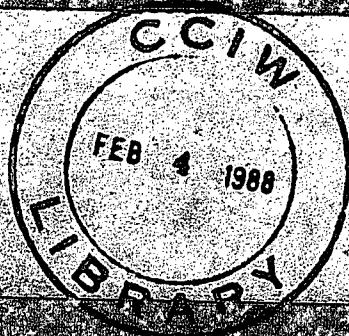


C. WATERS OR

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Inland  
Waters  
Directorate

Ontario  
Region

A REVIEW OF SOCIO-ECONOMIC  
IMPACTS OF LRTAP/ACID RAIN  
IN EASTERN CANADA

Direction  
générale  
des eaux  
intérieures

Region de  
l'Ontario

Canada

**L.J. D'Amore & Associates Ltd.**

**April, 1985**

**A REVIEW OF SOCIO-ECONOMIC  
IMPACTS OF LRTAP/ACID RAIN  
IN EASTERN CANADA**

A REVIEW OF SOCIO-ECONOMIC  
IMPACTS OF LRTAP/ACID RAIN  
IN EASTERN CANADA

PREPARED FOR: INLAND WATERS DIRECTORATE  
ENVIRONMENT CANADA

IN FULFILLMENT OF  
CONTRACT SERIAL NO. OSE84-00275

APRIL, 1985

L.J. D'AMORE & ASSOCIATES LTD.

# L.J. D'AMORE & ASSOCIATES LTD.

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May 28, 1984

Mr. T.C. Clarke  
Head, Planning Division  
Water Planning and Management  
Branch  
IWD, Ontario Region  
Department of Environment  
867 Lakeshore Road, P.O. Box 5050  
Burlington, Ontario  
L7R 4A6

Dear Mr. Clarke:

Attached is our report, "A Review of Socio-Economic Impacts of LRTAP/Acid Rain in Eastern Canada". This document examines impact statements from the most recent literature available to us.

Impacts are linked with biophysical damages to resources in each region to provide an overview of the problem as currently assessed. Assumptions, limitations, and reports of scientists and other concerned parties were noted to examine the estimates' validity and to consider the literature's relevance to those potentially affected by the problem.

In sum, we found that current studies are most concerned with impacts based on damages to resource commodities. Discussion of effects on human habitats, cultures, and lifestyles were secondary considerations, when observed. Assessment of future impacts was limited to standard discounting practices which downplay biophysical and social processes. In our view, present approaches are too narrowly defined to assess human impacts.

.../2

Mr. T.C. Clarke  
Page 2  
May 28, 1985

We have enjoyed working with you, Mr. Foerstal, Mr. Muir, and Mr. Reynolds on this assignment and would like to thank the many advisors who offered their assistance. In particular, we thank Daryl Cowell, Floyd Elder, Fern Filion, A.S. Fraser, G.A. Fraser, Mary McKennirey, Ken Minns, and Pierre Vachon for their time and comments.

Sincerely yours,



L.J. D'Amore

LJD/cs

## TABLE OF CONTENTS

	<u>Page</u>
EXECUTIVE SUMMARY .....	i
A. INTRODUCTION .....	1
B. REVIEW GUIDE .....	2
C. THE REVIEW	
Agriculture .....	4
Materials .....	11
Commercial Fisheries .....	20
Sport Fishery .....	25
Forestry .....	37
Humans (Health) .....	41
Wildlife .....	48
Comments and Discussion .....	54
D. APPENDICES .....	
a) Regional Summary Charts	
b) Bibliography	
c) Personal Communications	
d) List of Abbreviations	

## EXECUTIVE SUMMARY

Socio-economic research proceeds by translating physical data on effects and damages into dollar values. This may be done by identifying a resource inventory which receives acid depositions and applying a dose-response function to estimate damages.

Impacts are assessed by evaluating damages in terms appropriate to the resource as a market commodity. Impact statements thus reflect lost resource values, sometimes extended into employment and income losses. Future impacts may then be derived by discounting current values over an infinite time horizon, using a given discount rate.

Impacts on social (i.e., non-market) values are sometimes assessed by asking respondents to evaluate present and future opportunities for using a resource or engaging in a resource-based activity. These contingent valuations are usually expressed as respondents' willingness-to-pay for protection or future use of resources.

The reports present order-of-magnitude estimates for comparative purposes, rather than actual impacts. While these approximate relative current costs of LRTAP-related damages, statements do not adequately describe social impacts.

A summary of research conclusions and commentary from field sources illustrates the differing concerns of researchers and potentially affected citizens.

### Agriculture

- Damage estimates range between an annual yield loss of 85,000 tonnes (mostly carrots and beets) and a 10 percent reduction of the 1980 corn crop. One regional study, focusing on short- and long-range ozone damage, suggests potential yield losses for green beans, lettuce, radish, tobacco and others. One report cites a 152,000 tonne (1981) increment for potatoes.
- The variability of these findings reflects the early state of scientific research. No damage functions exist for most crops, and none are available from Canadian studies. Tenuous dose-response relationships probably invalidate damage estimates and impact statements.
- Socio-economic researchers rank impacts as low to moderate in relation to other resources. Statements range from a \$105 million (1980) loss to a contribution of nearly \$7 million.

**Field Comment:**

- Unlike researchers, agricultural federations, farmers and native groups expressed anxiety about potential effects. While causes are unknown, damage to various crops is observed. LRTAP/Acid rain is one of several suspected agents.
- Sources have experienced difficulty in obtaining information about crop damages. Respondents seek guidance to protect resources, and they request more Canadian research.
- Responses include:
  - setting up an environmental monitoring program on a reserve.
  - networking activities (information handbooks, local and national meetings, informal contact).
  - lobbying through the Canadian Coalition on Acid Rain (CCAR).

**Materials**

- Physical inventories are being upgraded through current research. Assessments focus on materials with an explicit economic value (mainly zinc galvanized surfaces and oil-based exterior paints).
- Nearly 37 million m<sup>2</sup> of surface area is affected, at a yearly cost of \$102 million. Most damages and maintenance costs occur in Ontario. Another estimate suggests costs ranging from \$310-470 million (1971) per year for atmospheric corrosion due to air pollutants. The proportion of these costs due to LRTAP/Acid Rain was not cited.
- Knowledge of impacts on materials of socio-cultural value is scant, although damage may be high. Almost 300 historic sites, parks, buildings and monuments are potentially affected. About 85 percent of these are found in Ontario.
- While economic loss is ranked moderate to high relative to other sources, researchers caution that damage due to sulfur dioxide and acid rain has not been distinguished from effects of other pollutants and environmental factors.

Field Comment:

- Although a constituency for commercial materials was not identified, there appears to be some concern about historic resources. Respondents noted that international research implies a need for abatement rather than more study.
- Efforts are apparently under way to assemble a committee of experts to serve as an advisory group to the Federal Government.

Commercial Fishery

- Three hundred ninety-one tonnes of the annual catch are lost, mostly from inland and Atlantic salmon fisheries. Losses are heavily concentrated in the Atlantic fishery. The Great Lakes are largely excluded.
- Socio-economic impacts include \$0.6 million/year in income loss and up to 7,500 person-years in lost employment. Impacts on fish processing and secondary income are assumed but not stated.
- The potential to assess damages is considered acceptable, but knowledge of impacts is low to moderate.

Field Comment:

- Local impacts can be serious for areas losing most of the resource. Maritime fishermen and local populations are sensitive to the loss of salmon rivers which account for a major share of local income and employment.
- Responses are both regional and international, and range from lobbying governments to publicizing damages. The U.S. government was cited as a key lobby target.
- Joint citizen-government action was reported in the Gaspé region of Quebec where commercial salmon fishermen are encouraged to replenish fish stocks.

### Sport Fishery

- Fishing at risk includes both resident and non-resident (tourism-related) activity. Angling mostly occurs in Ontario, although Quebec has the largest affected water surface area.
- Biophysical damage is high relative to resources considered to be at risk. An 8.5 percent annual loss in fish stocks is estimated. Another study cites a 3.6 percent annual productivity loss, excluding moderately sensitive lakes.
- A yearly loss of 3.7 million angler days (due to reduced fish stocks) generates a total loss of \$63 million (1981). Another report estimates a \$50 million (1980) loss due to moderate acidification.
- Regional employment losses could total 1,540 person-years, resulting in \$25 million of lost regional income. Almost \$16 million of the loss (on expenditures of \$26 million) is attributed to Ontario. An Ontario study estimates a loss in expenditures of about \$7 million (no income loss cited). Estimates' variance reflects different assumptions about size of affected fish stocks, extent of recruitment losses and range of economic activities affected.
- Recent scientific findings suggest that damages and impacts are underrated due to an upward revision in estimated affected surface waters--from 94,650 km<sup>2</sup> to 161,890 km<sup>2</sup>.

### Field Comment:

- Sport fishing interests were among the first groups to publicize acid rain. Awareness, organization and diversity of involved groups lead most resource sectors.
- Respondents see risks to be greater than researchers' estimates. One source noted that \$600 million directly related to boating expenditures was at risk. The top research estimate of total direct expenditures at risk is \$500 million.
- Sources were very concerned that industries and whole local economies are heavily damaged by acid rain. Most feel that sufficient research exists to document damages, and that emissions abatement should be the main priority.

- Responses range from membership in CCAR to advocacy of tourism bans concerning the Quebec fishery.

### Forestry

- Research has not verified damages. Usable dose-response functions are not available. Damage to forest productivity and dieback of some species is suspected.
- While absence of data on the rate and ratio of damages precludes risk estimates, the value of resources within deposition zones is substantial (i.e., \$4 billion in yearly production, excluding the pulp and paper industry).
- Research started in 1984 to monitor effects of acid rain on forests may help establish damages.

### Field Comment:

- Attention is focusing on forests through the sugar maple dieback issue. Studies conducted in Quebec have confirmed damages, with acid rain as one of the suspected agents (especially in the Beauce region).
- Ontario woodlot owners have also noticed dieback of maple and other species, but no estimates of affected production were discovered.
- The range and number of concerned interests appears to be growing. Unions and industry are starting to discuss mutual interests. The pulp and paper industry has formed a committee to assess potential impacts. Woodlots are being monitored as part of an environmental assessment program on an Ontario reserve.
- Uncertainty and anxiety about impacts also appear to be growing. Suspected future impacts include mill closures, loss of jobs, income loss for lot owners and syrup producers, long-term damage to forests and extinction of tree species, degradation of crop lands, threats to community life, social instability and reduced confidence in government.

### Human Health

- Aggravation of respiratory ailments for younger and older persons is suspected. Contamination due to mobilization of metals in water distribution systems and in the food chain is also considered possible, but not as likely.

- One estimate cites 34,000 morbidity incidents (linked with respiratory problems) and over 4,000 premature deaths related to LRTAP/acid rain. Values for lost productivity and health care costs are estimated at \$54 million (respiratory) and \$292 million (all diseases) annually. The figure for all diseases is considered highly speculative.
- Absence of research and damage functions suggest that potential to quantify impacts is low.

**Field Comment:**

- Canadian health associations are apparently slow to recognize LRTAP-related health issues, although groups such as the American Lung Association are active in the U.S.
- Municipal health administrators and social planners are just beginning to question impacts. One source is involved in a project to observe impacts on persons at various life-cycle stages. Another cited uncertainty about effects and the conservatism of the medical establishment as factors working against further action.
- Growing publicity about health risks from toxic contaminants has helped decentralize medical research in one Ontario city. Further development of this precedent is foreseen, with communities taking an active role in assessing local health effects.

**Wildlife**

- Damage and socio-economic estimates are not available. Effects on hunting, recreation, well-being and way-of-life are proposed but not assessed.
- Damages are suspected for amphibians, waterfowl, nesting birds and terrestrial mammals. Impacts could include reduced aesthetics and hunting values, reflected by income and employment losses. The lack of inventories and damage functions precludes estimation of impacts.

**Field Comment:**

- Sources echo responses of other constituencies (i.e., cut emissions, lobby government, monitor research), but stress interest in the environment as a whole.
- Respondents acknowledge that reductions of wildlife species are not as dramatic as with other resources.

General

Field comment also stresses that government has not anticipated social concerns, nor responded to local problems, although some respondents acknowledge the federal abatement strategy as a first step.

Other sources dealt with general and connected issues. Some perceive acid rain as a byproduct of energy-intensive development. Others draw links between "high-growth" development strategies and pollution, or discuss acid rain in the context of nuclear disarmament, Canada-U.S. relations, free trade and social services.

The scope and development of opinion and organization suggests that environmental activism is here to stay. Support for environmental issues despite recession and irregular growth, conservation, and awareness of fundamental issues suggests continued pressure for abatement options. Attention to previously unconnected policy sectors such as health, energy and external affairs could also increase.

## INTRODUCTION

The purpose of this review is to assemble, synthesize, and assess current knowledge of socio-economic impacts of LRTAP/Acid Rain in Eastern Canada. The review examines damage estimates and impact statements in light of recent scientific research and comments from field sources. From this exercise emerges a discussion of the literature's relevance to social concerns and potential for noting social impacts.

Our investigation began after obtaining the most recent reports available on physical effects, damages and socio-economic impacts. Initial contact was made with sources in the relevant federal agencies, including the Inland Waters and Land Directorates of Environment Canada, Environmental Protection Service, the Canadian Forestry and Wildlife Services, Department of Fisheries and Oceans, and Health and Welfare Canada.

Preliminary findings were profiled in an interim draft report, and presented to scientific and socio-economic advisors for commentary. Advisors reviewed the draft's content and suggested changes in format. We then approached key researchers to assess damage functions used in the socio-economic reports, and to discuss research trends and developments.

During the project's concluding phase, we contacted a wider range of field sources, including provincial and regional officials, local groups, potentially affected interests, and Non-Governmental Organizations to identify impacts and issues that concern them. Their views were then considered in terms of general research priorities, and contrasted with researchers' opinions on the scope and nature of the threat to resource receptors.

The socio-economic estimates presented are generally considered as orders of magnitude rather than actual impacts due to the uncertainty of dose-response relationships linking LRTAP with physical damages. However, these figures do offer a preliminary assessment of LRTAP-related impacts within current and future contexts. In so doing, this review offers a fairly complete inventory of the most recent and relevant literature to date.

## REVIEW GUIDE

The review is arranged in chart form to facilitate access to general and regional data. The charts consist of four basic categories:

- (1) causal agents,
- (2) damage estimates,
- (3) socio-economic impacts, and
- (4) comments.

Read in this sequence, the format conveys: (1) a description of biophysical effects specifically related to each impact statement, (2) the range of physical damages estimated to occur due to LRTAP/Acid Rain, (3) the socio-economic impacts derived from these damages, primarily expressed in terms of changed resource values, income and employment, (4) assumptions, estimate limitations, and recent findings bearing on each study under review.

Reviewed reports (in parentheses) are listed under these four categories within each resource section. The resource sections are:

- Agriculture,
- Building Materials,
- Commercial Fishery,
- Sport Fishery,
- Forestry,
- Humans (Health), and
- Wildlife.

Each section first presents data for Eastern Canada, followed by disclosures for Atlantic, Quebec, and Ontario regions. While some reports present both consolidated and regional estimates, others discuss impacts for one region only.

Impact statements are based on deposition of sulphuric and nitric acids, considered in terms of both direct and indirect effects. Some studies identify long-range transport of sulphur and nitrogen oxides mixed with ozone, but short-range air pollutants have been excluded.

Communications with experts, local officials, and group spokespersons contribute to our assessment of the literature in the Comments and Discussion section. This section considers the potential of socio-economic research to discern human impacts.

An Executive Summary profiles key estimates, and contrasts researchers' assessments with field sources. Responses are given for each resource receptor. Regional Summary Charts offering a concise range of figures by region are found in the Appendices.

The geographic scope of this review is confined to Eastern Canada as it is considered the area within Canada most seriously affected by LRTAP/Acid Rain. Localized and potential LRTAP-related problems may exist in Western Canada, but sensitive receptors are not considered subject to comparable emission levels or deposition loadings.

In sum, this document covers the most recent available information concerning our topic. Reports in process and some internal studies were unavailable for review. Methodology studies were excluded unless these offered recent estimates. Scientific opinion was canvassed, and some key papers included, but an exhaustive survey of this literature was not intended.\*

\*Scientific references are either cited directly, or as secondary sources from (a) socio-economic reports, and (b) personal communications with researchers. Citations from reports appear under main entries, and are identified by encapsulation of publication dates following the author's name. Personal communications are preceded by the abbreviation, PC. All references are listed in the appendix under the appropriate heading.

THE REVIEW

RECEPTOR: AGRICULTURECAUSAL AGENTS

- (DPA: August 1984) Direct acidic deposition involving effects of nitrogen and sulphur oxides derived from LRIFAP. Net response of crops a function of positive sulphur and nitrogen fertilization, negative effects of acidity, and interaction of these factors with soil characteristics, climate, other pollutants. Indirect effects through soil (considered minimal) and effects of photochemical oxidants (considered significant) are not included.

Effects observed for Eastern Canada.

- (Forster: November 1984) Acid deposition and transported ozone (long and short range)\* both alone, and in combination with SO<sub>2</sub> and NO<sub>x</sub>. Damage estimates are based on assumed ambient concentrations of 0.04 ppm to 0.05 ppm. Both direct exposure to pollutants and indirect effects through changes in soil quality are considered. Effects observed for Eastern Canada.

\* Note: Reports estimate effects linked with acid deposition and long-range transport of ozone. LR ozone estimates include short-range effects as proportionate impacts not indicated.

DAMAGE ESTIMATES

- (DPA: August 1984) Damages based on productivity change defined in terms of: 1) Yield loss of marketable crops and 2) foliar damage (percent of injured leaf area). Study uses loss coefficients from Lee et. al. (1981), and Evans and Lewin (1981) to translate productivity changes into socio-economic values. (See comments.) Losses for Eastern Canada estimated at 85,221 tonnes (1981)--due mostly to reduced carrot production.

Yield increments of 151,735 tonnes were attributed to acid rain (based on Lee et. al.). Potato crop represents 90 percent of increment. Onion, cauliflower, tobacco, beets, and lettuce crops also benefit.

Both losses and increments are assessed at pH 4.0 seasonal average. Effects on animal husbandry not assessed.

- (Forster: November 1984) Acid deposition: yield reductions for corn and soybeans only damages considered as estimates based on U.S. experimental field evidence of 9 percent decline in yield at pH 4.0. If results hold for Canada, the 1980 corn crop may have been reduced by 10 percent.

LR ozone: Most significant damage factor for crops on north shore of Lake Erie. Yield losses vary from moderate (1975-78) to severe (1973, 75). Soybeans, corn and wheat represent most significant losses in Ontario based on NCLAN (1983). Physical production losses not cited for relevant area.

Acid deposition unlikely to cause deterioration in soil quality for properly-managed lands, although marginal lands characterized by low cation base and exchange capacity are sensitive. 1.75 million ha or 16 percent of total agricultural lands in Eastern Canada are classified as sensitive. Yield losses are not estimated for these lands.

Effects on animal husbandry not assessed.

RECEPTOR: AGRICULTURECAUSAL AGENTSDAMAGE ESTIMATESAtlantic Region

- (DPA: August 1984) Productivity increment of 90,124 tonnes at pH 4.0 (mostly potatoes in P.E.I. and New Brunswick). Loss of 9,156 tonnes representing 27 percent of the region's carrot production at pH 4.25, net increment - 80,968 tonnes (1981). Foliar damage of 4 tonnes for beets at pH 4.0 (P.E.I. - 3 tonnes/N.S. - 1 tonne).

- (Forster: November 1984) Direct damages not assessed. Indirect damage inferred for sensitive agricultural land - especially in P.E.I. where 215,433 ha (77.5 percent of total) is rated sensitive (1981). However, fertilizer contributes nearly three times as much to soil acidity as atmospheric sources (Coote et al.: (1981)). No crop or livestock damages are assessed.

Note: SEDAP(1981) identifies feed and forage crops, potatoes, tobacco, Livestock, and dairying as the main resources based on this land but does not assess damages. New Brunswick: pockets of sensitive soils are found south of Chaleur Bay and around Chatham where livestock, dairying, forage crops and pasture dominate.

RECEPTOR: AGRICULTURECAUSAL AGENTSDAMAGE ESTIMATESQuebec

- (DPA: August 1984) Productivity increment of 25,900 tonnes at pH 4.0 (mainly potatoes). Loss of 38,443 tonnes, mostly carrots with some spinach at pH 4.18-4.47. Net yield loss - 12,543 tonnes (1981). Foliar damage of 16 tonnes to beets at pH 4.0.
- (Forster: November 1984) Best land in central St. Lawrence lowlands of Montreal plain receive high deposition, constitute major concern. Corn grown in this area considered sensitive to acidic deposition, but no yield loss estimated. Concern also re marginal and mismanaged soils, since atmospheric contributions exceed 40 percent of total soil acidity.  
Indicates upper Ottawa and Saguenay Valleys; north shore of St. Lawrence from Trois Rivières to Quebec City has sensitive land which support market gardening and dairying. No damages cited.

Ontario

- (DPA: August 1984) Increment of 35,711 tonnes at pH 4.0 (mainly potatoes, followed by cauliflower, onion and tobacco). Loss of 37,622 tonnes, mostly carrots with some spinach and radish at pH 4.07-5.02. Net yield loss - 1,911 tonnes (1981). Foliar damage of 18 tonnes for beets at pH 4.0.
- (Forster: November 1984) Most of 10 percent yield loss for Eastern Canada corn crop (1980) occurred here due to acid deposition. For LR ozone, corn yield reduction of <3.1 percent at 0.04 ppm. Specific volume not cited. Other crops affected are tobacco (up to 35 percent foliar injury near lakeshore, but <1 percent further inland), soybeans and wheat. Soil mediated damages not significant.

RECEPTOR: AGRICULTURECAUSAL AGENTSDAMAGE ESTIMATES

- (Linzon et al: Jan. 1984) Study considers effects of photochemical oxidants ( $O_3$ , PAN,  $NO_2$ ) on vegetation, produced through atmospheric reactions between hydrocarbons and nitrogen oxides emitted during combustion of fossil fuels.
- This review omits most ozone effects. Study noted in view of long-range ozone deposition reported by Forster (1984).
- Combination of  $O_3$  with  $NO_2$  and  $SO_2$  may act synergistically on Ontario crops (tobacco, soybeans and radishes).

Ontario (continued)

- (Linzon et al: Jan. 1984) Experimental damages reported for tobacco, tomatoes, onions, grapes and cucumbers with relevance to Ontario species. Various studies in NE USA suggest potential yield losses for green beans, lettuce, radish, rutabaga, soybean, spinach, sweet corn and wheat crops. Crops grown in ozone region 5, primarily covering north shore area of Lake Erie (prime receptor of long-range ozone). Yield losses not reported by region.

Experimental results show that low levels of  $NO_2$  (0.10 ppm) with  $SO_2$  (0.10 ppm) injured 5 plant species. Tingley et al (1971). Preliminary study Heck (1968) showed mix of  $NO_2$ ,  $SO_2$  and 0 each at 0.05 ppm injured tobacco plants. Menser & Heggstad (1966) report tobacco plants suffered 25-38 percent leaf damage at 2 hour exposure to  $SO_2$  (0.24 ppm) and 0<sub>3</sub> (0.27 ppm). Reinert & Gray (1981) indicate reduced radish growth from mix of  $SO_2$ ,  $NO_2$  and 0 at 0.2 or 0.4 ppm for 3 or 6 hours' exposure. Jacobson et al (1980) show reduced growth and yield of soybeans with 3 rain treatments of pH 2.8, 3.4 and 4.0.

Estimates of related yield reductions unavailable.

SOCIO-ECONOMIC IMPACTSRECEPTOR: AGRICULTURECOMMENTS

- (DPA: August 1984) Estimates represent changes in producer surplus, with unit crop values applied to damage estimates. Annual producer surplus loss in crop production due to LRTAP - \$10.786 million (1981), plus \$0.005 million attributed to beet foliar damage.

Present value of future losses discounted by 10% annually is \$108 million for Eastern Canada. Annual losses assumed to remain constant.

- (DPA: August 1984) Study recognizes limitations of translating experimental results to yield loss coefficients. Results not obtained under natural field conditions, thus (1) may not be reproduced, (2) omit assessment of O<sub>3</sub>-SO<sub>2</sub> combinations (3) disregard episodic deposition events of low pH ( 3.9) which may augment direct damages.

PC: Field research by Irving (1983) indicates visible foliar damage due to LRTAP events, but no yield reduction for Amsoy cultivar.

Overestimation of damage may also occur as estimates based on loss coefficients for pH 4.0, which is less than average levels at monitoring stations.

Economic assessment limited by omission of potential crop substitution. Authors hypothesize that prolonged crop reductions would prompt crop-switching to more resilient species.

PC: Loss coefficients derived from Lee et al (1981) and Evans and Lewin (1981) have been superseded by more recent research. Shriner and Evans regard Evans (1983, 1984), Banwart (1983, 1984) and Moskowitz (1984) as more accurate re dose-response relationships. Moskowitz notes that recent studies suggest a range of non-linear d-r relationships for different crop species. Data for soybeans more accurate than for other crops.

PC: Estimates of productivity increments for potatoes undermined by difficulty of projecting damage function from Amsoy cultivar to other crops. Field studies on potatoes by Pell (1982, 1983) showed no effects either way.

<u>RECEPTOR: AGRICULTURE</u>	<u>COMMENTS</u>
<u>SOCIO-ECONOMIC IMPACTS</u>	
<ul style="list-style-type: none"> <li>• (Forster: November 1984) Major impact is \$105 million loss for 1980 corn crop in Eastern Canada, based on Lee &amp; Neely (1980) yield-loss estimate.</li> </ul> <p>Estimates not cited for long-range O<sub>3</sub>, although receptor area (Lake Erie north shore) produces high proportion of effected crops. Eastern Canada: estimated total loss of potential production is \$23 million (1980) for corn, soybeans, and wheat. No assessment of other sensitive crops.</p> <p>Estimates not cited for soil-mediated effects. Affects poorly managed and marginal soils. Agricultural soils receive net benefit from acid deposition due to productivity gains from sulphate input, valued at \$2.6 million (1980). Estimate represents increased timing costs less estimated market cost of sulphate input.</p>	<ul style="list-style-type: none"> <li>• (Forster: November 1984) Corn loss estimate regarded as highly speculative given uncertainty of Lee &amp; Neely results. (1) Findings not replicated in year two of study, (2) Results based on greenhouse experiments (transfer to field debatable) and, (3) subject to constant rain chemistry rather than episodic depositions.</li> </ul> <p>Value of atmospheric sulphur input (1980 Cdn \$58.50 per long ton). Assumed that increased consumption of low sulphur fuels and reduced SO<sub>2</sub> emissions will cause sulphate deficiencies in soil. Note: No yield increments or rate of sulphur reduction reported.</p>

SOCIO-ECONOMIC IMPACTS

Atlantic Region

- (DPA: August 1984) Current value of yield increments (1981) is \$8.1 million, most of which shared between New Brunswick and P.E.I. re value of potato crop. Value of yield loss is \$1.1 million. Net value of increment is \$7 million.

Affected areas:

New Brunswick - St. John River Valley; Carleton, Victoria and York Counties (potatoes); Victoria County (processing)

Nova Scotia - Annapolis Valley (cash crops); Kentville, Berwick (processing)

P.E.I. - east Kings, west Queens counties (potatoes); Bedeque, New Annan (processing)

Newfoundland - Grand Falls, Bishops Falls, Deer Lake, Lethbridge (mixed vegetables)

COMMENTS

- (DPA: August 1984) Current value of yield increments (1981) is \$3.5 million. Value of yield loss is \$4.6 million. Net loss is \$1.1 million. Yield loss of carrot offsets increment to potato crop.

Affected areas: not indicated.

SOCIO-ECONOMIC IMPACTSOntario

• (DPA: August 1984) Current value of yield increments (1981) is \$5.9 million. Value of yield loss is \$4.1 million. Net increment is \$1.8 million. Potato crop accounts for 60 percent of increment value, but cauliflower, tobacco and onion crops also important.

Affected areas: Niagara peninsula, Southwestern Ontario (mixed vegetables); Lake Erie counties (tobacco); Niagara, Toronto-Centred region, Kitchener-Waterloo (processing).

• (Linzon et al: Jan. 1984) Five crops (soybeans, potatoes, tobacco, white beans, wheat) account for 80 percent of total potential benefits due to  $O_3$  reduction. 70 percent of potential benefits would occur in Region 5 (mostly lower Southwest Ontario north of Lake Erie). Potential benefits to farmers in Region 5 range from \$5.8 million to \$13.6 million for these crops (1978-80 average).

No distinctions made between short and long-range  $O_3$  transport. No estimates for combined  $O_3$ /Acid deposition.

RECEPTOR: AGRICULTURECOMMENTS

- (DPA: August 1984) Economic benefits of reduced crop damage assume increase in crop yields through reduction of  $O_3$  concentrations from 0.05 ppm (7 hour seasonal mean) to 0.03 ppm or less. Yield of various crops according to locations included in dose-response functions. See pp 31-39 for method.
- (Linzon et al: Jan. 1984) Economic benefits of reduced crop damage assume increase in crop yields through reduction of  $O_3$  concentrations from 0.05 ppm (7 hour seasonal mean) to 0.03 ppm or less. Yield of various crops according to locations included in dose-response functions. See pp 31-39 for method.

Authors suggest results may be overstated if production increments entail extra costs. Production varies yearly, but no forecasts for production or prices available. Estimates indicate orders of magnitude, not precise benefit forecasts.

RECEPTOR: MATERIALSCAUSAL AGENTS

- (DPA: August 1984) Report considers impact  $\text{SO}_2$ ,  $\text{SO}_4$ ,  $\text{NO}_x$  (Not O<sub>3</sub>). Four types of physical damage to materials associated with LRTAP:

- 1) Corrosion: (Metals) Must distinguish between local pollutant sources and LRTAP.
- 2) Service Life of Paints and Coatings: While zinc is used as a protective coating for steel products, coating can be corroded by  $\text{SO}_2$  at a rate which is a function of the  $\text{SO}_2$  concentration, time of wetness, etc... Paint erosion results from the action of  $\text{SO}_2$ , light, and O<sub>3</sub>.
- 3) Acid Absorption:  $\text{SO}_2$  can be a source of absorbed acid in fabrics, papers, and leather.
- 4) Weathering of Inorganic Building Materials: Erosion occurs more rapidly in presence of  $\text{SO}_2$ . Difficult to determine whether physical impact on these materials due to LRTAP or to effect of high relative humidity, abrupt temperature changes, or micro organisms.

DAMAGE ESTIMATES

- (DPA: August 1984) Zinc, galvanized metals, and oil based exterior paints are estimated to account for 52 percent of the economic losses due to LRTAP (Salmon, 1970).
- As most sensitive materials normally protected (galvanized and/or painted), damage functions that relate damage to paint and zinc to the ambient levels of sulphur dioxide more useful than corrosion data.
- As estimates of inventory at risk based on consumption per capita of material resources, most damage occurs in heavily populated provinces, Ontario and Quebec account for over 98 percent of increments in maintenance requirements.

CAUSAL AGENTSRECEPTOR: MATERIALSDAMAGE ESTIMATES

- (DPA: August 1984)
  - Inventories and LRTAP impacts are based on consumption data.
  - Consumption estimates are given in weight measures (kg) and converted to surface measures ( $m^2$ ) indicating surface area exposed to acid deposition.
  - Estimates of the total stock of resources at risk in each deposition zone derived applying above coefficients to population figures.
- (Shaffer: March 1981)
  - Agents not specified for estimates. Discussion follows on mechanisms of atmospheric corrosion.
  - Review of corrosion studies indicates damage to oil-based exterior paint and zinc most evident. Fibers, concrete, nickel, rubber, tin, plastics, aluminum, copper deteriorate to lesser extent. Physical damage rates not cited.

RECEPTOR: MATERIAL

CAUSAL AGENTSDAMAGE ESTIMATESAtlantic region

**Incremental maintenance requirements based on reduced coating life:**

galvanized materials	wire:	249 thousand m <sup>2</sup> /yr	(20-40 kg/ha/yr)
	sheet:	430 thousand m <sup>2</sup> /yr	(20-40 kg/ha/yr)
	profile:	135 thousand m <sup>2</sup> /yr	(20-40 kg/ha/yr)

oil-based painted surface: 39 thousand m<sup>2</sup>/yr (20-40 kg/ha/yr)

Damage estimates for Newfoundland not available.

Quebec

**Incremental maintenance requirements based on reduced coating life:**

galvanized materials	wire:	2.4 million m <sup>2</sup> /yr
	sheet:	4.2 million m <sup>2</sup> /yr
	profile:	1.3 million m <sup>2</sup> /yr

oil-based painted surface: 0.4 million m<sup>2</sup>/yr

98% of damage within deposition regime 20-40 kg/ha/yr

Ontario

**Incremental maintenance requirements based on reduced coating life:**

galvanized materials	wire:	7.9 million m <sup>2</sup> /yr
	sheet:	13.8 million m <sup>2</sup> /yr
	profile:	4.3 million m <sup>2</sup> /yr

oil-based painted surface: 1.3 million m<sup>2</sup>/yr

Nearly 80% of damages within deposition regime > 40 kg/ha/yr

<u>RECEPTOR: MATERIALS</u>	<u>COMMENTS</u>
<u>SOCIO-ECONOMIC IMPACTS</u>	
• (DPA: August 1984)	• (DPA: August 1984)
-Impacts of LRTAP can be divided into two groups:	Estimates for economic losses given in terms of maintenance costs only.
1) Effects on resources of sociocultural value.	Selected materials include galvanized wire, sheet, and profile and oil-based paint. Reasons for selection:
2) Effects on products of economic value.	-metals and paints constitute 52 percent of the economic losses due to the action of air-pollution on materials Salmon (1970)
-Many masonry buildings, sculptures, stained glass windows, and archeological sites are susceptible to LRTAP damage.	Estimate limitations include:
Difficult to ascribe a monetary value to sociocultural resources since market values do not apply.	-limitations to list of materials covered (only paint and galvanized materials)
-NOI (1983) lists affected national historic sites, buildings, museums and monuments (see regional breakdown).	-Inventory estimates - resources at risk among provinces and deposition zones are estimated using per capita consumption and population distributions. (areas of industrial and commercial activity not examined separately)
-Impacts regarding products of economic value:	-Physical damage estimates - as rated difficult to estimate damage due solely to LRTAP. Combinations of pollutants and other factors could produce compounding effects not captured in estimates. (ie. some dose-response functions based on laboratory studies of corrosion rates)
1) Financial losses - direct effects of incomes and expenditures.	-Labour costs of installation and replacements not determined.
2) Amenity losses - based on attributes (eg. view of historic building) which do not have market value.	The socioeconomic impacts on sociocultural resources not estimated. No evaluation of lost benefits of works of art, architecture, etc. was attempted.
-Maler and Wyzga (1976) list types of financial losses:	
1) <u>Replacements costs</u> : the principle impact is to reduce the longevity (or service life) of a material.	Study in process (Leman Consultants) to quantify urban materials subject to atmospheric pollutants in Eastern Canada. Results expected to assist future analysis of LRTAP-related materials costs.
2) <u>Reduced productivity costs</u> : LRTAP may impair the productivity on service performance of a material.	
3) <u>Design costs</u> : LRTAP may necessitate the redesign of a product using a satisfactory substitute material.	

SOCIO-ECONOMIC IMPACTSRECEPTOR: MATERIALSCOMMENTS

## ● (DPA: August 1984)

- 4) Production costs: For a product to be useful in the presence of LRTAP, protective coatings may be applied.
- 5) Maintenance costs: Cleaning of material may be required due to LRTAP.
- Maler and Wynga (1976) also list the following amenity losses:
- losses due to soiled materials
  - losses due to damaged materials
  - losses due to inferior materials.

Incremental materials maintenance costs as a result of LRTAP are estimated at about \$102 million per year. Over half of the cost (\$51 million/year) is related to damage to galvanized wire. Another third (\$35 million/year) is accounted for by galvanized profile. Galvanized sheet accounts for 13 percent or \$13.2 million. Oil-based exterior paint accounts for 3 percent or \$3.2 million.

## ● (DPA: August 1984)

- materials expected to be significantly affected by acid deposition (ie. high rating).
- damage functions are known or can be reasonably estimated.
- sufficient information to develop inventory for affected areas of Canada..

-cost estimates have been extrapolated on straight line trend basis. Implies that LRTAP levels remain constant over time, and dose-response (hence, annual physical damage) does not change from year to year.

-under these assumptions the long-term cost is about \$1 billion.

Note: present value

-long-term impacts discounted over an infinite time horizon, using a discount rate of 10 percent.

SOCIO-ECONOMIC IMPACTSRECEPTOR: MATERIALSCOMMENTS

## • (Shaffer: March 1981)

(Shaffer: May 1981) Total cost of corrosion in U.S. is 4.2 percent of GNP (National Bureau of Standards). Cost related to air pollutants is 5 to 8 percent of corrosion cost. Similar percentages expected for Canada.

Canadian costs due to air pollutants: \$310-470 million (1971) per year. Proportion of costs due to LRATP/Acid Rain not cited.

## • (Shaffer: March 1981)

Estimate based on input-output analysis of U.S. economy by Battelle Columbus Laboratories (1975). Original estimate adjusted downward from 4.9 to 4.2 percent.

Corrosion costs include replacement of equipment and buildings, maintenance and repair, engineering research and development, corrosion control, design and insurance costs, excess capacity, and product loss. First four elements ascribed to air pollutant costs.

Upward NBS cost estimate exceeded by 70% (\$9.5 billion/yr.) in one report reviewed by Shaffer. Extreme variability in estimates suggests low degree of accuracy for results.

RECEPTOR: MATERIALSSOCIO-ECONOMIC IMPACTSAtlantic Region(DPA: August 1984)

Actual physical damages to materials relatively minor. Materials maintenance costs amount to \$2.4 million per year. Nova Scotia experiences over 50 percent of costs and damages in region followed by New Brunswick and P.E.I. Costs in Newfoundland negligible.

About 25 percent of the historic sites at risk in Eastern Canada are in region. Over half in Nova Scotia.

Quebec

(DPA: August 1984) -annual incremental materials maintenance costs amount to \$23 million.

-only 37 percent of Quebec's material resources at risk to LRTAP situated in the sulphate deposition zone of over 40 kg/ha/yr.

-Some 21 percent of Eastern Canada's historic sites at risk are in Quebec.

Ontario

(DPA: August 1984) Ontario experiences the most damage in Eastern Canada.

-annual incremental materials maintenance costs of \$76 million.

COMMENTS(DPA: August 1984)

-Geographic distribution of resources at risk parallels population density, with over half the resources located in Ontario. Difficult to estimate damage to materials due solely to LRTAP because of simultaneous impacts of other air pollutants or atmospheric conditions.

SOCIO-ECONOMIC IMPACTS

• (DPA: August 1984)

Ontario (continued)

-due to high population density/concentration of materials/zones of high sulfate deposition, Ontario's relative share of actual damages rises to 75 percent of total for Eastern Canada.

Roughly 83 percent of the damage to selected materials occurs in the zone of the highest sulfate deposition ( 40 kg/ha/yr).

Over 51 percent of exposed historic sites in Eastern Canada located here (mostly in zones of high sulfate deposition).

RECEPTOR: MATERIALSCOMMENTS

RECEPTOR: COMMERCIAL FISHERIESCAUSAL AGENTS

- (DPA: August 1984) Fishing resources affected by acid precipitation or from leaching acidified soils (including snowmelts)
- Direct effects - increase in fish mortality.
- Indirect effects - changes in food availability and other aquatic ecosystem changes. (i.e. mobilization of heavy metals).
- primary toxicant aluminum - present in snowmelt Schofield (1980)
- mercury content in fish higher in acidified lakes.
- low pH levels associated with: smaller average fish size; fish deformities; extinction of some species.

DAMAGE ESTIMATES

- (DPA: August 1984)
  - fresh-water fishery at greatest risk, high sensitivity (low buffering capacity) of lakes in Precambrian Shield.
  - Great Lakes fishery not at risk, protected by underlying bedrock preventing acidic build-up.
  - ocean fisheries not affected (high buffering of carbonate substances). Only salmon fishery threatened as spawning grounds are sensitive inland waters.
  - annual damage: 391 tonnes /yr. (about 8% of fishery in deposition zone).
- (DPA: August 1984) Almost 70 percent of total landed catch of Eastern Canada concentrated in Atlantic provinces.
  - 6.1 percent loss of fish stock (percent of water area subject to snowmelt acid shock times 20 percent). (20 percent figures arbitrary, based on assumed total loss of harvestable stock, five years average).
  - most of catch from waters with sulfate deposition of 20-40 kg/ha/yr. (over 30 percent of the region's water surface falls in this deposition regime).
  - total of 280 tonnes per year of fish estimated lost to acid deposition (80 tonnes of salmon lost).

CAUSAL AGENTS

DAMAGE ESTIMATES

Quebec

- (DPA: August 1984) Little information on Quebec surface waters.
  - surface water area affected about 21,240 km<sup>2</sup> (triple the area of Atlantic Canada's affected waters) representing over 52 percent of Quebec's total water area.
  - estimated loss in fish stock 10.5 percent.
  - total of 79 tonnes of fish yield lost annually.

Ontario

- (DPA: August 1984) Damage slight compared to other eastern provinces.
  - less than 2 percent of surface water unable to sustain yields.
  - 4,700 km<sup>2</sup> of water subject to snowmelt acid shock.
  - just over 3 percent loss of fish stock due to LRTAP.
  - bulk of Ontario's catch taken from buffered Great Lakes.
  - 33 tonnes of fish yield lost annually

## RECEPTOR: COMMERCIAL FISHERIES

SOCIO-ECONOMIC IMPACTS

- (DPA: August 1984) Short-term impacts: loss in employment in secondary sector, loss of exports.  
Long-term impacts: loss in employment (direct and indirect)  
loss in labour income, dependent communities, loss in exports.
- two indicators used to described socioeconomic inventory of commercial fisheries at risk: gross value of production and employment.

COMMENTS

- (DPA: August 1984) Impact assessments may be measured through the cost of mitigative measures such as lining or enhancement, or a market value approach to capture loss in producer surplus from reduced catch levels. (Latter used in DPA: August 1984). Does not account for price changes or substitution possibilities.
- Estimates of socioeconomic impacts embody data uncertainties with respect to:
  - employment estimates (many part-time fishermen, licenses not always reliable measure).
  - average values (fishery at risk may not be representative of the provincial fishery as a whole).
  - multipliers - are ten years out of date in some cases (i.e. 1974 data for inter-industry flow data).

Present value estimates not included in this review due to problem of forecasting yearly losses incurred as producers move in and out of market. DPA also assumes no change in structure of commercial fishery.

Assumptions: see appendix 11.1-1 for average values per tonne, jobs per tonne live weight, employment multipliers. Taken from Canadian Fisheries Annual Statistics Review (Vol. 14) 1981; Ontario Ministry of Natural Resources; Statistics Canada.

RECEPTOR: COMMERCIAL FISHERIESSOCIO-ECONOMIC IMPACTSAtlantic Region

- (DPA: August 1984)

Lost production value: \$0.4 million (1981)  
 (present value: \$1.1 million)  
 Salmon accounts for 83% of loss.

Employment loss: 4,600 person years  
 (direct); 1,800 p/yr (indirect).  
Total: almost 7,000 p/yr

Atlantic Region

- (DPA: August 1984) Despite high loss potential difficult to assess affects on region's economy and residents (particularly in terms of income losses). Mitigating factors may include: switching of income sources to sea fishery, to other fish species, to activities other than fishing.

Estimates are further obscured by seasonal nature of fishing, effects of catch substitution, extent hunting and trapping affect fishing-specific multipliers and length of adjustment time to find alternative sources of income.

Communities in major salmon producing areas may have livelihood threatened (i.e. North Cape, Breton Island and Antigonish in Nova Scotia and areas surrounding St. John and Miramichi Bay and Restigouche county in New Brunswick).

Quebec

- (DPA: August 1984)

Lost production value: \$185,000 (1981)  
 (present value: \$0.8 million)  
 Salmon accounts for 27% of loss.

Employment loss: 300 person years  
 (direct); 300 p/yr (indirect).  
Total: 600 p/yr

COMMENTSAtlantic Region

- (DPA: August 1984) Despite high loss potential difficult to assess affects on region's economy and residents (particularly in terms of income losses). Mitigating factors may include: switching of income sources to sea fishery, to other fish species, to activities other than fishing.

Estimates are further obscured by seasonal nature of fishing, effects of catch substitution, extent hunting and trapping affect fishing-specific multipliers and length of adjustment time to find alternative sources of income.

Communities in major salmon producing areas may have livelihood threatened (i.e. North Cape, Breton Island and Antigonish in Nova Scotia and areas surrounding St. John and Miramichi Bay and Restigouche county in New Brunswick).

Quebec

- (DPA: August 1984) Centers dependent on inland fishery as primary source of income critical but difficult to gauge without profiles of economic structure. (potentially affected districts: Maskinonge, Nicolet, St. Jean and Yamaska).

Unlike the Atlantic fishery where salmon losses are responsible for most loss in value, a range of fish species contribute toward greatest losses in Quebec.

RECEPTOR: COMMERCIAL FISHERIESSOCIO-ECONOMIC IMPACTSCOMMENTSOntario

- (DPA: August 1984)

Loss production value: \$36,000 (1981)  
all from various species inland.  
(present value: \$106,000).

No employment loss cited.

Ontario

- (DPA: August 1984) High buffering qualities of dominant Great Lake fishery.

RECEPTOR: SPORT FISHERYCAUSAL AGENTS

- (DPA: August 1984) Effects of acid rain on water bodies. Lakes with no buffering capacity cannot sustain fish. Lightly buffered waters subject to recruitment loss of fish stocks, particularly from snowmelt acid pulses. (Aluminum often released in runoff.) Acidification also mobilizes previously insoluble heavy metals (e.g. mercury) which then accumulate in fish.

Effects also include fish deformities, smaller fish size, extinction of some species, leading to reduced diversity of aquatic ecosystems.

DAMAGE ESTIMATES

- (DPA: August 1984) Productivity declines and fish stocks based on area of surface water damaged. Damage assessed in terms of 1) Lakes with no sustained yield, 2) lakes subject to snowmelt shock. Estimates based on Minns (1984) matrix of lake areas and alkalinity, plus MOI (1983).

Loss in fish stocks directly proportional to affected surface water. In second case (2), loss in fish stock assumed to be 20 percent of affected water area.

Estimated total loss in fish stock is 8.5 percent annually--from 94,650 km<sup>2</sup> water area.

- (Rivers et al: November 1983) Biophysical damages not examined, except via effects on consumer surplus per angler day. Focus on hypothetical future damages based on discount rates of 0.5, 7.5, and 10 percent.

Angler days rated in terms of risk level attributed to lakes and rivers in each region.

CAUSAL AGENTS

RECEPTOR: SPORT FISHERY

DAMAGE ESTIMATES

Atlantic Region

- (DPA: August 1984) 3.5 percent of waters, potentially affected by LRTAP ( $828 \text{ km}^2$ ) have no sustainable yield. Over 30 percent of waters ( $7,094 \text{ km}^2$ ) subject to snowmelt shock, adding recruitment losses of over 6 percent annually. Figures are preliminary indicators (do not consider fishing intensity).

Quebec

- (DPA: August 1984) Yield loss estimates unavailable, but province has largest water area at risk ( $45,559 \text{ km}^2$ )--36 percent of which receives moderate to heavy sulphate depositions (20-40 or 40+ kg/ha/yr). Over 52 percent of affected water area is subject to snowmelt shock, leading to a 10.5 percent annual recruitment loss.

Note: figures are preliminary indicators (do not consider fishing intensity).

- (Econosult: 1982) Physical damages not considered by study.

RECEPTOR: SPOTT FISHERYCAUSAL AGENTSDAMAGE ESTIMATESOntario

- (DPA; August 1984) Fishery suffers 1.9 percent yield loss within 30,444 km<sup>2</sup> of affected surface waters. Over 15 percent of area subject to snowmelt shock, adding over 3 percent recruitment loss of fish stocks/year.

Note: figures are preliminary indicators (do not consider fishing intensity).

Ontario: Northwest, Northeast, East, and Muskoka, Haliburton, Parry Sound regions

- (CCL: 1982) Acid deposition on lakes and watersheds, excluding acid pulse. As aquatic pH falls below 5.6, toxic elements mobilized, increasing toxicity stresses on aquatic life. As lakes become acidified, fish reproductive failures increase and food chain is disrupted resulting in reduced nutrient cycling. Reproduction is assumed to cease when lakes reach pH 4.5. Watersheds in above regions are considered acid-sensitive since underlying geology has limited buffering and neutralizing capacities. Great Lakes are excluded due to high buffering capacity.

- (CCL: 1982) Result is reduced fish quantity. Increasing lake acidity translated into decreasing fish productivity, estimated for current (1980) and projected future scenarios. Productivity estimates based on Ontario Fish Yield Estimates. Appendix V in study.

- Muskoka, Haliburton, Parry Sound: Current productivity losses at 1980 deposition levels are 13,242 kg, or 3.6 percent of total regional productivity. Estimates include acidified and extremely sensitive lakes, but not moderately sensitive lakes.

For intermediate scenario (extreme lakes are acidified, moderate lakes become extreme); annual loss is 109,153 kg or 30 percent of potential regional productivity.

In worst case scenarios (extreme and moderate lakes acidify, low-sensitivity lakes become extreme), 83 percent of potential productivity is lost.

No schedule for acidification or deposition rate is defined for scenarios 1 and 2. All estimates exclude Great Lakes. Most sensitive species are smallmouth bass, walleye, lake trout.

RECEPTOR: SPORT FISHERYCAUSAL AGENTSDAMAGE ESTIMATES

## • (CCL: 1982)

-Acid Sensitive Eastern Ontario: Current losses are marginal but potential losses are moderate. Scenario 1 losses represent 2.4 percent of potential productivity in region. Scenario 2 losses are 80,681 kg/yr., representing 13 percent of productivity. Above conditions apply.

-Northeastern Ontario: Region includes Sudbury, Timiskaming, Nipissing, Manitoulin, Cochrane, Algoma areas. Current productivity losses of 153,183 kg/yr. represent 4.6 percent of annual productivity. Scenario 1 potential losses of 377,404 kg/yr. or 11 percent of annual productivity. Scenario 2 losses of 958,229 kg/yr. represent 29 percent of productivity. Sudbury area is currently most affected, but most of Nipissing productivity based in moderately sensitive lakes.

-Northwestern Ontario: Region includes Thunder Bay, Kenora, Rainy River. Current losses are marginal. Scenario 1 losses of 233,240 kg/yr. and Scenario 2 losses of 2.3 million kg/yr. represent substantial increases.

Conditions cited in Muskoka, Haliburton, Parry Sound Region apply.

<u>SOCIO-ECONOMIC IMPACTS</u>		<u>RECEPTOR: SPORT FISHERY</u>	<u>COMMENTS</u>
• (DPA: August 1984) <u>Resources At Risk</u>	About 45 million angler days at risk in Eastern Canada. <u>Resident anglers</u> account for 92 percent of participation at risk. <u>Non-resident anglers</u> participation at risk: 3.4 million days annually.	• (DPA: August 1984) <u>Resources At Risk</u> Catches not directly valued, but as part of recreation experience. Indicators of resources at risk measure quality and amount of current fishing activity within deposition zones. Inventory expressed as participation or angler days.	Inventories derived from OME 1980 survey of Ontario's Resident & Non-Resident Sport Fishermen; Recreational Use of Fish & Wildlife Resources in Quebec, GO, 1981; DFO, 1980 Survey of Sport Fishing in Canada (Atlantic Figures).
			<u>Value of participation assessed in terms of 1) resident user value to domestic participants, 2) non-resident export value: expenditures by non-Canadians, including multiplier effects.</u>
1) <u>Resident User Value at risk (1981) - \$500 million (low estimate); high estimate &gt; \$900 million.</u>	Based on low user value estimate, 15,200 person-years of employment and \$303 million annually at risk in Eastern Canada.	1) User values imputed due to lack of markets for recreation sites. Willingness-to-pay approach used, based on range of estimates derived from review of 7 WTP studies (DPA Appendix 11.5.4). Range: \$12/day, \$17/day, \$22/day.  Regional impacts significant due to labour intensity of supporting industries. Baseline coefficients for direct employment derived from Shaffer (1982). E. Reid & Associates (1981) p 4/83: DPA.	
2) <u>Non-resident income generated/at risk &lt; \$80 million (1981) in Eastern Canada.</u> Estimates include share of expenditures on package tours, lodging, food, and travel at risk to LRAP.	Non-resident employment generated/at risk - 3,900 person-years.	2) Based on resident coefficients, income generated from non-resident expenditures - \$610 of every \$1000 generated from direct spending by all participants.	

RECEPTION: SPORT FISHERYSOCIO-ECONOMIC IMPACTS

- | <u>COMMENTS</u>   |
|---|
| <p>• (Rivers et al: November 1983) Study estimates value which sports fishermen would lose as acid rain impacts intensify. This <u>use value</u> is equated with consumer surplus and measured by travel cost method. Option and bequest values (see comments, DPA) not assessed. Use value of \$17/day applied to damage scenarios.</p> <p>Severe case projects present value losses of 5.8, 8.5 and 14.1 billion dollars, depending on discount rate. Variable rates used to simulate range of resource sensitivities, (e.g. lower rate = greater impacts). Losses occur within 25 year period.</p> <p>Slight case projects present value losses of 2.5, 4.1, and 7.8 billion dollars. Losses occur over 100 year period.</p> <p>• (Rivers et al: November 1983) Travel cost method considers costs of travel to and from fishing site, on-site accommodation, tackle and bait purchases, meals, license fees, and time spent fishing, valued at its next best use as indication of anglers willingness-to-pay for recreation fishing.</p> <p>Note: \$17/day estimate based on 1980 valuation of travel costs in Muskoka-Haliburton region of Ontario. Estimate may not be valid for other locations. Authors state that figure underestimates use value of resource.</p> <p>Assumed that expenditures and fishing activity decrease linearly as LRTAP-related fishing opportunities decline.</p> <p>Projections facilitate regional comparison by order of magnitude re. future losses. These should not be taken as estimates of complete or actual losses.</p> |
| <u>Note:</u> Estimates under revision   |

<u>SOCIO-ECONOMIC IMPACTS</u>	<u>RECEPTOR: SPORT FISHERY</u>	<u>COMMENTS</u>
<p>• (DPA: August 1984) <u>Socio-Economic Losses</u></p> <p>Over 3.6 million angler-days lost in Eastern Canada annually. Nearly 95 percent of losses are in resident sport fishery. Based on this loss, lost user benefits range between \$40 million and \$75 million depending on willingness-to-pay. Base case loss is &gt;\$57 million (\$17/day; 1981)</p> <p>Total income loss re. base case is \$25.4 million (1981). Total employment loss re. base case is 1,247 person-years.</p>	<p>• (DPA: August 1984) <u>Socio-Economic Losses</u></p> <p>S-E Resources at risk do not describe impacts per se. LRTAP-related decline in fish stocks "rephrased" in terms of lost fishing activity or angler-days. Report assumes a) angling success proportional to fish stocks, b) angling effort (days) proportional to angling success, c) substitute lakes unavailable.</p> <p><u>Estimate Limitations include:</u></p> <ul style="list-style-type: none"> <li>- Possible overestimation of impacts due to assumptions of direct proportional relationship between declining fish stocks and angling effort; 2) assumption of no substitution for acid damaged lakes in terms of proximate lakes or recreational activities.</li> <li>- Possible underestimation since option and bequest values not assessed (e.g. dealing with future benefits to current non-users and future generations). Estimates for non-resident fishery based on licensed users only.</li> </ul> <p>Reduced participation in non-resident fishery results in a total income loss of \$5.9 million (1981) and an annual employment loss of 293 person-years. Reduced income considered a national rather than regional loss as income assumed to leave Canada.</p> <p>Combined resident and non-resident employment loss is about 1,540 person-years annually. Assumptions: displaced persons not rehired, and income generated by substitute recreation not included in estimates.</p>	<p>Note: Kelso, Minns et al (in press) cite revised estimates of affected lakes which suggest DPA estimates are <u>understated</u>. Earlier estimates of four to five hundred thousand lakes receiving deposition "considerably above background", revised upwards to 700,000 lakes in Eastern Canada.</p> <p>Single willingness-to-pay figure assumed for Eastern Canada, which may bias estimates for regions. As indicators of regional value, WTP responses often vary according to respondent's lifestyle and cultural perceptions. Constant estimates likely to obscure value and differences.</p>

<u>SOCIO-ECONOMIC IMPACTS</u>	<u>RECEPTOR: SPORT FISHERY</u>	<u>COMMENTS</u>
<u>Atlantic Region</u>		
• (DPA: August 1984) About 5.4 million angler days are at risk, more than 98 percent of which are attributed to resident fishery. Estimated user values of resident angler days at risk range from \$64 million to \$117 million (1981), depending on willingness-to-pay estimates applied. Direct expenditures by resident anglers are \$56 million, contributing to 1,700 person-years at risk (mostly direct employment), and total income at risk of \$34 million.	• (DPA: August 1984) Comparative export value of region's non-resident fishery is small, but locally important to Grand Lake, Digdequash, Tracadie, Little Southwest Miramichi, Tobique, Nashwash, and Salmon Rivers in New Brunswick. Digby county, Five Islands, Stewiacke-St. Mary's rivers in Nova Scotia, and Cheticamp River in Cape Breton also dependent.  Combined present value of lost income not cited.	
Decline in resident fishing effort is 0.5 million angler days, resulting in lost user benefits of \$6 - \$11 million. Annual employment losses of 162 person-years, result in income losses of \$3.3 million.	Expenditures by non-resident at risk are low (\$6.2 million) in comparison with Ontario (\$105 million) and Quebec (\$26 million). Also, income of \$3.3 million generated at risk, and 100 person-years in potential employment losses.	Decline in non-resident angling effort due to LRTAP is 7,000 angler days, amounting to \$0.3 million in annual income losses. Seventeen person-years of employment losses result.
Combined impacts due to LRTAP: \$3.6 million annual income on expenditures of \$5.9 million. Annual employment loss is 179 person-years.	Combined impacts due to LRTAP: \$3.6 million annual income on expenditures of \$5.9 million. Annual employment loss is 179 person-years.	• (Rivers et al: November 1983) Moderate case projects present value loss of \$0.45 billion within 50 year period.
		• (Rivers et al: November 1983) Simulation case estimate based on \$17/day surplus per angler day at 7.5 percent discount rate. Moderate case used for comparative purposes. See comments for Eastern Canada.

SOCIO-ECONOMIC IMPACTSQuebecRECEPtor: SPORT FISHERYCOMMENTS

- (DPA: August 1984) About 11.6 million angler days at risk in resident fishery. Resident user values based on above loss range from \$139 million (1981: \$12/day) to \$254 million (\$22/day). Direct expenditures at risk are \$162 million, resulting in potential employment losses of nearly 5,000 person-years, and \$97 million in annual income.

Decline in resident angling effort is 1.2 million angler days, responsible for lost user benefits of \$14.4 - \$26.3 million. Annual employment losses of 500 person-years bring income losses of \$10.3 million.

Non-resident expenditures at risk are over \$26 million (1981). About 16 million in generated income at risk, with 800 person-years.

Decline in non-resident fishing effort is 54,000 angler days, resulting in lost expenditures of 2.7 million (1981), \$1.7 million in lost income, and 83 person-years in lost employment.

Combined due to LRTAP: \$12 million income on expenditures of \$19.5 million. Annual employment loss is 583 person-years.

- (Rivers et al: November 1983) Moderate case projects present value loss of \$1 billion within 50 year period.
- (Rivers et al: November 1983) Simulation case estimate based on \$17/day surplus per angler day at 7.5 percent discount rate. Moderate case used for comparative purposes. See comments for Eastern Canada.

Note: Kelso, et al (in press) indicate that Quebec has the largest area of high acidity waters in Eastern Canada by a considerable margin. ( $\rightarrow 65,361.9 < 100 \text{ km}^2$  eqL-1; e.g. nearly triple Ontario's area). Future potential of this resource not captured by historical data used in simulations.

RECEPTOR: SPORT FISHERYSOCIO-ECONOMIC IMPACTSCOMMENTS

- (Econosult: March 1982) Expenditures by sports fishermen totaled close to \$251 million in Quebec in 1981. Annual average of \$259 per fisherman (annual expenditures in more isolated regions of Northern Coast and Saguenay/Lac St. Jean higher, \$520 and \$440 respectively). Of total \$251 million, \$86.4 million generated in indirect revenues for the Quebec government and \$18.3 million for the Federal government. An estimated 5,258 persons employed through fishery related goods and services.

Five municipalities (St.-Michel-des-Saints, Rivière-à-Pierre, Les Escoumins, St.-David-de-Falardeau, Ferme Neuve) on northern coast of St. Lawrence polled. All sites entrance ports to large fishing areas and dependent on tourism. Of 118 enterprises surveyed, a total loss of 119 employees was estimated.

Range of job losses predicted (for 1987-1994) from 20 to 60 percent in Les Escoumins, from 17.4 percent to 37.7 percent in Rivière-à-Pierre, and 27.8 percent to 37 percent in St.-David-de-Falardeau.

Note: Actual loss not predicted.

- (Econosult: March 1982) Data drawn from 1980 survey by Quebec Ministry of Hunting, Fishing and Recreation.

-Results based on responses to questionnaires distributed to municipal governments and commercial enterprises in each region to determine the loss of revenues and employment if sport fishing were to disappear.

Figures do not allow for an estimate of total economic value of sport fishing (non-monetary values not determined).

RECEPTOR: SPORT FISHERYSOCIO-ECONOMIC IMPACTSOntario

- (DPA: August 1984) Resident angler days at risk: 24.6 million (more than Quebec and Atlantic Canada combined). Resident user values at risk range from \$295 million (\$12/day: 1981) to \$541 million (\$22/day). Direct expenditures at risk are \$283 million, resulting in potential employment losses of 8,600 person-years, and \$172 million in annual income.

Decline in angling effort is about 1.7 million angler days, leading to lost user benefits of \$20 to \$37 million. Annual employment losses of 582 person-years bring income losses of \$11.8 million.

Non-resident expenditures at risk are \$105 million (1981). About \$60 million in related income is at risk, with 3,000 person-years. Decline in non-resident fishing effort is nearly 0.2 million angler days, bringing lost expenditures of 6.4 million (1981), about 4 million in lost income and 193 person-years in lost employment.

Combined LRTAP-related losses: \$15.7 million income on expenditures of \$25.8 million. Annual employment loss is 775 person-years.

- (Rivers et al.: November 1983) Has largest proportion of fishing days in Canada, but less exposed to immediate risks of acidification than other regions. Moderate case projects present value loss of \$5 billion within 50 year period.

COMMENTS

- (DPA: August 1984) Ontario's non-resident fishery accounts for major share (11%) of angler participation within the province. This translates into an especially large export value at risk (e.g. about four times that of Quebec's). Dependent areas include Muskoka, Haliburton, Renfrew, Nipissing, and Parry Sound - all east of Georgian Bay.

- (Rivers et al.: November 1983) Simulation case estimate based on \$17/day surplus per angler day at 7.5 percent discount rate. Moderate case used for comparative purposes. See comments for Eastern Canada.

SOCIO-ECONOMIC IMPACTSRECEPTOR: SPORT FISHERYCOMMENTS

- (CCL: 1982) At 1980 deposition levels, current loss in direct fishing related expenditures is \$2.7 million/year. Indirect loss is \$4.1 million/year. Total loss is estimated at \$6.8 million, focused on Muskoka/Parry Sound/Haliburton and Northeast regions.
- Scenario 1 estimates \$21 million/year in total losses with 606 person-years of annual employment potentially affected (based on direct expenditure loss of 1980 \$13.4 million). Almost 90 percent of employment losses would be divided between M/P/S/H and Northeast regions.
- Scenario 2 estimates \$70 million/year in total losses with 2,042 person-years of annual employment potentially affected (based on direct loss of \$45 million). Under worst case M/P/S/H region losses 82 percent of angler effort, Northeast region losses 29 percent of angler effort. Provincial effort reduced by 18 percent.

(CCL: 1982) Estimates of fish productivity were translated into changes in "angler effort", and subsequently interpreted to suggest anglers' response to reduced fishing quality and supply. The study assumes that anglers may shift effort to other areas inside or outside Ontario, thereby reducing angler effort and angler occasions. Other possibilities are noted pp. 42-43 Review of Socio-Economic Methods to Assess Acid Deposition Effects, April, 1984.

Resulting loss of angler occasions linked to changes in overnight stays and associated economic activity. Separate estimates for these factors are not included in reviewed documents.

Authors suggest that socio-economic loss estimates may be overstated due to the possibility that some lost expenditures could be spent elsewhere in Ontario. Granting this possibility, losses to directly affected lodges, communities, and areas would likely still hold (given the assumption re. anglers' response). Estimates of employment losses may be understated as these are based on loss of direct expenditures only.

<u>CAUSAL AGENTS</u>	<u>RECEPTOR: FORESTRY</u>	<u>DAMAGE ESTIMATES</u>
<ul style="list-style-type: none"> <li>• (DPA: August 1984) Direct and possibly indirect LRTAP/acid deposition. Studies reviewed suggest range of agents, including sulphur and sulphate depositions (connected with reduced growth of Scotch Pine in Sweden and forest die-back in West Germany); and combined effects of acid rainfall with chronic gaseous pollution on various species in NE USA. Results inconclusive according to DPA.</li> </ul>	<ul style="list-style-type: none"> <li>• (DPA: August 1984) Usable dose-response functions for LRTAP-related effects not available. Damage functions available for point source sulphur dioxide emissions, not for LRTAP. Long-term negative effects on forest productivity suspected (e.g. calcium loss, heavy metal accumulation) but quantitative estimates not available. Physical forest resources at risk examined in terms of area and physical yield per deposition regime. Inventory not considered a forecast of potential losses in absence of dose-response functions.</li> </ul>	<p><u>Atlantic Region</u></p> <ul style="list-style-type: none"> <li>• (DPA: August 1984) Almost 93 percent of the region's total annual yield taken within an area potentially sensitive to acid deposition (20-40 kg/ha/yr). Most resources concentrated among yields of soft and mixed woods. Nova Scotia and New Brunswick have significant hardwood yields receiving high amounts of sulphate deposition.</li> </ul> <p><u>Note:</u> (SEDAF: 1981) In the case of these two provinces, the potential impacts of acidic precipitation could be greater than forest capability, although the separation of acidification effects from insect-related damage is problematic.</p>

CAUSAL AGENTSRECEPTOR: FORESTRYDAMAGE ESTIMATESQuebec

• (DPA: August 1984) Forest zone from Ottawa Valley northeastward to the Lower St. Lawrence to Quebec City is most likely affected area. Most of the province's annual yield (81.5 million m<sup>3</sup>) falls within this deposition zone. Quebec faces the greatest potential volume losses. About 5 percent of the affected yield falls within a zone receiving more than 40 kg/ha/yr. Most of affected annual yield is either soft (62 percent) or mixed wood (32 percent).

Ontario

• (DPA: August 1984) Little of Ontario's yield taken from moderate to heavily deposited zones (13.5 million m<sup>3</sup>). Area between Georgian Bay and the Ottawa Valley is region most likely affected.

RECEPTOR: FORESTRYSOCIO-ECONOMIC IMPACTS

- (DPA: August 1984) Without appropriate dose-response functions, socio-economic impacts cannot be usefully estimated. Inventories of production values considered potentially at risk (values linked to resources within deposition zones). Annual roundwood shipments of \$1.2 billion roughly at risk in Eastern Canada. Total annual wood industry output at risk is about \$2.8 billion (excluding pulp & paper values).

Atlantic Region

- Annual (1981) value of production at risk for region is \$288.4 million in roundwood shipments, contributing to annual wood industry output of \$365 million. (Newfoundland forestry values not included).

New Brunswick industry at risk comprised of 10 licencees operating small logging camps and mills. Major sawmills in north-central area. St. John, Edmundston, Dalhousie-Bathurst areas are major processing centres. Eastern Nova Scotia most productive area at risk, but 200-300 sawmills scattered across province. Newfoundland's harvesting occurs in central, western areas.

Actual impacts unknown.

Quebec

- (DPA: August 1984) Annual production at risk is \$614.7 million in forestry revenues, and \$1.7 billion in annual wood industry output. Quebec resources account for major proportion of resources potentially at risk in Eastern Canada. (e.g. 50 percent of roundwood shipments, 61 percent of wood industry output).

Actual impacts unknown.

COMMENTS

- (DPA: August 1984) Lack of information on nature, ratio and rate of damage means resources at risk should be considered highly speculative.
- PC: Turner emphasizes three "schools of thought" re forestry mechanisms which may be relevant to future Canadian estimates of LRTAP-related damages:

- (1) Oxidants ( $\text{SO}_2$  and  $\text{O}_3$ ) imply direct damage in proximity to ozone sources, probably affecting southern forest areas.
- (2) Oxidants plus acid rain with some soil-mediated effects possible. This scenario implies a wider range of potential impacts than (1) due to combination of direct and indirect effects.
- (3) Root damage due to aluminum toxicity, triggered by acidic deposition. Impacts potentially most widespread of three options.

Without consensus on biophysical mechanisms, dose-response functions remain speculative at best. Depending on assessment of criteria, conclusions can be drawn suggesting extensive or confined effects. Canadian Forestry Service presently conducting Delphi survey of expert opinion on LRTAP-related effects which may help clarify debate.

SOCIO-ECONOMIC IMPACTSOntarioRECEPTOR: FORESTRYCOMMENTS

- (DPA: August 1984) Much of resource at risk (softwood) used for pulp and paper, which is excluded from valuation of industry at risk. Ontario has least value of forestry and wood industry resources at risk in moderate deposition zone (20-40 kg/ha/yr), assessed at \$64.4 million and \$115 million respectively. Total respective figures are \$322.6 million and \$790 million.

Boreal forests in north have most logging and processing activity (Kapuskasing, Longlac, Smooth Rock Falls, Marathon, Iroquois, Hearst, Dryden, Kenora, Thunder Bay). Sault Ste. Marie areas has major sawmill operations. Major hardwood areas are Parry Sound Haliburton, Muskoka, Pembroke, Huntsville, Bracebridge, North Bay are primary processing centres.

Actual impacts unknown.

RECEPTOR: HUMANS (Health)CAUSAL AGENTS

- (DPA: August 1984) Direct effects of acid deposition are largely unknown. It has not been possible to determine how much harm has resulted from long-range sources of pollution. The elderly, children, asthmatics and adults with pre-existing chronic heart or lung ailments are particularly at risk to direct effects of LRTAP pollutants. In general, LRTAP-related mortality is attributable to degeneration of already weak or vulnerable respiratory systems.

The indirect effects of LRTAP include:

- 1) Contamination of drinking water through leaching of toxic chemicals from watersheds and water storage systems and from corrosion in water distribution systems.
- 2) Contamination of edible fish by toxic chemicals, particularly mercury.
- 3) Contact with contaminated water in recreation areas.

DAMAGE ESTIMATES

- (DPA: August 1984) Morbidity estimates based on mortality dose-response function (Morgan et al: OTA 1982) on assumption of OECD study (1981) that increase in LRTAP-related mortality leads to similar percentage change in morbidity. Function assumes premature death linearly related to SO<sub>4</sub> exposure with no threshold constraints. Damage estimates range from five cases of LRTAP-related ailments for every premature death see Hamilton (1980) to (Bates and Sizto 1983) 20 hospitalizations for every premature death, suggested by 10 marker conditions based on Canadian morbidity and mortality statistics.

Estimates of acute respiratory ailments (incl. bronchitis, emphysema, asthma) considered most accurate. Second set of morbidity estimates re. all diseases presented for comparative purposes.

Note: Aluminum concentration as high as 372 ppb found in Canadian lakes (toxic to fish from 100 ppb). High concentrations linked to dialysis encephalopathy or dialysis dementia. Aluminum also associated with types of dementia, Alzheimer's disease, and Parkinson's disease.

Note: MOI 1983 Poorly buffered waters in areas remote from any point source of discharge have been found to contain fish with elevated levels of mercury. Tomlinson et al (1979) found examples in poorly buffered lakes and rivers in Quebec and New Brunswick.

Impact Scenario

Under the "average" impact (3.7 deaths per 10<sup>5</sup>  $\mu\text{g}/\text{m}^3$ ). 4,163 annual deaths (1981). Under the "low" impact (1.85 deaths per 105  $\mu\text{g}/\text{m}^3$ ), 2,082 deaths are attributed to LRTAP annually. (Low values are provided as a point of comparison).

RECEPTOR: HUMANS (Health)CAUSAL AGENTSDAMAGE ESTIMATESAtlantic Region

- (DPA: August 1984) No discussion of regionally-specific health effects.
- Excess mortality (1981): 496 deaths (avg); 248 deaths (low).
- Morbidity/average/respiratory (1981): 5,100 workdays; 18,200 disability days; 6,000 doctor visits; 21,900 hospital days.
- Morbidity/all diseases (1981/avg): 79,000 workdays; 247,000 disability days; 153,000 doctor visits; 88,000 hospital days.

Quebec

- (DPA: August 1984) Most people reside in a 20-40 kg/ha/yr band along the St. Lawrence River, resulting in a 30 percent share of LRATP-related health problems in Eastern Canada.
- Excess mortality (1981): 1,375 deaths (avg); 688 (low).
- Morbidity/respiratory (1981/avg): 14,000 workdays; 650,500 disability days; 16,500 doctor visits; 61,900 hospital days.
- Morbidity/all diseases (1981/avg): 223,000 workdays; 682,000 disability days; 426,000 doctor visits; 220,000 hospital days.

Ontario

- (DPA: August 1984) Almost 60 percent of health problems occur in Ontario, primarily because the large population centres of Toronto, Hamilton and Kitchener receive more than 40 kg/ha/yr of sulphate deposition.

CAUSAL AGENTS

RECEPTOR: HUMANS (Health)

DAMAGE ESTIMATES

Ontario continued

• (DPA: August 1984)

Excess mortality (1981): 2,292 deaths (avg); 1,146 (low).

Morbidity/respiratory (1981/avg): 23,400 workdays; 84,200 disability days; 27,400 doctor visits; 101,600 hospital days.

Morbidity/all diseases (1981/avg): 372,000 workdays; 1,137,000 disability days; 710,000 doctor visits; 367,000 hospital days

• (Bates: September 1984) Rural populations are exposed to significant concentrations of ozone or sulphates and nitrates from long-range transport of photochemical pollutants and sulfate aerosols.

Note: (Bates: September 1984) SO<sub>4</sub> aerosol and temperature play a role in accounting for 11.4 percent of the variance in total respiratory admissions in the summer, and with O<sub>3</sub>, these variables account for 10 percent of the variance in admissions of children with asthma.

Note: Long-term effects are not discussed (other than acute admissions to hospitals may be assumed to have long-term impacts). Findings were in accord with Whittemore and Korn (1980) indicating increased risk of asthmatic attacks as oxidant and particulate pollutant levels rise.

RECEPTOR: HUMANS (Health)

SOCIO-ECONOMIC IMPACTS

- (DPA: August 1984) The five major socio-economic impacts of increased morbidity due to LRTAP are, medical care costs, pain and suffering, lost productivity, moving expenses, research costs.

Respiratory ailments (avg estimate) associated with LRTAP result in:

- 42,500 work days lost  
cost: \$3.6 million/yr income; present value \$36.2 million
- 152,800 disability days.  
cost \$6 million/yr; present value \$60 million
- 185,500 hospital days.  
cost \$4.2 million/yr; present value \$472 million
- total cost: \$53.6 million/yr; present value \$536 million
- 50,000 doctor visits.  
cost: \$0.45 million/yr; present value \$4.5 million

The primary indicators of the socio-economic impacts of LRTAP on morbidity levels are:

- 674,000 work days lost (lower dose response coefficient: 336,000)
  - total disability days exceed 2 million  
cost: \$108.5 million/yr
  - 96,400 hospitalizations  
cost: \$172.3 million/yr
  - 1.3 million additional visits to doctor  
cost: \$11.7 million/yr

These costs represent income loss of \$108 million annually, on total costs of \$299.4 million. (present value x10).

COMMENTS

- (DPA: August 1984) Pain and suffering, moving expenses, research costs not included in estimates. Medical costs include drugs, operating costs, doctor expenses.

Productivity values based on (1) averaged male/female gross pre-tax employment income plus 25 percent for benefits; (2) province-specific gross pre-tax work income - 220 days/yr to denote housework values.

Impacts that are not directly linked to the severity of illness include resources devoted to medical research, costs to alleviate or counter the health effects, costs incurred by individuals who choose to move away from high acid deposition areas.

RECEPTOR: HUMANS (Health)SOCIO-ECONOMIC IMPACTS

- (DPA: August 1984) For Eastern Canada:  
No estimates for mortality.

COMMENTS

- (DPA: August 1984) Low potential for estimating economic values for changes in mortality rates. Conceptual, philosophical problems assigning dollar value on human life (pp. 4-123,124).

Productivity costs involve workdays missed and activity days lost, which includes non-income house workers in total estimate. Work days valued at weighted average pre-tax compensation levels (1980) divided by 220 days. Housework days calculated from gross employment income, weighted by gender participation rates. A 25 percent factor included for benefits. See Appendix 11.7.3 for provincial averages.

Present values based on constant ambient sulphate level and damage, discounted over an infinite time period using a 10 percent discount rate.

Estimate limitations include:

- Uncertainty re. impact on health due to problem of isolating LRTAP from other relevant factors.
- Provincial estimates of medical costs not available.
- Wage-averaging boosts estimates in some regions (e.g. Newfoundland) and dampens estimates in others (e.g. Toronto-Centre Region).
- No allowance for changes in demographic structure.
- No allowance for changes in deposition levels.
- No allowance for compounding effects over time (e.g. chemical accumulation in food and water supply).

Present value of future health costs likely underestimated.

RECEPTOR: HUMANS (Health)SOCIO-ECONOMIC IMPACTSAtlantic Region

- (DPA: August 1984) Morbidity: \$ Millions (1981)

Productivity losses:      Respiratory      All Diseases

<u>Workdays</u>	0.36	5.62
<u>Activity days</u>	0.60	10.71

Health costs:

Hospital costs	5.74	22.65
Doctor visits	0.05	1.38
<u>Total costs:</u>	6.39	34.70

Note: present value estimates - costs x 10

Quebec

- (DPA: August 1984) Morbidity: \$ Millions (1981)

Productivity losses:      Respiratory      All Diseases

<u>Workdays</u>	1.23	19.54
<u>Activity days</u>	1.94	34.60

Health costs:

Hospital costs	15.94	57.55
Doctor visits	0.15	3.85
<u>Total costs</u>	18.03	96.00

Note: present value estimates - costs x 10

COMMENTS

RECEPTOR: HUMANS (Health)SOCIO-ECONOMIC IMPACTSOntario

- (DPA: August 1984) Morbidity - \$ Millions (1981)

Productivity losses:      Respiratory      All Diseases

Workdays	2.03	32.89
Activity days	3.41	62.14

Health costs:

Hospital costs	25.50	92.12
Doctor visits	2.5	6.43
<u>Total costs:</u>	<u>29.16</u>	<u>160.69</u>

Note: present value estimates - costs x 10

COMMENTS

RECEPTOR: WILDLIFECAUSAL AGENTS

- ⑥ (DPA: August 1984) Indirect effects of acidic deposition upon wildlife, including (1) accumulation of heavy metals; (2) loss of essential nutrients in food (e.g. excessive SO<sub>2</sub> and SO<sub>4</sub> retards selenium uptake in plants); (3) reduction of food sources (aquatic and terrestrial).

Eastern Canada

Note: Mink, otter very susceptible to bioaccumulation of mercury from fish in diet. Wren et al (1980). Link between acidified lakes and breeding impairment is high aluminum content in insects on which birds feed Nyholm (1981). Cited in Fischer.

DAMAGE ESTIMATES

- (DPA: August 1984) Reduction of food sources potentially most serious negative effect on wildlife. Damage estimate re food supply are unavailable, but data on fish yield reductions suggest damages could be significant. Note: Report cites MOI (1983) estimate of 94,650 km<sup>2</sup> of affected surface water supporting fewer species and fish yields. (No sustained yield for 1,500 km<sup>2</sup> water area). Kelso et al (in press) estimate that most of 161,890 km<sup>2</sup> of freshwater area receives SO<sub>4</sub> depositions above 20 kg/ha/year. 4,243 km<sup>2</sup> of surface waters represent acidified lakes which do not sustain fish.

No damage functions identified from literature, hence no physical damage estimates available.

<u>RECEPTOR: WILDLIFE</u>	<u>CAUSAL AGENTS</u>	<u>DAMAGE ESTIMATES</u>
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- (SEDAP: 1981) Acid deposition, Eastern Canada

Atlantic Region

- (SEDAP: 1981) High capability sport fish streams in Nova Scotia susceptible, dampens food supply for migrating and wintering waterfowl. Most of the moose, deer and caribou habitats in Newfoundland are in susceptible regions. Central New Brunswick, area north of Minas Basin in Annapolis Valley (N.S.) of potential concern re. ungulates.

Quebec

- (SEDAP: 1981) High capability wildlife (e.g. wintering waterfowl and ungulates) found in susceptible areas including the Central Ottawa Valley, Lac-St-Jean/Saguenay areas and the north shore of the St. Lawrence around Quebec City. Boreal nesting birds may be indirectly affected given large sensitive water and soil zones in the province.

Ontario

- (SEDAP 1981) Aluminum, an element released into adjacent water during acidification, is implicated in the impaired breeding of the Eastern Kingbird in the Killarney area of central Ontario.

- (SEDAP 1981) Wildlife potentially at risk in area between Georgian Bay and Ottawa Valley. Wildlife in Great Lakes marshes and South-western Ontario are not considered at risk due to well-buffered soils and surface waters. Exceptions are Upper Thames and Lower Grand River basins, which are of potential concern re. wintering ungulates.

Note: waterfowl potentially sensitive in central Ontario

RECEPTOR: WILDLIFECAUSAL AGENTS• (Fischer: December 1984)

**Direct and indirect effects of acid deposition, runoff and leaching on wildlife habitats.**

Amphibians: Many frog, toad and salamander species breed in acidic pools formed by meltwater/spring rains. Lab bioassays using eggs collected in field show "drastic" reductions in hatching success at pH 5.0 and below for pickerel frog, spotted salamander, and wood frog. Decreased hatching also found in stream experiments where egg stage of common toad and wood frog showed decreased survival after one day of exposure to pH 4.3 (Clark and Hall in press.). Other findings also suggest amphibian eggs highly sensitive to aluminum in dilute acidic waters. Larvae of resilient species also susceptible to acidic breeding conditions.

Eastern Canada

Indirect effects of acid deposition constraining food supply (see UPA). Most vulnerable area appears to be aquatic habitats. Effects on aquatic invertebrates (molluscs, crustaceans) and fish affect availability for waterfowl and aquatic mammals.

DAMAGE ESTIMATES• (Fischer: December 1984)

**Productivity of terrestrial wildlife linked to reduced food supply: Even insectivorous waterbirds affected when water acidity drops below 5.0 (resilient insects decrease).** Most waterfowl species nest in headwater lakes and ponds, both are very sensitive to anthropogenic acidification. Potential contamination of wildlife by heavy metals mobilized through increased acidity also appears high. Insectivores (flycatchers, swallows, common goldeneye) susceptible since cadmium and lead accumulations transferred through insects.

**• (Whiting: 1984) Primarily indirect effects of acid deposition on wildlife found in southern Ontario and the Maritimes.**

**• (Whiting: 1984) Evidence of alterations in the chemical composition of solid and aquatic environments, damage to vegetation, reductions in invertebrates, fish and amphibian populations. Changes in these parameters (e.g. leading to reductions in number, distribution and productivity of wildlife) assumed to alter the flow of values derived from wildlife, or change capability to maintain values. Incomplete knowledge of dose-response relationships affecting parameters precludes estimates of physical losses needed to establish values.**

RECEPTOR: WILDLIFESOCIO-ECONOMIC IMPACTS

**• (Whiting: 1984)** In absence of values based on biophysical losses, value is related to human uses. Wildlife uses defined as (1) consumptive, (2) non-consumptive and (3) psychological.

**Consumptive**  
These uses cover impacts which reduce wildlife number and distribution. This includes a range of specialized uses with the following implications:

**Subsistence activities**, involving use of wildlife for food, clothing and preparation of products for sale, may be central to a particular group's lifestyle and culture. Reduction of these activities could threaten existence of dependent groups.

**Commercial activities** (trapping, game outfitting) generate income for communities which extend beyond primary production to include processing, retailing and local multiplier effects. Reduction of wildlife inventory can reduce income, expenditures and employment locally and beyond.

**Recreational uses** (hunting, collecting) may be constrained with corresponding reductions of economic and health benefits, according to various expenditure patterns and geographic locations.

**Scientific consumptive uses** (culling of herds for resource management, destruction of animals for biological research, public safety or disease) could be impaired by LRTAP-related wildlife reduction or redistribution. Costs could include additional research expenditures (e.g. to transport or monitor animals).

COMMENTS

**• (Whiting: 1984)** "Benefits approach" taken to determine nature and extent of wildlife-related values reduced by acid rain. Lack of biophysical loss estimates makes reduction in value hypothetical. This review thus considers nature of socio-economic impacts. For discussion on development of valuation method, and speculative values, refer to report.

**Note:** Author estimates 3 of 11 sources of value from wildlife (two sources considered, partial estimates, e.g. non-resident values excluded). Values not considered statistically valid, but as departure for future examination.

**Note:** Fillion et al (1981) inventory participation, attitudes, time and monetary expenditures related to wildlife activities in Canada. Survey illustrates that wildlife a resource of major importance to many Canadians (e.g. survey estimates that \$4.2 billion (1981) spent on wildlife-related activities; 82 percent of Canadians feel preserving endangered species very or fairly important).

SOCIO-ECONOMIC IMPACTS

- (Whiting: 1984)

Commercial non-consumptive purposes. (e.g. wildlife films, recordings, literature, domestication of species, transgenic breeding) suggest costs and benefits derived from specialized markets for wildlife-related products.

Scientific includes contributions of wildlife-related research toward resolution of health problems, increase of food yields, etc. Benefits or values theoretically limitless.

Non-Consumptive Uses

These uses have no direct impact on numbers of birds/animals. Reduced opportunity to participate in such uses, with corresponding reduction in perceived quality-of-life is possible result of LRAP-related impacts. Inadequate knowledge of affected users. Following uses include:

Purposeful recreation (outings, observation, photography)

Incidental recreation occurs when users perceive wildlife in the context of another activity. Participation difficult to assess.

Psychological

These "uses" or purposes refer to knowledge that wildlife and related activities exist or may exist in future. Evaluation in strict monetary terms problematic, although consequences of wildlife loss may have dramatic impact on people, communities and cultures.

Way-of-life may be at risk due to trauma of reduced wildlife. Impacts go beyond loss of subsistence uses as cultural identity may depend on existence of species.

Option demand is a potential use reflecting value derived from having option of future participation.

Existence demand is seen as value (satisfaction) of knowledge that species exists, continues to exist or has been discovered.

COMMENTS

RECEPTOR: WILDLIFESOCIO-ECONOMIC IMPACTS

- (DPA: August 1984) Estimates based on Whiting (1984). For resources at risk and socio-economic impacts (see pp. 4-99 to 4-111).

Atlantic Region

- Hypothetical estimates found in Whiting, DPA but not reported here due to absence of dose-response data and wildlife inventories.

Quebec

- see Atlantic Region

Ontario

- see Atlantic Region

COMMENTS

- (DPA: August 1984) Resources at risk and socio-economic impacts not presented as:
  - Dose-response function unavailable
  - No information on ratio or rate of damage to wildlife resources
  - Estimates "hypothetical" (see Whiting, comments)

### COMMENTS AND DISCUSSION

From commentary of researchers, activists, officials, affected interests, and the reports reviewed, we offer the following observations about socio-economic research on LRTAP/Acid Rain in Eastern Canada.

Many of the reports discuss limitations regarding the biophysical processes on which economic assessments are often based. Lack of knowledge about dose-response relationships linking LRTAP with physical damages especially limits evaluation of agriculture, forestry, health hazards, and wildlife.

However, the absence of damage functions has not prevented researchers from estimating impacts based largely on conjecture or inappropriate scientific results. Assessment of yield increments for potato crops is a case in point. Agricultural damage functions focus on the response of the Amsoy soybean cultivar under various conditions. Researchers are reluctant to transfer Amsoy data to other cultivars and do not recommend applying its results to other crop species. Field studies on potatoes conducted to date show no effects on productivity due to acid deposition (Pell: 1982, 83). Only sulphur-deficient soils offer some prospect of benefit from acidic depositions, but this trait does not generally describe agricultural lands in Eastern Canada.

As similar problems qualify all resource impacts to some extent, the question arises as to the implications of sanctioning impact statements with scientific findings alone. Scientists have observed that statements are often derived from outdated results. But, so long as scientific research continues, socio-economic researchers will be faced with the problem of constantly having to revise statements. The results of this approach is to risk confusion through frequent revisions while conveying a false sense of confidence in socio-economic findings. This point is underscored by the tendency of socio-economic analyses to offer quantitative assessments regardless of the availability of damage functions.

Estimates of resources at risk are compromised by a similar lack of scientific understanding about damage rates within deposition zones, and the ratio of susceptible to resistant resources. Inventories of potentially affected resources could serve a useful function beyond determining frames of reference for impact statements. Qualitative descriptions of the resources, ecosystems, as well as the scope and nature of connected human activities would express a social context for policy. Viewed from this perspective, policymakers may begin to ask whether potential socio-environmental costs are worth short-term economic benefits.

Techniques used to describe impacts which extend beyond current market conditions are also misleading.

Contingent valuations, including compensation required to offset damages and willingness-to-pay for preservation or use of resources, are not reliable indicators of social response to environmental damage. Researchers note concerns about the reliability of personal economic forecasts, with extreme variability in findings not uncommon. In the studies reviewed, selection of contingent valuations tends to be arbitrary. Uniform application of a single valuation or range obscures culturally meaningful distinctions among different peoples and regions.

The use of present value projections to discount future impacts (e.g. based on current market values) excludes both the nature of biophysical processes and socio-economic development from consideration. On these bases alone, present values convey a false view of the future as a linear extrapolation of current market conditions.

The bias toward current markets inherent in socio-economic research subordinates long-term human and market interests to polluters' immediate constraints. Contingent valuation methodology implicitly sanctions pollution rights by placing the onus on people to bid their limited resources in order to offset (willingness-to-pay) or approve (compensation required) damages. At best, this method reveals how much users feel they are able to pay at a given time to defer environmental impacts. On the other hand, present valuations reinforce the view that current relationships will simply be extended into the future. This fallacy detracts from efforts to anticipate market forces and social requirements alike.

As the foregoing points suggest, socio-economic research is not especially revealing of social impacts of LRATP/Acid Rain. We suspect that this oversight is not due to budget limitations but stems from the tendency of cost-benefit studies to downplay local and regional impacts by balancing-off losses in one areas with gains in another. Thus, adverse affects on disadvantaged communities, including native settlements, single-industry towns, and economies based on unique or sensitive ecosystems are not seriously examined.

The process of marginalizing human impacts not only risks social conflict arising from feared and ignored damages, but wastes opportunities to discern future trends from local innovations.

For example, market-oriented economics is not sensitive to developments in the informal sector, which includes voluntary groups, direct trade and barter exchanges, household activities, and mutual aid networks. Statistics Canada estimates the value of informal transactions at nearly fifty percent of Canada's

market economy (GNP). More important, informal activities reveal how people cope with social and economic demands by making adjustments. Some of these adjustments affect the market economy through shifts in expenditure patterns but other changes are not captured by mainstream indicators.

These responses may include new forms of entrepreneurship, political activism, or social malaise (e.g. increased drug taking, family violence and so on). To miss these developments is to disregard the changing needs of society and increase the prospect of obsolescence in current policies.

Our discussions with field sources indicate that socio-economic research on LRTAP has not anticipated social concerns, nor considered their meaning. Basic changes are occurring in social thought and actions related to the environment in general, and to acid rain as one of several environmental issues.

Skepticism concerning official positions on acid rain appears to be growing. Some potentially affected interests express frustration with government research which does not seem to remedy observed damages. Concern is also expressed by joining environmental lobbies, creating informal networks, and by forming watchdog groups to monitor policy, damages, and polluter behaviour. One native band is establishing a research program to monitor impacts on its resources.

Wider appreciation of, and response toward institutional forces is another important factor. Curtailment of research programs and the involvement of media and interest lobbies are seen as pivotal forces in forming perceptions which influence environmental policy. The recent filing of grievances regarding the Ontario Ministry of Environment's alleged obstruction of scientific findings by the Ontario Public Service Employees' Union, suggests that civil servants (and perhaps corporate staff) will increasingly question their employers in public forums.

Revisions in public perception will also yield far-reaching and unlooked-for impacts. A small but diverse range of field sources now perceive acid rain as a byproduct of energy intensive development. This view has already contributed to lifestyle changes with implications for energy policy. Environmental issues have played a role in increased energy conservation in North America; the results of which have been realized as falling electricity demand and a slack market for nuclear power. As people have learned to conserve energy without hardship, political attitudes about energy development have also changed.

Support for environmental standards during recession, interest in renewable energy, and awareness of fundamental issues in the field (e.g. centralized vs. decentralized energy paths) mainly emphasize

**APPENDICES**

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that basic cultural and economic change is underway. The shift to information-intensive development means that vested interests in the old energy-intensive industries will diminish, further reinforcing shifts in public opinion. We may also expect closer public scrutiny of events linking developments in the defense industry with energy and environment.

Field reports indicate that environmental conflicts could sharpen as more people perceive connections among problems like acid rain and previously "unconnected" areas. Citizen groups and environmentalists already discuss acid rain in the context of nuclear development, disarmament, Canada-U.S. diplomacy, free trade, regional development, energy policy, foreign investments, and social services.

In sum, social research on LRTAP, and its use as a policy instrument will not be advanced through dependence on current socio-economic approaches. The exclusion of non-scientific data, community profiles, and contextual thinking concerning social, cultural, and economic developments confirms that the knowledge base used to consider impacts is both narrow and rooted in the past. Social change is dynamic in the sense that it ensues through diverse influences. For instance, scientific and public concerns can no longer be separated in policy development. As the Sugar Maple dieback issue indicates, environmental science often follows up local observation, which may then generate political pressure to pursue the issue.

Future work in this field will yield more useful results by considering a mix of scientific, political, economic, and cultural analyses at various levels of observation.

**REGIONAL SUMMARY CHARTS**

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ATLANTIC REGION

RECEPTOR: COMMERCIAL FISHERY

Physical Damages

Almost 70% of landed catch in Eastern Canada concentrated here. Fish stock subject to 6% annual loss. 280 tonnes/yr. lost, including 80 tonnes of salmon.

Socio-Economic Impacts

Loss of production value (1981) \$357,000/yr. (83% salmon). Present value of future loss is \$1.1 million.

RECEPTOR: SPORT FISHERY

3.5% of affected surface waters (828 km<sup>2</sup>) does not sustain yields. Over 30% of water area (7,213 km<sup>2</sup>) subject to snowmelt acid shock. Annual recruitment loss about 6% (Tonnage not cited).

Resident Fishery: Annual lost user benefits: \$6-11 million. Annual employment loss of 162 person-years. Annual income loss of \$3.3 million.  
Non-resident Fishery: 7,000 angler days lost. Annual income loss is \$0.3 million. Annual employment loss is 17 person-years.

Combined: \$3.6 million/yr. in income on direct expenditures of \$5.9 million. Annual employment loss - 179 person years.

ATLANTIC REGION

RECEPTOR: AGRICULTURE

Physical Damages

Productivity gain of about 90,000 tonnes, mostly  
potatoes (P.E.I., New Brunswick) at pH 4.0.  
Loss of 9,000 tonnes, mostly carrots at pH 4.25.  
Net increment - 81,000 tonnes (1981).

Socio-Economic Impacts

Current value of yield increments is \$8.1 million.  
Value of loss is \$1.1 million. Net incremental  
value is \$7 million.

Note: Recent studies question validity of crop  
increments, suggest no change due to LRTAP.

Foliar damage to beets of 4 tonnes at pH 4.0.

Forage crops, potatoes, tobacco, livestock,  
and dairying based on sensitive lands but no  
damage functions concerning resources.

Affected areas:

New Brunswick - St. John River Valley, Carleton,  
Victoria (processing), York counties...  
Nova Scotia - Annapolis Valley (cash crops),  
Kentville, Berwick (processing)...  
Most of P.E.I. - Bedeque, New Annan (processing)...  
Newfoundland - mixed vegetable yields potentially  
reduced for local consumption.

No employment estimates.

ATLANTIC REGION

RECEPTOR: BUILDING MATERIALS

Physical Damages

Incremental materials maintenance requirements based on reduced coating life are as follows:  
galvanized materials:

wire: 249 thousand m<sup>2</sup>/yr (20-40 kg/ha/yr)  
sheet: 430 thousand m<sup>2</sup>/yr (20-40 kg/ha/yr)  
profile: 135 thousand m<sup>2</sup>/yr (20-40 kg/ha/yr)  
oil-based painted surface: 39 thousand m<sup>2</sup>/yr  
(20-40 kg/ha/yr)

Damage estimates not available for Newfoundland.

25 historic sites considered susceptible, but damage rates not available. About half of these are in Nova Scotia.

Socio-Economic Impacts

Cost of repainting/replacing/galvanizing eroded materials is \$2.4 million/yr. (1981). Cost of replacing wire accounts for half of loss.

Present value of future losses is \$24 million.

Figures for Newfoundland unavailable.

Costs of damage to historic sites not assessed.

## ATLANTIC REGION

RECEPTOR: FORESTRY

### Physical Damages

Almost 93% of annual yield may be susceptible (mostly soft and mixed wood). Nova Scotia and New Brunswick have significant hardwood resources potentially at risk.

No damage functions.  
(damage rates and ratios unknown)

### Socio-Economic Impacts

Actual impacts unknown.

About \$288 in annual roundwood shipments, and \$365 million in wood industry output may be affected. North-central New Brunswick, eastern Nova Scotia, west-central Newfoundland areas potentially affected.

RECEPTOR: HUMANS (HEALTH)

No discussion of regionally-specific health effects.

Direct damage assumed in association with respiratory diseases (acute ailments, bronchitis, emphysema, asthma).  
Indirect damages may include cardiovascular, other ailments.

Excess mortality: 248 deaths (low),  
496 deaths (avg.)

Morbidity impacts: \$ millions (1981) (based on average mortality estimates)

Productivity loss: (respiratory/all diseases) - workdays  $0.36/5.6$ ; activity days  $0.60/10.7$

Health costs: (respiratory/all diseases) - hospital,  
 $\frac{5.7}{5.7/22.7}$ ; doctor visits,  $0.05/1.4$

Total costs: \$41 million/yr.

ATLANTIC REGION

RECEPTOR: WILDLIFE

Physical Damages

No damage functions or estimates.  
Potential damage to waterfowl due to affected  
fish stocks inland. Most of moose, deer,  
caribou habitats in Newfoundland in potentially  
susceptible regions.

Socio-Economic Impacts

Region-specific estimates confined to inventory  
of resources and related uses within deposition  
zones.

QUEBEC

RECEPTOR: AGRICULTURE

Physical Damages

Productivity gain of 25,900 tonnes at pH 4.0 (potatoes). Loss of 38,443 tonnes (carrots, some spinach) at pH 4.2-4.5. Net yield loss of 12,543 tonnes (1981).

Foliar damage of 16 tonnes to beets.

Concern that marginal soils may sustain damage, but no data available (market gardening, dairying may be at risk)

Socio-Economic Impacts

Net current yield loss is \$1.1 million.

Note: Recent studies question validity of increment, suggest no changes due to LRTAP.

St. Lawrence Valley, marginal areas in shield affected.

No employment estimates.

QUEBEC

RECEPTOR: BUILDING MATERIALS

Physical Damages

Incremental maintenance requirements based on reduced coating life are as follows:

galvanized materials:

wire:	2.4 million m <sup>2</sup> /yr
sheet:	4.2 million m <sup>2</sup> /yr
profile:	1.3 million m <sup>2</sup> /yr

oil-based painted surface: 0.4 million m<sup>2</sup>/yr

98% of damages within deposition regime of 20-40 kg/ha/yr.

18 historic sites susceptible, but damage rates not available. 5 of these receive sulphate depositions over 40 kg/ha/yr.

Socio-Economic Impacts

Cost of repainting/replacing/galvanizing eroded materials is \$23 million/yr (1981).

Present value of future losses is \$232 million.

Costs of damage to historic sites not assessed.

QUEBEC

RECEPTOR: COMMERCIAL FISHERY

Fish stock subject to 10.5% annual loss, or 79 tonnes, mostly various species (11 tonnes salmon).

Loss in production value (1981) is \$185,000/yr.  
Present value of future loss is \$71,000.

RECEPTOR: SPORT FISHERY

Physical Damages

Annual recruitment loss of 10.5% estimated from 40,600 km<sup>2</sup> affected water area, 52% of which is subject to snowmelt acid shock. Tonnage not cited.

Socio-Economic Impacts

Resident Fishery: Annual lost user benefits: \$14.4-26 million. Annual employment loss of 500 person years. Annual income loss of \$10.3 million.

Non-resident Fishery: 54,000 angler days lost. Annual income loss is \$1.7 million. Annual employment loss is 83 person years.

Combined: \$12 million in lost income on direct annual expenditures of \$19.5 million. Annual employment loss is 583 person years.

QUEBEC

RECEPTOR: FORESTRY

Physical Damages

Ottawa Valley northeastward to lower St. Lawrence and Quebec City contains most of annual provincial yield potentially at risk (mostly softwood with above one-third mixed wood).

No damage functions.  
(rates and ratios unknown)

Socio-Economic Impacts

Annual forestry production potentially at risk is \$615 million in forestry revenues, and \$1.7 billion in wood industry output. Figures are potential maximum.

RECEPTOR: HUMANS (HEALTH)

Province accounts for estimated 30% share of LRTAP - related health problems in Eastern Canada. (see Atlantic Region for nature of potential direct and indirect damages).

Excess mortality: 688 deaths (low), 1,375 deaths (avg.)

Morbidity impacts: \$ millions (1981) (based on average mortality estimates)

Productivity loss: (respiratory/all diseases)  
workdays, 1.23/19.5; activity days 1.9/34.6

Health costs: (respiratory/all diseases) - hospital,  
15.9/57.6; doctor visits, 0.15/3.9

Total costs: \$114 million/yr

QUEBEC

RECEPTOR: WILDLIFE

Physical Damages

No damage functions, estimates.  
Boreal nesting birds, wintering waterfowl,  
ungulates may be affected.

Socio-Economic Impacts

Estimates confined to inventory of resources and  
related uses within deposition zones.

Hunting, non-consumptive recreation, way-of-life  
of dependent communities may be at risk -  
particularly in central Ottawa Valley, Lac St.  
Jean/Saguenay, north shore of St. Lawrence near  
Quebec City.

RECEPTOR: AGRICULTURE

ONTARIO

Physical Damages

Productivity gain of 35,711 tonnes, mostly potatoes, cauliflower, onion, tobacco at pH 4.0. Loss of 37,622 tonnes (carrots, some spinach, radishes). Net annual yield loss is 1,911 tonnes. Most of the 10% yield loss estimated for 1980 corn crop concentrated here. Tonnage not estimated.

U.S. studies suggest potential yield losses for green beans, lettuce, radishes, rutabaga, soybean, spinach, wheat...especially in southwestern region.

Foliar damage of 18 tonnes for beets; variable damage to tobacco, soybeans, wheat.

Socio-Economic Impacts

Current value of net yield increment is \$1.8 million/yr.

Note: Recent studies question validity of increment, suggest no change due to LRTAP. Most of \$10.5 million annual loss estimated for corn in province. Proportion not cited.

Potential lost benefits in lower southwestern Ontario due to constant LRTAP estimated from \$5.8-\$13.6 million for soybeans, tobacco, potatoes, white beans, wheat.

Potential impacts suggested for processing in Kitchener-Waterloo, Toronto region.

No employment estimates.

ONTARIO

RECEPTOR: BUILDING MATERIALS

Physical Damages

Incremental maintenance requirements based on reduced coating life are as follows:

galvanized materials:

wire: 7.9 million m<sup>2</sup>/yr  
sheet: 13.8 million m<sup>2</sup>/yr  
profile: 4.3 million m<sup>2</sup>/yr

oil-based painted surface: 1.3 million m<sup>2</sup>/yr

Socio-Economic Impacts

Cost of repainting/replacing/galvanizing eroded materials is \$76 million/yr (1981).

Present value of future losses is \$761 million.

Nearly 80% of damages within deposition regime of >40 kg/ha/yr

44 historic sites, 201 buildings and museums, 11 parks and monuments susceptible, but damage rates not available. 62% of resources receive depositions above 40 kg/ha/yr.

Costs of damage to sites, buildings, monuments not assessed.

ONTARIO

RECEPTOR: COMMERCIAL FISHERY

Physical Damages

Damage slight compared to other provinces.  
Fish stock subject to 3% annual loss, or  
33 tonnes, various species.

Socio-Economic Impacts

Loss in production value (1981) is \$36,000/yr.  
Present value of future loss is \$106,000.

RECEPTOR: SPORT FISHERY

Nearly 2% of affected water area (609 km<sup>2</sup>) does not sustain yields. Over 15% of water area (4,688 km<sup>2</sup>) subject to snowmelt acid shock. Annual recruitment loss is 3%. (Tonnage not cited).

Another estimate puts loss at 13,200 kg/yr Muskoka/Haliburton/Parry Sound area, and 153,000 kg/yr for Northeastern Ontario. Total productivity loss is 166,400 kg/yr of current stocks. Small mouth bass, walleye, lake trout most sensitive species.

Resident Fishery: Annual lost user benefits: \$20-\$37 million. Annual employment loss of 582 person years. Annual income loss of \$11.8 million.

Non-resident Fishery: 0.2 million angler days lost. Annual income loss is \$0.4 million. Annual employment loss is 193 person years.

Combined: \$15.7 million in lost income on direct expenditures of almost \$26 million. Annual employment loss is 775 person years.

Estimate based on reduced fish production and angling effort indicates loss of \$0.7 million/yr in combined expenditures. Loss focused in Muskoka, Haliburton, Parry Sound, Northeastern Ontario.

RECEPTOR: FORESTRY

ONTARIO

Physical Damages

Comparatively little of annual provincial yield taken from moderate to heavily deposited zones. Area between Georgian Bay and Ottawa Valley is most likely area affected.

No damage functions.  
(damage rates and ratios unknown)

Socio-Economic Impacts

Actual impact unknown.

Much of resource potentially at risk is softwood used for pulp and paper (valuation not cited).

1981 values for remaining forestry and wood industries potentially at risk (depositions of 20-40 kg/ha/yr) are \$64.4 million and \$115 million.

RECEPTOR: HUMANS (HEALTH)

Almost 60% of health problems in Eastern Canada occur here. (see Atlantic Region for nature of potential damages).

Excess mortality: 1,146 (low), 2,296 (avg.)

Morbidity impacts: \$ millions (1981) (based on average mortality estimates)

Productivity loss: (respiratory/all diseases)  
workdays, 2.0/32.9; activity days, 3.4/62.1

Health costs: (respiratory/all diseases) - hospital  
25.5/92.1; doctor visits, 2.5/6.4

Total costs: \$189.9 million

ONTARIO

RECEPTOR: WILDLIFE

Physical Damages

No damage functions or estimates.

Wildlife potentially at risk in the area between Georgian Bay and Ottawa Valley.

The upper Thames and lower Grand River basins are of potential concern regarding wintering ungulates.

Socio-Economic Impacts

Estimates confined to inventory of resources and related uses within deposition zones.

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### LIST OF ABBREVIATIONS

- CCL : Currie, Cooper & Lybrand  
CWS : Canadian Wildlife Service  
DFO : Federal Department of Fisheries and Oceans  
DPA : Development Planning Associates  
LR-Ozone: Long-Range Ozone  
LRTAP : Long-Range Transport of Air Pollutants  
MOI : U.S.-Canada Memorandum of Intent on Transboundary Air Pollution: Final Report, 1983  
NCLAN : National Crop Loss Assessment Network  
OTA : U.S. Office of Technology Assessment  
PC : Personal Communication  
pH : potential hydrogen ion concentration (measure of acidity, ranging from 0, or maximum acidity, to 14, which is maximum alkalinity)  
SEDAP : Socio-Economic Damages of Acidic Precipitation (Draft, 1981)  
WTP : Willingness to pay

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