton populations will depend on results of ongoing statistical assessment. It is likely that efforts will revolve around monitoring diversity and community structure, with consideration for seasonal aspects of dominance.

16. Anticipated Outputs:

Publication as technical report and/or in primary literture.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

The deposition scenario in Newfoundland and Labrador is still highly speculative, awaiting a finer spatial resolution, and could not be included in the assessment of lake status.

II 7.1

18. Reports and Publications:

Scruton, D. A. 1983. A Headwater Lake Survey of Insular Newfoundland, with Special Reference to Acid Precipitation. Can. Tech. Rep. Fish Aquat. Sci. 1195: V + 110 p.

Chengaleth, R., W. J. Bruce, and D. A. Scruton. 1984. Rolifer and crustacean plankton communities of lakes in insular Newfoundland. Verh. Verein. Limnol. (in press).

PROJECT INFORMATION FORM

1. Discipline:

Project Number: 7.2

Aquatic/Fisheries

3. Agency and Department:

Department of Fisheries and Oceans

4. Project Title:

Headwater Lakes Survey of Labrador

5. Principal Investigator(s) (include addresses):

Mr. David A. Scruton
Mr. H. Bain
Fisheries and Oceans
Newfoundland Region
P.O. Box 5667
St. John's, Newfoundland
A1C 5X1
(709) 772-4485

6. Cooperating Agencies and Investigators: (Continued)

1) Dobrocky Seatech (Nfld.) Ltd. (field data collection, water chemistry)

2) Barringer Magenta Ltd. (fish tissue)

3) Dr. H. Duthie, U. of Waterloo (identification and enumeration of phytoplankton, statistical analysis of phytoplankton assembleges)

4) Dobrocky Seatech (Nfld.) Ltd. - (zooplankton identification and enumeration)

5) Dr. J.H.C. Carter, U. of Waterloo - (statistical analysis of crustacean zooplankton.)

7. Project Duration:

April 1982 to March 1983

8. Resources:

	1981/82	1982/83	1983/84
a) Person years	-	1.0	0.5
b) Operating and Maintenance ($000)	-	340	10
c) Capital ($000)	-	4	-

F7.2

9. Service or Agency Objectives:

To protect freshwater and anadromous fisheries resources threatened by acid precipiation and related pollutants and ensure the long term maintenance of the social and economic benefits associated with the fisheries resources.

10. Project Objectives:

To determine the chemical status and sensitivity of headwater lakes in Labrador in relation to acid deposition.

To establish a data base for water chemistry, fish, and plankton to permit temporal assessment of the effects of acid deposition and for possible use in future monitoring programs.

To provide data for a regional assessment of lake and biota status in relation to anthropogenic acidification (NIS synthesis).

To establish background levels of aluminum and mercury in fish tissue in relation to lake chemistry and its determinants.

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Labrador (south of N57° Latitude)

12. Ecosystem Types Included in Research (where applicable):

Headwater lakes ranging from oligotrophic to dystrophic.

13. Purpose of Hypotheses to be Examined:

To obtain a comprehensive and reliable data base on lake morphometry, chemistry, fish, and plankton for lakes in a remote northern region with limited available data.

14. Study Design/Methodology (include lab and data analyses to be employed):

One hundred and thirty (130) remote lakes, 95 for detailed assessment and 35 for water chemistry only, were visited by aircraft. For all lakes a water sample was obtained for detailed analysis (pH, conductivity, alkalinity, major ions, nutrients, aluminum, dissolved organic carbon). For 95 lakes bathymetric surveys were obtained. Plankton samples (zoo- and nanno-) were collected from these 95 lakes and were subsequently enumerated and identified. Fish were also collected from these lakes by gill net for age, growth, and tissue analysis. Mercury and aluminum in fish tissue was determined for length stratified subsamples, and for a number of top carnivors.

Lake sensitivity was established by nationally accepted criteria. Lake status was examined by models developed by Henriksen, Dillon, and others.

Assessment of planktonic community structure in relation to morphometric and chemical variables using principal component ordination factor analysis, stepwise multiple regression, and canonical correlation is ongoing (complete by March 1984).

Assessment of fish data has not been initiated.

#7.2

15. Results and Conclusions to Date:

One hundred and thirty (130) lakes, ranging in size from 5.0 to 1217.5 ha, were surveyed from August 16 to October 20, 1983. Ninety-five (95) lakes were sampled for morphometry, water chemistry, zoo- and nanno-plankton, and fish while thirty-five (35) lakes were surveyed for water chemistry only. Chemistry was variable between lakes with lithology, the major feature and input of marine aerosols, input of organic matter from the watershed, and atmosphere deposition of anthropogenic pollutants minor features controlling variability. Lake pH ranged from 4.80 to 7.84 (mean of 6.40) with three lakes of pH less than 5.50. Ninety-seven lakes and alkalinities of less than 200 μeq L-1 indicating moderate to high sensitivity to potential acidification. Excess sulphate values varied from 3.7 to 90.2 μeq L-1 (mean of 27.2). Total aluminum in lake water ranged from 10 to 394 μg L-1 (mean of 71). Models developed by Henriksen and others did not indicate strong evidence of anthropogence acidification in Labrador lakes, despite the high sensitivity of study systems. Ten fish species were netted from study lakes including brook trout, lake trout, arctic char, Atlantic salmon, lake whitefish, round whitefish, northern pike, white sucker, longnose sucker, and burbot. Aluminum and mercury levels were determined in tissue from 1191 fish. Long lived and/or piscivorous fish demonstrated the highest levels of mercury while there was strong evidence of bioaccumulation of mercury in several species.

16. Anticipated Outputs:

Publication as technical reports and/or in primary literature.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

18. Reports and Publications

Kendaris, T. A. 1983. An Acid Rain Inventory Survey of Selected Labrador Lakes. Technical Report (DSS File No. 07SC. FP001-2-1168) submitted to Fisheries and Oceans, Newfoundland Region, January 1983.

Scruton, D. A. 1983. (In press) A Survey of Selected Headwater Lakes in Labrador, with Special Reference to Acid Precipitation. Can. Tech. Rep. Fish. Aquat. Sci.

PROJECT INFORMATION FORM

1. Discipline: Project Number: 7.3

Aquatic/Fisheries

3. Agency and Department:

Department of Fisheries and Oceans

4. Project Title:

a) Monthly Survey of Water Chemistry on Selected Atlantic Salmon Rivers in Insular Newfoundland.

b) Survey of Water Chemistry on Labrador Rivers.

5. Principal Investigator(s) (include addresses):

Mr. David A. Scruton
Mr. H. Bain
Fisheries and Oceans
Newfoundland Region
P.O. Box 5667
St. John's, Newfoundland
A1C 5X1
(709) 772-4485

6. Cooperating Agencies and Investigators:

Contractors: 1) Memorial University of Newfoundland (water analysis - 1981/82)

2) Victoria Public Hospital, Environmental Chemistry Laboratory (water analysis - 1982/83)

3) Ocean Chem Ltd. (water analysis - 1983/84)

4) Environment Canada, Water Survey of Canada (water sample collection, Labrador, October 1982-March 1984)

7. Project Duration: a) May 1981-May 1982
b) August 1982-March 1984.

8. Resources (show PYs, capital and non-salary O&M by year):

		1981/82	1982/83	1983/84
a)	Person Years	0.5	0.5	0.5
b)	Operating and Maintenance ($000)	49	40	10
c)	Capital ($000)	-	-	-

#7.3

9. Service or Agency Objectives:

To protect freshwater and anadromous fisheries resources threatened by acid precipiation and related pollutants and ensure the long term maintenance of the social and economic benefits associated with the fisheries resources.

10. Project Objectives:

To determine the status and sensitivity of lentic systems in Newfoundland and Labrador to acid precipitation and the relationships to resident aquatic biota, particularly Atlantic salmon.

To examine the temporal variability in water chemistry of sensitive rivers and to determine if episodic problems do occur.

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

a) Insular Newfoundland
b) Labrador

12. Ecosystem Types Included in Research (where applicable):

Major river systems principally draining igneous geotypes.

In insular Newfoundland rivers were selected that had significant populations of Atlantic salmon, or potential to produce salmon.

13. Purpose or Hypotheses to be Examined:

To determine if the province's river systems are being significantly influenced by acidic deposition, and consequently if fish populations are limited or threatened by potential acidification.

14. Study Design/Methodology (include lab and data analyses to be employed):

Twenty four (24) river systems in insular Newfoundland were accessed monthly from May 1981 to May 1982 (13 months). A water sample was collected for analysis (pH, alkalinity, conductivity, major ions, nutrients, trace metals, dissolved organic carbon). Hydrological data from WSC gauging sites was later integrated (either directly or as extrapolated data).

Thirty-six (36) rivers in Labrador were sampled for water chemistry once in August 1982. Nine (9) guaging rivers in Labrador continue to be sampled opportunistically in connection with WSC guaging operations (to March 1984)

Water chemistry data for insular Newfoundland rivers is to be assessed in relation to watershed and hydrological characteristics. Volume weighted mean data and minimum data is to be assessed in relation to sensitivity indices and acidification models.

River systems on the island continue to be sampled opportunistically during high runoff periods.

#7.3

15. Results and Conclusions to Date:

Volume weighted mean pH for the 24 systems on the island ranged from 5.08 to 6.27 (mean of 5.65), with 20 systems in the 5.00 to 6.00 range, and no mean pH below 5.00. South coast rivers (n = 10) and Northern Peninsula rivers (n = 2) had the lowest average pH's of 5.46 and 5.44, respectively. Weighted mean alkalinity ranged from 9.5 to 64.0 eg L^{-1} (mean of 27.2). All rivers fell below the 200 eg L^{-1} standard for sensitivity, with 20 systems below the 40 eg L^{-1} standard for extreme sensitivity. River systems were all relatively highly coloured, with values ranging from 31 to 91. Eighteen systems had weighted mean values in excess of 50 and are classified as highly coloured. Excess sulphate values ranged from 27.8 to 65.1 eg L^{-1} (mean of 43.3). Four systems had pH minima below 5.00, and 16 systems below 5.50. Most rivers demonstrated pH depressions both in the spring and in the late fall. Twelve systems had a minimum alkalinity of 0 or less indicating bicarbonate exhaustion. Twenty systems are showing a sulphate dominance over bicarbonate. The annual range in pH varied from 0.96 to 2.28 units. Log discharge was strongly correlated to pH (negatively) on 14 systems; alkalinity (negatively) on 12 systems and to sulphate (positively) on 5 systems.

For the 36 rivers sampled in Labrador in 1982, pH's ranged from 5.15 to 7.17 with two rivers with pH of less than 6.00, and one with pH of greater than 7.00. Alkalinity ranged from 23 to 257 eg L^{-1}, with three systems having a value of less than 40 eg L-1 (extreme sensitivity), and one system with a value in excess of 200 eg L^{-1}.

Study results and results of an electrofishing survey (July 1983) on the south coast will be used to select a set of rivers for a continuing chemical and biological monitoring program. Rivers selected will be those demonstrating sensitivity and having good salmon producing habitat. Water chemistry, fish, and benthos will be monitored. Water chemistry monitoring will look at long term and episodic responses to deposition, aluminum availability and toxicity, and organic influences. Fish monitoring will look at population density, age class distribution, possibly growth and feeding, and will focus on fry producing habitats. Field studies may be supported by laboratory experiments (flow-through bioassays). Stream benthos will be monitored to investigate changes in diversity particularly in acid-sensitive taxa (e.g. Ephemeroptera).

More thorough evaluation of the data is ongoing.

16. Anticipated Outputs:

Presentation of results in technical reports and/or primary literature.

17. Identify Problems Encountered e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.:

NON REGIONAL CONTRACTS

PROJECT INFORMATION FORM

1. Discipline:

Aquatic/Fisheries

2. Project Number: 8.1

3. Agency and Department:

Department of fisheries and Oceans

4. Project Title:

Mechanism of Toxic Action of Hydrogen Ion and Aluminum on Fishes in Natural Waters

5. Principal Investigator(s) (include addresses):

H.H. Harvey, Professor, Dept. of Zoology, University of Toronto
Grant Fraser, Research Assistant

6. Cooperating Agencies and Investigators:

Fisheries and Oceans, University of Toronto, Ontario Ministry of the Environment

7. Project Duration:

1982-83

8. Resources (show PYs, capital and non-salary O&M by year):

Total budget = $3,443.62 (exclusive of salary of principal investigator).

9. Service or Agency Objectives:

D.F.O. Objectives: To establish the mechanism(s) of action of acid precipitation in the loss of fishes and fish populations from lakes and streams.

10. Project Objectives:

To separate the toxic components in acidified waters, Al and H^+ in terms of stress and mortality on rainbow trout. In this study stress is measured as changes in concentration of Na^+, K^+, Cl^-, in blood plasma, and as changes in concentration of Na^+, K^+, Ca^{2+}, Mg^{2+}, Cl^- in muscle tissue.

Project # 8.1

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Plastic Lake, Muskoka - Haliburton Regions, South-central Ontario

12. Ecosystem Types Included in Research (where applicable):

A lake susceptible to acid loading (alkalinity 20-40 micro-equivalent/liter), plus inlet and outlet streams. This lake has a history of episodic fish kills.

13. Purpose or Hypotheses to be Examined:

To date we have exposed rainbow trout to two different test conditions and monitored (at 4-hr intervals) changes in ionic composition of blood and muscle. These natural waters were:

1. Plastic Lake inlet, at pH 4.1 and total Al 320-340 µg/L.
2. Plastic Lake outlet, at pH 5.3 and total Al 70-87 µg/L.

Al speciation of the inlet stream yielded the following composition: organic 22%, Al^{3+} 4%, $AlOH^{2+}$ 1.5%, $Al(OH)_2^{+}$ 0.4%, Al F 44.2%, $Al F_2$ 27.2%, $Al F_3$ 0.6%

From these results it can be concluded that some natural waters are toxic to fishes, but it cannot be established how much of the stress was due to H^+ vs. Al^{3+}, $Al OH^{2+}$ and $Al(HO)_2^{+}$. The Al and H^+ effects could be disaggregated experimentally by either:

1. Removal of Al from the water of the inlet stream; this is difficult given that Al can not be easily chelated.
2. Increasing the H^+ conc. of the outlet stream from pH 5.3 to 4.1, with total Al conc. unchanged, and Al species monitored.
3. Decreasing the H^+ conc. of a portion of the inlet stream water, by addition of base, such as KOH. Again, Al species would be monitored.

14. Study Design/Methodology (include lab and data analyses to be employed):

Project # 8.

14. Study Design/Methodology (include lab and data analyses to be employed):

A portion of the outlet stream of Plastic Lake, at the base of the weir, was diverted into a head-box, where pH was adjusted manually to 4.1 with sulfuric acid. Flow into the head-box was constant and drip addition of H_2SO_4 monitored and adjusted frequently. A constant flow was drawn from the head-box and fed to the fish holding tank. Water chemistry parameters were measured on samples drawn from the holding tank. At the site and time of sampling, pH, alkalinity, fluoride, temperature and oxygen were determined. Water samples for laboratory analysis of all metals, sulfate and Al species were drawn in duplicate, twice daily.

Fish were obtained from the (soft-water) Milford Bay Trout Hatchery, as in previous studies. Control fish, transported from the hatchery showed no significant changes in ion concentration, pre-blood vs. post-transport. Thus we believe it is sound procedure to transfer fishes directly from the hatchery to the holding tank.

Blood and tissue analyses were conducted at the hatchery pre-transport, and at the experimental site at 0, 4, 8, 12,etc. to 48 hours. Based on our previous work, this spans the critical period of Al and H^+ toxicity, and the data would be comparable to our previous work on rainbow trout held in Plastic L. inlet and outlet streams.

A temporary field station (trailer) was established at the outlet-weir site at Plastic Lake, and was manned continuously during the study period.

Project # 8.1

15. Results and Conclusions to Date:

Rainbow trout exposed to inlet stream #1 of Plastic L. showed a rapid build-up of Al on the gills, and the loss of Na^+ and Cl^- from blood and muscle, coincident with low pH and high Al conc. in the water. In toxicity tests, all fish died in 24-48 hours. Trout held in lake outlet water, at higher pH and lower Al showed little effect, but trout held in outlet-stream water at (artificially) reduced pH and the same Al conc. showed gill, blood and muscle conditions intermediate between those of the first and second sites.

16. Anticipated Outputs:

1. Peer review and publication in a primary journal.
2. Incorporation of this information into the data base constituting the concern with acid loading to the environment, as exemplified by NRCC Publ. No. 18475 and the U.S. - Canada Memorandum of Intent.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

(a) Project remained within budget, hence not so constrained.

(b) Field work proceeded on schedule and without hitch; no constraints.

(c) Project was conducted within three jurisdictions and conflicts were avoided by discussions with all involved agencies in advance of research.

(d) Gill aluminum analysis and water aluminum speciation lagged other analyses, but all data processed statistically by December 1983.

PROJECT INFORMATION FORM

1. Discipline:

Aquatic/Fisheries

2. Project Number: 8.2

3. Agency and Department:

Department of Fisheries and Oceans

4. Project Title:

Status of the Biota and Mechanism of Action of Acid Stress in Acidifying Lakes of South-central Ontario

5. Principal Investigator(s) (include addresses):

Dr. H.H. Harvey	Dept. of Zoology	University of Toronto
Mr. M. McArdle	Dept. of Zoology	University of Toronto

6. Cooperating Agencies and Investigators:

Fisheries & Oceans, University of Toronto, Ontario Ministry of Environment

7. Project Duration:

May 1983 to March 1984

8. Resources (show PYs, capital and non-salary O&M by year):

Total budget = $8,574.74 (exclusive of university salary to principal investigator and chemical analysis of water)

9. Service or Agency Objectives:

a. Identification acid-stressed waters.

b. Description of the effects of such stress on fish populations.

10. Project Objectives:

The purpose of this study is to define the status of selected organisms in waters of low pH and alkalinity suspected of being in the process of acidifying. It is the further purpose that the biological information derived will be used as a surrogate for time-trend water chemistry data in the acidification concern.

Project # 8.2

11. Physiographic Region and Province(s) in Which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

South-central Ontario, Parry Sound - Muskoka - Haliburton

12. Ecosystem Types Included in Research (where applicable):

Lakes were chosen on the basis of alkalinity, pH and color (blue-green), including spotting of clear-water lakes by bush pilots.

13. Purpose or Hypotheses to be Examined:

In studies over the past 20 years we have defined the fish community and status of fish populations in several lake sets (Manitoulin 52 lakes, Bruce 62 lakes, La Cloche 68 lakes, Wawa 50 lakes, Muskoka-Haliburton 25 lakes, Parry Sound 11 lakes). Acid-stressed lakes have yielded a variety of effects apparent at the population level, such as reduced abundance, failed recruitment with the associated changes in age-class composition, altered growth rates, etc. These attributes of stressed fish populations are now being found in lakes from Parry Sound to Haliburton, far removed from any point source of emissions.

The thrust of this study is to: (1) Identify candidate lakes, based on recent measurements of pH and alkalinity (2) assess the status of the fish populations present (3) where these populations are in an identifiable state of flux, to examine fish status as a potential indicator of acidification stress.

14. Study Design/Methodology (include lab and data analyses to be employed):

Project # 8.2

Methods

1. Selection of candidate lakes on the basis of currently available data on color, pH, and alkalinity. Emphasis will be placed on blue- and green-water lakes, but with one or two dystrophic lakes in the sample. Geographically these lakes are located in "hot-spots" of low alkalinity in Hinden, Georgian Bay, Conger, Ferguson, and Lawrence Townships.

2. Inventory the fish populations by means of trammel, gill, trap and seine nets, plus baited and plastic traps. For larger species, record vital statistics and retain material for determination of age, samples of 50-100 fish, each major species, each lake, as per published accounts.

3. Data anlysis will take the form of (a) description of fish community and comparison with stressed and unstressed communities elsewhere; (b) description of age-class composition for sensitive fish species and comparison with results obtained from lakes known to have acidified recently.

4. A major effort will be made to put causality to observed perturbations of fish populations.

Project # 8.2

15. Results and Conclusions to Date:

Ten lakes (McDonald, South McDonald, North, East, Axe, Irvine, Fisher, Maggie, Little Coon, Cradle, were studied, July-October, 1983. These lakes ranged from pH 4.65 to 6.49 and 13 species of fishes were found in total. Maggie L. was devoid of fishes and a survey of benthic organisms (50 cores) was substituted for the fishes in the attempt to relate biota to degree of acidification. The ages of fish collected are being determined currently for description of age-class composition. Benthos samples have been floated and seived for identification. Water analyses have been completed.

16. Anticipated Outputs:

These data plus those already available may be enough to define the fish communities of acid-stressed lakes, Parry Sound - Haliburton. Certainly these lakes can be compared with known acid-stressed lakes of Wawa, La Cloche, etc. The benthos of Maggie L. will be compared with that of the 25 La Cloche and 22 Muskoka - Haliburton lakes. The age-class composition of the major fish populations will be compared with that of acid -stressed and unstressed lakes elsewhere in Ontario. Components of this work should be suitable for publication in (a) primary journals (b) volumes identifying the concern with acid deposition.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

(a) Funding was adequate for the data collection and data analysis identified above.

(b) Principal constraint was difficulty of lake access to small remote lakes, and the prohibitive cost of helicopter time.

(c) Good co-operation from all interested agencies.

(d) No problems re data availability.

III SOCIO - ECONOMIC PROGRAM

PROJECT INFORMATION FORM

1. Discipline:

Aquatic/Fisheries

2. Project Number: 9.1

3. Agency and Department:

Department of Fisheries & Oceans

4. Project Title:

Socio-Economic Evaluation of Recreational Fisheries Endangered by Acid Rain.

5. Principal Investigator(s) (include addresses):

Ray Rivers, Archie Tuomi
240 Sparks Street
Ottawa, Ontario
K1A 0E6

6. Cooperating Agencies and Investigators:

Ontario Ministries of Environment & Natural Resources
Québec Ministère d'Environement & Ministère du Loisir, de la Chasse et de la Pêche.
Department of Lands & Forests, Nova Scotia.

7. Project Duration:

Continuing and ongoing from 1981.

8. Resources (show PYs, capital and non-salary O&M by year):

	PY	Capital	O&M
80/81	0	0	$ 30,000
81/82	0	0	85,000
82/83	0	0	75,000
83/84	0	0	200,000

9. Service or Agency Objectives:

Socio-economic research with respect to fisheries & ocean related issues, policies and problems.

Project # 9.1

10. Project Objectives:

Socio-economic evaluation of present and future acid rain impacts for affected areas of Canada.

11. Physiographic Region and Province(s) in which Research Conducted (e.g. St. Lawrence Lowlands, Quebec):

Muskoka/Haliburton/Bracebridge regions of Ontario.
Province of Quebec.
Province of Nova Scotia.

12. Ecosystem Types Included in Research (where applicable):

Recreational Fish Habitat.

13. Purpose or Hypotheses to be Examined:

While various approaches to valuation of the recreational fisheries have been suggested, the successful application of values to these public goods were prices or fees charged are not relevant as a pricing mechanism has yet to be accomplished. The purpose of this effort is to obtain a set of values that are defensible and irrefutable for the resources at risk to acidic precipation.

14. Study Design/Methodology (include lab and data analyses to be employed):

The socio-economic models used for evaluation are currently in the state of development and have their basis in latest generation micro-economic theory. Data to be used in these models (hedonic and talhem "travel cost", contingency evaluation) will be obtained directly from samples of anglers and other Canadians. Estimates need to be made of option and existence values as well as the current use value.

These models will be tested in Ontario, Quebec and Nova Scotia for their ability to estimate consistently for a number of criteria.

15. Results and Conclusions to Date:

A 1983 study by the consulting firm of Victor and Burrell Consulting for the Department of Fisheries & Oceans and using the Talhem "Travel Cost" methodology arrived at a value of $17/angler

Project # 9.1

day use value for the Muskoka/Haliburton Region of Ontario. Difficulties with the data-used, and questions of representativeness of this region have led to

1) the requirement for comparing these results with those of other socio-economic models.

2) expanding the areas studied to test for stability of these recreational use values.

3) expanding the study to consider non-use valuation (option, existance).

16. Anticipated Outputs:

- A survey methodology for obtaining data for these models by April 1, 1984.

- Extensive Surveys of pilot regions - Ontario and Quebec summary of 1984.

- Preliminary results for Ontario and Quebec by April 1, 1985.

17. Identify Problems Encountered (e.g. funding limitations, unexpected constraints, jurisdictional, data availability, etc.):

Surveys of anglers, to be effective in terms of reliability, consistency, etc. have to be conducted when the anglers are either on-site or "fresh-from" site. This requirement limits the time horizon available for conducting the data gathering exercise. Before surveys can be conducted, banks of information need to be created, the public has to be informed, and all attempts must be made to avoid response and other types of bias from entering the survey. These demands are very heavy from the point of view of orchestrating the data gathering exercise.