AQUATIC ECOSYSTEM CONSERVATION BRANCH

National Water Research Institute
Environment Canada

Biennial Report
1997-1999

Environment Canada Environnement Canada

NWRI-INRE

AQUATIC ECOSYSTEM CONSERVATION BRANCH

National Water Research Institute

Environment Canada

A biennial report for 1997 - 1999 highlighting the research achievements of the three projects comprising the Aquatic Ecosystem Conservation Branch
UV Impacts on Aquatic Ecosystems Project (UVIP)
Atmospheric Contaminants Impacts Project (ACIP)
Aquatic Ecosystem Health Assessment Project (EHAP).

compiled and edited by

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and
Freda Crisp, MA

Aquatic Ecosystem Conservation Branch
National Water Research Institute

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FOREWORD

It is my pleasure to present this Biennial Report of research highlights from the Aquatic Ecosystem Conservation Branch (AECB) of Environment Canada's National Water Research Institute for fiscal years 1997/98 and 1998/99. We hope that this document will provide useful information to our numerous governmental, university, private sector, non-governmental organisation and international partners and collaborators.

In 1998 the National Water Research Institute, Burlington, combined with the National Hydrology Research Institute, an EC water research facility located in Saskatoon, to become one aquatic research facility—the name NWRI was retained for both facilities.

The reorganisation resulted in a few of our staff leaving the AECB to work in other Branches and some staff located in Saskatoon joining the Branch. We wish those who departed all the very best in their new home and welcome those who have joined us and look forward to their fresh ideas and approaches.

Other changes that have occurred in the past two years include Dr. Rick Bourbonniere taking on the duties of Project Chief of the UV Impacts on Aquatic Ecosystems Project on the retirement of Dr Kristin Day; Dr. Derek Muir taking-over from Dr. William Strachan as Project Chief of the Atmospheric Contaminant Impacts Project; and Dr. Jim Sherry assuming responsibilities from Dr. Kelly Munkittrick as Project Chief of the Aquatic Ecosystem Health Assessment Project.

Throughout this time Debbie Challacombe, Freda Crisp, Linda Gysbers and Jill Parker have provided much appreciated support and continuity to Branch programs.

Finally, some of the research results presented in this report have not yet been published and should not be used without prior permission from the Project Chief concerned or the undersigned.

John Lawrence
Director, Aquatic Ecosystem Conservation Branch,
National Water Research Institute.

AVANT-PROPOS

Il me fait plaisir de vous présenter dans ce rapport bisannuel les faits saillants de la recherche menée par la Direction de la conservation des écosystèmes aquatiques (DCEA) de l'Institut national de recherche sur les eaux d'Environnement Canada pour les exercices 1997–1998 et 1998–1999. J'espère que ce document saura donner des renseignements utiles à nos nombreux collaborateurs et partenaires canadiens et internationaux des gouvernements, des universités, du secteur privé et des organisations non gouvernementales.

En 1998, l'Institut national de recherche sur les eaux (INRE), à Burlington, s'est associé avec l'Institut national de recherche en hydrologie (INRH), Centre national de recherche en hydrologie, à Saskatoon, en Saskatchewan, pour former un seul centre de recherche qui a gardé le nom d'INRE.

La réorganisation a causé le départ de quelques employés de la DCEA qui sont allés travailler pour d'autres directions et, d'un autre côté, des employés de Saskatoon ont rejoint notre Direction. Nous souhaitons à ceux qui nous ont quittés la meilleure chance dans leur nouvel environnement; nous accueillons à bras ouverts ceux qui se sont joints à nous, et attendons avec plaisir les idées nouvelles qu'ils ne manqueront pas de nous apporter.

D'autres changements sont survenus ces deux dernières années : la nomination de M. Rick Bourbonniere au poste de chef de Projet des impacts du rayonnement UV sur les écosystèmes aquatiques, après la retraite de M^me^ Kristin Day; le remplacement de M. William Strachan par M. Derek Muir en tant que chef du Projet des impacts des contaminants atmosphériques; et enfin, M. Jim Sherry a remplacé M. Kelly Munkittrick à la tête du Projet de l'évaluation de l'état des écosystèmes aquatiques.

Durant cette période, Debbie Challacombe, Freda Crisp, Linda Gysbers et Jill Parker ont été une précieuse source de soutien et de stabilité pour les programmes de la Direction.

Finalement, je dois signaler que quelques résultats présentés dans ce rapport n'ont pas encore été publiés et ne devraient donc pas être utilisés sans l'autorisation préalable du chef de projet concerné ou du soussigné.

John Lawrence
Directeur, Direction de la conservation des écosystèmes aquatiques
Institut national de recherche sur les eaux

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THE NATIONAL WATER RESEARCH INSTITUTE (NWRI)

"Generating, applying and communicating knowledge for a better environment"

The National Water Research Institute (NWRI) is Canada's largest freshwater establishment. It conducts a comprehensive program of research and development in the aquatic sciences, in partnership with the Canadian and international science communities.

THE INSTITUTE MISSION

Through ecosystem-based research, the National Water Research Institute creates and disseminates new knowledge and understanding of aquatic ecosystems required for the resolution of environmental issues of regional, national or international significance to Canada.

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EXECUTIVE DIRECTOR
Dr. J. Carey

GEMS/WATER	SCIENCE LIAISON	CORPORATE SERVICES
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	Aquatic Ecosystem Health Assessment Project Dr. J. Sherry	**Land Use Impacts on Hydrology and Aquatic Ecosystems Project** Dr. P. Chambers	**Exposure and Effects of Priority Substances Project** Dr. M. Servos	**Lake Assessment and Restoration Project** Mr. M. Charlton	
	UV Impacts on Aquatic Ecosystems Project Dr. R. Bourbonniere	**Climate Impacts on Hydrology and Aquatic Ecosystems Project** Dr. T. Prowse	**Sources and Fate of Toxic Substances Project** Dr. R.J. Maguire	**Sediment Assessment and Restoration Project** Dr. T. Reynoldson	

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Aquatic Ecosystem Conservation Branch

GOALS AND OBJECTIVES

The Aquatic Ecosystem Conservation Branch (AECB) conducts research to conserve the health and sustainability of aquatic ecosystems. To achieve this goal, AECB scientists undertake research to assess ecosystem changes occurring as a result of a range of anthropogenic stressors, from point source discharges to global scale changes. AECB scientists also develop early warning indicators to predict future change and generate knowledge required to produce effective mitigation measures. Current issues include persistent organic pollutants, atmospheric change (UV Radiation), pulp mill and petroleum refinery effluents, endocrine disrupting substances, and aquatic ecosystem health assessment.

Links to Environment Canada's Management Framework

As an integral part of NWRI, the AECB delivers research results within Environment Canada's Management Framework (Fig. 1.) AECB research contributes to the Business Lines, Clean Environment and Nature, and in particular to the three results printed in bold italics in the table.

BUSINESS LINE	CLEAN ENVIRONMENT	NATURE	WEATHER AND ENVIRONMENTAL PREDICTIONS	MANAGEMENT, ADMINSTRATION AND POLICY
OUTCOME	Protection from domestic and global sources of pollution.	Conservation of biodiversity in healthy ecosystems.	Adaptation to weather and related environmental influences and impacts on human health and safety, economic prosperity and environmental quality.	Strategic and effective departmental management to achieve environmental results.
RESULTS	***Adverse human impact on the atmosphere and on air quality is reduced. **** ***The environmental and human health threats posed by toxic substances and other substances of concern are reduced. ****	Biological diversity is conserved. ***Human impacts on the health of ecosystems are understood and reduced. ****	The impact of weather and related environmental hazards on health, safety and the economy is reduced. Adaptation to day-to-day and longer term changes in atmospheric, hydrological and ice conditions.	Strategic and integrated policy priorities and plans. Efficient and innovative shared services.

*** AECB research falls within these three EC results**

Figure 1. Environment Canada's Management Framework

UV Impacts on Aquatic Ecosystems Project (UVIP)

GOALS AND OBJECTIVES

The UV Impacts on Aquatic Ecosystems Project (UVIP) conducts research on the impacts of UV radiation to develop information necessary for the sustainable management of freshwater and wetland ecosystems. The Project contributes important knowledge used in Departmental policy and communications initiatives on Ozone Depletion/UV-B, the Montreal Protocol and the Great Lakes 2000 Atmospheric Change Program. The research team develops new indicators, models and assessment techniques for predicting the distribution and fate of UV radiation and examines UV impacts on aquatic ecosystem components or processes such as algal photosynthesis, bacterial growth and metabolic activity, dissolved organic matter, and forest stream communities. Particular emphasis is directed at the combined effects of multiple atmospheric stressors on the aquatic carbon cycle of the Great Lakes, wetlands and prairie lakes. Research on Arctic UV issues and climate change impacts and adaptation is done in collaboration with other government departments and universities.

PROJECT RESEARCH TEAM

Project Chief: Rick Bourbonniere, Ph.D.
(Inquiries regarding this project should be addressed to the Project Chief (905) 336-4547; Rick.Bourbon@CCIW.ca)

Team Study Leaders: R. Bourbonniere, M. Arts, R. Robarts, K. Day, R. Bukata, J. Jerome, M. Bothwell, S. Beltaos, G. Bobba, W. Schertzer, S. Wilhelm

Team Members: K. Edmondson, S. Kirby, M. Waiser , V. Tumber, F. Dunnett, J. Holland-Hibbert

The Impact of Ultraviolet (UV) Radiation and Multiple Stressors on Canadian Resources
Increases of UV-B radiation associated with declining stratospheric ozone levels can impact the sustainability of several Arctic fish populations. Experiments are underway to investigate the effects of UV radiation on algal and insect communities in Arctic rivers, with different natural levels of dissolved organic matter (DOM). The research is in collaboration with the National Science Foundation (NSF) funded long-term ecological research program at the Arctic research site at Toolik Lake, AK. In related environments, the vulnerability of arctic char eggs to UV radiation is also studied. Arctic char eggs are laid individually during the spring on shallow river beds. UV sensitivity of these eggs, the protection afforded by DOM and the development of char fry are also being investigated.

At several sites in British Columbia studies have been undertaken to determine the influence of increased UV radiation on stream biodiversity. Funded by Forest Renewal of British Columbia and with partners from the University of Alberta, the study included analysis of aquatic biological community structure, algae and invertebrates, in relation to physico-chemical factors such as UV radiation, temperature and DOM. Canopy removal experiments in streams in BC (Fig. 2) show how different components of the community react to changes in exposure to UV radiation.

• Intact canopy (13% of the UV reaches the stream)	- UVR has no effect
• Intermediate canopy (70% of the UV reaches the stream)	- grazers reduced by UVB - algae increase with UVA + UVB
• No canopy (100% of the UV reaches the stream)	- grazers very low - algae reduced by UVA + UVB

Figure 2. Canopy removal experiment in BC

The international BOREAS program is designed to investigate carbon exchange in terrestrial and aquatic systems in the boreal forest. Large fluxes of trace carbon gases were reported from the Boreal Ecosystem Atmosphere Study (BOREAS) beaver pond site at Thompson, MB. Carbon monoxide is produced photochemically by UV degradation of the dissolved organic matter DOM in the surface waters of the pond, and exhibits a supersaturation five times higher than any freshwater system previously reported. These results are applicable to both the UV radiation and climate change issues and demonstrate how organic matter can link both. Anthropogenic perturbations to the carbon cycle could disrupt the processes that enable the biome to store carbon, creating the possibility that the biome could change from being a net sink of atmospheric carbon to being a net source.

Wetlands

The importance of DOM in protecting aquatic organisms from UV damage is a central theme to many studies of the UV Impacts on Aquatic Ecosystems Project research. A partnership between the UVI Project and Ducks Unlimited (DU) is focusing on wetlands at the St. Denis National Wildlife Preserve. The Institute for Wetland and Waterfowl Research (IWWR) of DU funded a study entitled, “Effects of agriculture, climatic warming and UV-radiation on organic carbon cycles in prairie wetlands” as a component of its new freshwater initiative. Successful wetland conservation requires that society perceives broader values of freshwater wetlands than simply their role as wildlife habitat. The IWWR program aims to identify and quantify the functions and values of wetlands relative to the supply and quality of freshwater in North America, and to evaluate the economic and ecological impacts of policy changes related to preserving and restoring wetland functions.

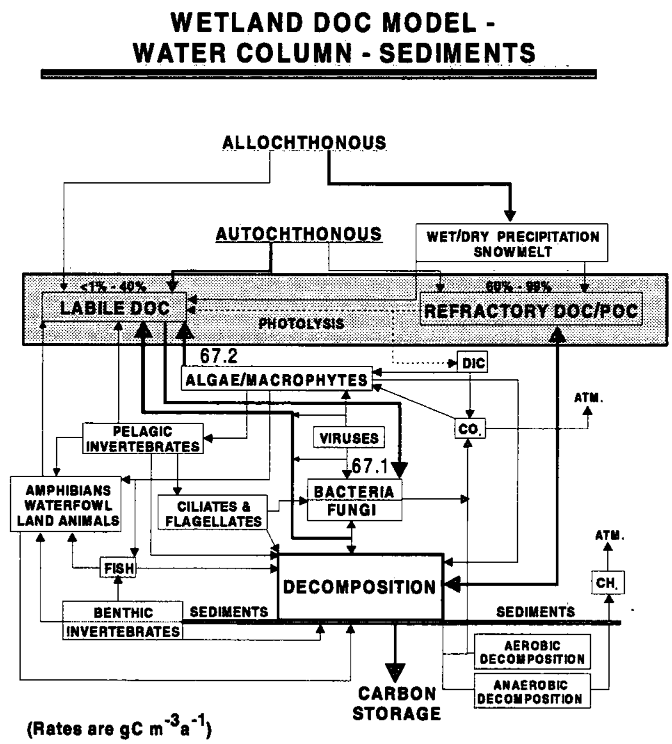
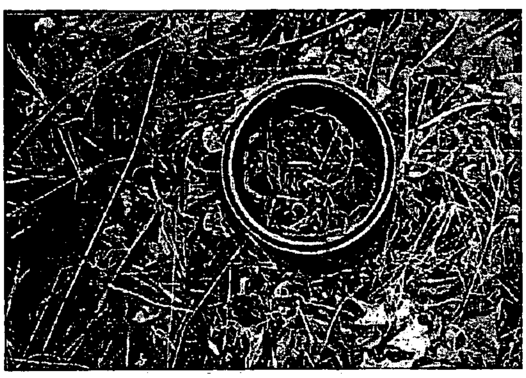


Figure 3. AECB model to describe the DOC cycle

One of the anticipated impacts of changes to the climate is the drawing down of water tables in wetlands. Wetlands can be either sinks of carbon from the atmosphere, or under dry conditions function as sources—releasing CO_2 to the atmosphere. Wetland carbon cycles are stressed by atmospheric changes and human encroachment, particularly in agricultural regions. To preserve and restore wetland habitat we must measure the changes, predict the responses and propose strategies to mitigate the impacts of multiple stressors. AECB research scientists devised a model to describe the Dissolved Organic Carbon (DOC) cycle within wetlands (Fig. 3). Studies are aimed at understanding and quantifying the relationships in this complex ecosystem.

A long-term collaborative study on the sensitivity of wetland biogeochemistry to drought is underway at Beverly Swamp, ON (Fig. 4). This cedar and hardwood swamp is a remnant of what used to be a common land type in southern Ontario before the region was cleared for agriculture. This research program is conducted in partnership with McMaster University and the Hamilton Region Conservation Authority. The study is providing information regarding the dependence of CO_2 and CH_4 exchange on wetland hydrology (Fig 5) which in turn is impacted by changing climate (drought). These results will provide the basis for future research regarding the cumulative impacts of climate change and agricultural practices on temperate wetlands, and will determine the ability of natural and restored wetlands to sequester atmospheric carbon.



(a) Gas exchange collars are inserted into the swamp peat

(b) Collar with chamber for determining soil gas fluxes

(c) Spencer Creek

Figure 4. Beverly Swamp Research Site

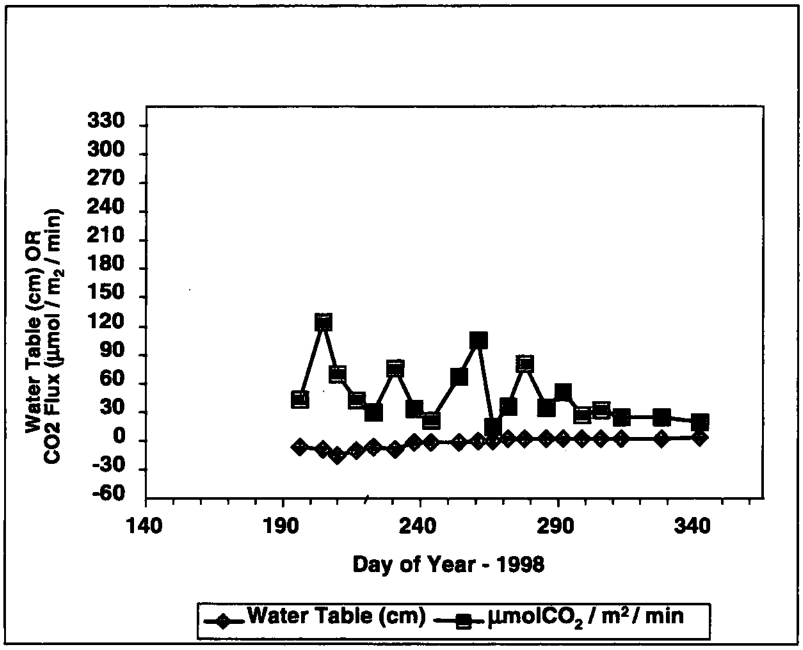


Figure 5. Spencer Creek site at 10 m from the Creek

UV Radiation and Microbial Activity

Aquatic organisms differ in the manner and degree of their response to increased UV radiation, as species and as diverse communities. These differences need to be measured and related to current impacts so that future aquatic ecosystem responses can be modeled.

Dissolved Organic Matter (DOM) is being broken down by UV light across a variety of prairie wetlands. In these situations bacteria are able to utilise the smaller carbon molecules. To determine whether microbial activity and production is enhanced or retarded by UV-radiation, experiments were undertaken with water from Prairie lakes and ponds, containing their natural DOM and microbial communities. Screening experiments using natural solar radiation indicated that photolysis rendered DOM more available to bacteria, but to different degrees depending upon its source.

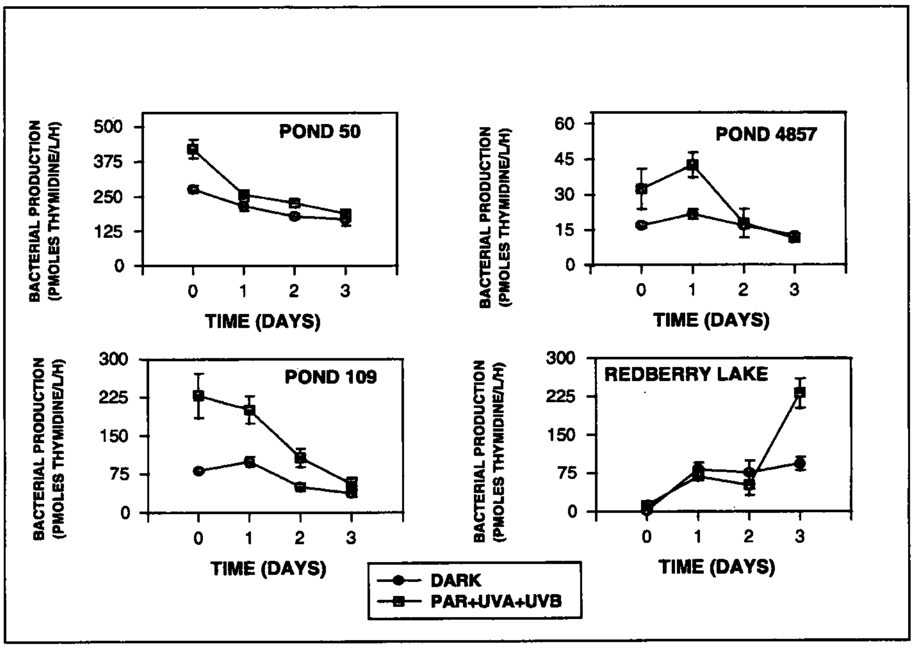


Figure 6. UV-light mediated breakdown of DOM in prairie wetlands and saline lakes

Results indicate (Fig. 6) that DOM is being broken down by UV radiation across a variety of prairie wetlands. Bacteria were able to utilise the smaller carbon molecules produced by this process. UV radiation may have a significant effect on the carbon cycle in these systems through changes to carbon availability.

Impact of UV on Metabolism, Growth and Behaviour of Aquatic Organisms

The high energy density of lipids makes them the energy storage biomolecule of choice for freshwater and marine zooplankton. Lipids, particularly energy reserve lipids, are sensitive to environmental perturbations, both natural and anthropogenic. For this reason lipids are a useful marker of environmental stress. Changes in fatty acid profiles could be used as an index of stress in zooplankton. Rates of photosynthesis are clearly depressed in many algae. Some marine algae have demonstrated altered fatty acid and reduced essential fatty acid (EFA) profiles following exposure to realistic fluxes of UV-B. The implication of these reductions in EFA may prove to be a valuable indicator of exposure to UV radiation.

To evaluate work to date, a book entitled: *The Ecological Role of Lipids in Freshwater Ecosystems* edited by Michael Arts and Bruce Wainman (Springer-Verlag, 1999) has been researched and written to include all current literature on aquatic lipids. The book addresses lipid composition and production in freshwater organisms, the function of lipids in aquatic food webs, lipids as indicators of health in fish populations and the similarities and difference between lipids of marine and freshwater origin.

Adaptive strategies of organisms in response to UV radiation were tested through experiments conducted in laboratory exposure systems. The IncUVator facilities at CCIW comprise two 15 compartment exposure systems capable of providing computer controlled manipulated light fields from xenon arc lamps. This laboratory exposure system is used for photochemical and photobiological experiments to determine response functions to varying solar radiation (Fig. 7).

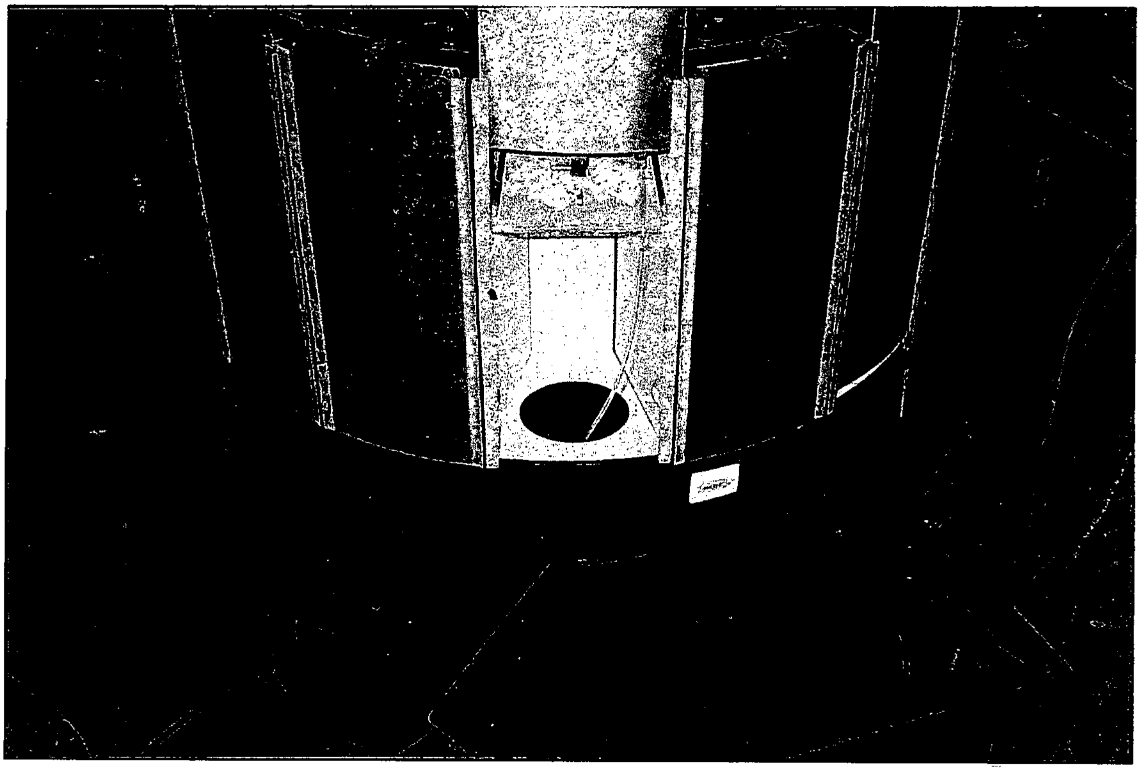


Figure 7. Controlled exposure system, IncUVator, at CCIW

Using the IncUVators the effects of UV radiation on algal species (especially Microcystis aeruginosa) were investigated (Fig. 8) and research was conducted on invertebrate avoidance behaviour in response to UV radiation. The Phototron manipulated light facility (NHRC, Saskatoon) was used to study the effect of UV radiation doses and pesticides on algae. Various growth and metabolic indicators were used to determine susceptibility.

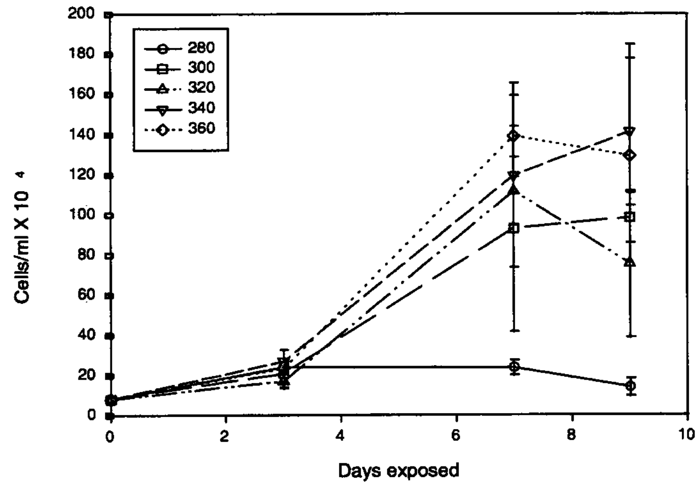


Figure 8. Cell counts of *Microcystis aeruginosa* as a function of time when cultured under various light regimes

Dispersal of Subsurface UV Radiation
By combining a solar spectral irradiance model, a water column optical model, and specific action spectra for photochemical and photobiological processes, the impacts of ultraviolet radiation (and therefore, the impacts of ozone depletion) as a function of depth within natural water bodies was determined. Using directly-measured values of the composition, concentrations, and inherent optical properties of numerous Canadian water bodies, it was shown that resident concentrations of DOM in most Canadian waters affords as much or more protection to aquatic biota than does the ozone layer itself. In suspended-sediment-free water columns DOM absorbs over 80% of UV-B radiation while another 10% is either reflected from the surface or absorbed by the water molecules. The biota absorb about 20% of the UV-A radiation. Thus, despite UV radiation being both an agent of bare DNA damage and an inhibitor of photosynthesis, the composition of inland Canadian waters are, in general, self-mitigated against adverse impacts to aquatic photobiology caused by stratospheric ozone depletion. In a similar manner it was illustrated that the hydrogen peroxide production in Lake Ontario would be expected to increase by only 3.5% if over one-third of the ozone layer concentration were to be removed.

Quantifying Ozone Depletion Impacts on Photochemical and Photobiological Processes
An action spectrum defines an organism's or a compound's wavelength-dependent response function to an incident irradiance spectrum. Using twenty actual action spectra in conjunction with a family of theoretical action spectra, a mathematical characteristic of UV action spectra was obtained that enabled a quantification of the

severity of impacts to specific photoprocesses resulting from stratospheric ozone depletion. By the use of this characteristic (labelled RI in Fig. 9) two very important questions may be realistically entertained once action spectra are either already known or determinable, viz., "What photochemical and photobiological processes are at greatest risk to ozone depletion?" and "What are critical levels of ozone depletion for each photoprocess?". Figure 9 illustrates answers to these questions in graphical form. Once an action spectrum is selected, its RI is determined and located on the abscissa. The ordinate then gives the increase in action relative to initial strato spheric ozone conditions for ozone depletions of 10%, 25%, and 50%.

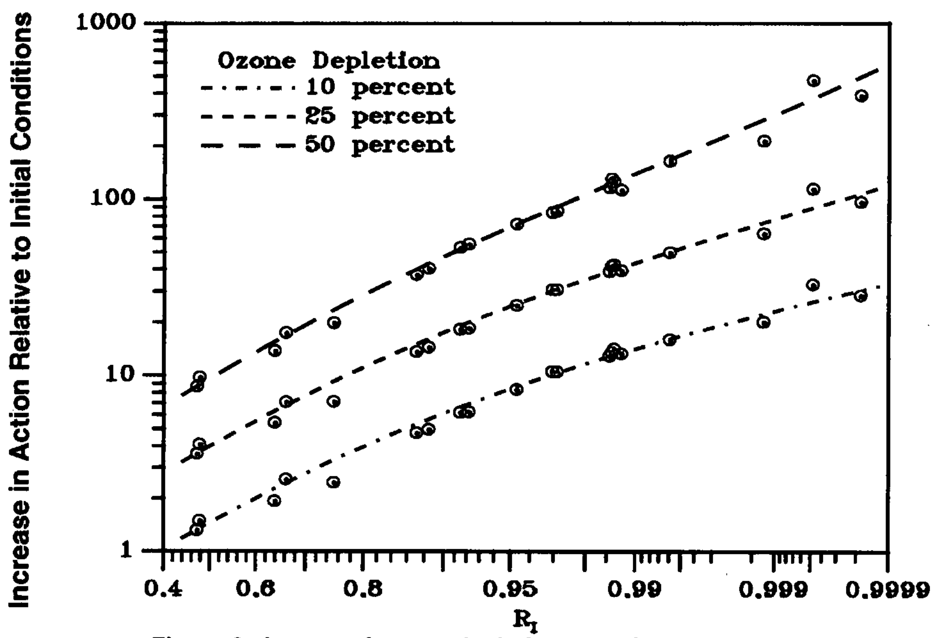


Figure 9. Impact of ozone depletion senarios on action spectra

Remote Sensing

Conventional experimental research and water quality monitoring networks are designed to acquire data on selected parameters for predefined areas or regions. While the temporal dimension of water can usually be assessed with sufficient accuracy, the limited number of stations associated with the water quality networks can prohibit the spatial dimension of the water quality issue to be monitored with comparable accuracy. Remote sensing is a means of overcoming this problem by obtaining synoptic measurements of the optical returns (reflected or emitted) from targeted water bodies. This optical return must then be transformed, through models, algorithms, or methodologies, into estimates of water quality parameters.

The dedicated POES/AVHRR tracking station at NWRI collects large-scale synoptic overviews of the Canadian terrain including the Great Lakes Basin. Incorporation of

[1] Concepts are explained in the book: Bukata P.R., J.J.H. Jerome, K.Ya. Kondratyev, D.V. Pozdnyakov. 1995. *Optical Properties and Remote Sensing of Inland and Coastal Waters.* Boca Raton, Fl.: CRC Press, pp. 362.

these data with GIS methodologies, link the impacts of concurrent atmospheric stressors (temperature, precipitation, solar radiation) on aquatic ecosystems. For example, the extremes of floods and droughts on coastal wetlands have been tracked.

FUTURE DIRECTIONS

The Project team will assess the sensitivities of lakes, streams and wetlands to multiple stressors using laboratory and field programs and identify adaptive strategies for aquatic biota. Increased focus will be directed towards wetlands, biodiversity, aquatic carbon cycle dynamics, northern ecosystems and the quantification of direct dose response of aquatic organisms to manipulated radiation fields. Future research will enhance departmental capabilities for assessing alternative management strategies for dealing with increased UV radiation, climate change and multiple atmospheric stressors on aquatic ecosystems.

Symposia and Workshops Organized by UVI Project Staff

"Effects of UV Radiation on Algae and Invertebrates: Implications for Trophic Energy Transfer" at the XVII Societas Internationalis Limnologiae (SIL) Meeting, Dublin, Ireland, 8-14 Aug 1998. (co-hosted with H. Rai, Contact: M. Arts, (306) 975-6012, Michael.Arts@ec.gc.ca).

"DOC degradation in freshwater and marine systems: microbial versus photochemical processes" at the 8th International Symposium on Microbial Ecology, Halifax, NS, 9-14 Aug 1998. (co-hosted with P. Kepkay, Contact: R. Robarts, (306) 975-6047, Richard.Robarts@ec.gc.ca).

"Interactions Between Solar UV Radiation and Carbon, Nutrient & Metal Cycles in Aquatic Systems" at the Society of Environmental Toxicology and Chemistry (SETAC) Annual Meeting, Charlotte, NC, 15-19 Nov 1998. (co-hosted with R. Zepp, Contact: R. Bourbonniere, (905) 336-4547, Rick.Bourbon@cciw.ca).

"Experts Workshop on Carbon Fluxes" for Climate Change Action Fund, Downsview, ON, 18-19 Jan 1999. (Chaired Wetlands Working Group, Contact: R. Bourbonniere, (905) 336-4547, Rick.Bourbon@cciw.ca).

"Composition and Reactivity of DOC: Comparisons Across Freshwater and Marine Environments" at the Aquatic Sciences Meeting, (ASLO), Santa Fe, NM, 1-5 Feb 1999. (co-hosted with J. Bauer, Contact: R. Robarts, (306) 975-6047, Richard.Robarts@ec.gc.ca).

"Nuisance Blooms and Toxin Production: Controlling Mechanisms in Freshwater and Marine Environments" at the Aquatic Sciences Meeting, (ASLO), Santa Fe, NM, 1-5 Feb 1999. (co-hosted with M. Kumagai, Contact: R. Robarts, (306) 975-6047, Richard.Robarts@ec.gc.ca).

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Atmospheric Contaminants Impacts Project (ACIP)

GOALS AND OBJECTIVES

The Atmospheric Contaminants Impacts Project (ACI) investigates the spatial distribution, and temporal trends of persistent organic pollutants (POPs), metals (especially mercury) and acids in water, precipitation and sediments as well as in aquatic food chains, and subsistence human food sources. The ecosystems investigated are impacted mainly by long range transport rather than local sources. The project is also involved in the development of methods for sampling and analysis of new and emerging POPs. The information contributes to national and international assessments of POPs and mercury for the Arctic Council/AMAP, Northern Contaminants Program, Great Lakes Integrated Atmospheric Deposition Network, Hazardous Air Pollutants program, NAFTA tri-national, and US/Canada bi-national activities on long range transport and deposition. The project has the lead on reporting and assessment of acid rain impacts in Canadian freshwater ecosystems.

PROJECT RESEARCH TEAM

Project Chief: Derek Muir, PhD

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The Canadian North

The Northern Contaminants Program (NCP) investigates contaminant levels in the Canadian north with a particular focus on contaminants that may be found in traditional, country foods across a wide area of the Arctic and sub-Arctic. The information is used to assess effects on the health of northern ecosystems including that of humans. Knowledge is also used to provide insight into sources, transport, transformation and surface exchange processes of contaminants. Information is required to validate models of contaminant pathways in the northern environment. The NCP provides information to assist northerner's in decision making for international agreements and cooperation to control contamination at a global level. The Canadian Arctic Contaminants Assessment Report (CACAR) was a major scientific report that summarised the results of research conducted by scientists involved in the NCP and the Arctic Environmental Strategy (AES). As such, CACAR is the front-line document summarising knowledge and recommending research studies on contaminants important to the health of northern ecosystems.

Derek Muir, Project Chief of the Aquatic Contaminants Impacts Project, was senior author of Chapter 3 of the CACAR document *Ecosystem uptake and Effects of organic* *and other contaminants in the Canadian Arctic.* This report provided the first major assessment of contaminants data, based on the 6 years of study under the Arctic Environmental Strategy (AES). It documented spatial and temporal trends and biological effects. Contributions were also made to the Chapter on POPs in the Arctic Monitoring and Assessment Program (AMAP) report on Arctic Pollution. The Branch contributed much of the scientific assessment of information in the report on spatial and temporal trends of contaminants in the circumpolar Arctic. The chapter on POPs assessed the current information on the distribution, biomagnification and biological effects of organochlorine contaminants (OCs) in Arctic air, snow, seawater, and the marine mammal food chain, and identified knowledge gaps and future priorities for phase II of AMAP. The POPs assessed in the report include major classes of OC, hexachlorocyclohexanes (HCH), hexachlorobenzene (HCB), toxaphene, chlordanes, PCBs, DDT and dioxin/furans. Further action was recommended to identify sources of persistent organic contaminants and to study biological effects. In addition, several workshops were held during the summer of 1997 to address research directions for the NCP. The ACI project was involved in three of these workshops which focused on proposed studies in the upper Mackenzie River basin, the Nunavik/Labrador region, and the Archipelago.

ACIP scientists examined contaminants in the surface water and air of the Archipelago region, the western part of the Parry Channel, and contributed to the commissioning expeditions for the Surface Heat Budget of the Arctic (SHEBA) project in the Beaufort Sea. Results for 1997-'98 and 1998-'99 were presented at the NCP results Workshop (January 1998) and are published in the Canadian Arctic Contaminants Assessment Report.

Studies were completed on the impact of the decommissioned Pine Point lead-zinc mine. The investigation involved determinations of metal levels in fish, water, and sediments in the Resolution Bay area of Great Slave Lake. Using these study results scientists were able to alleviated community concerns regarding purportedly elevated metallothionein levels in burbot kidney collected from the Slave River.

With PERD funding, scientists began a collaborative investigation with Fisheries and Oceans Canada to determine concentrations, composition and probable sources of hydrocarbons found in Lake Athabasca and the Peace-Athabasca delta lake sediments. The study, which includes analysis of sediment cores collected in Mamawi Lake located within the delta region, will assess the potential impacts of the upstream hydrocarbon industrial operations on these northern lake ecosystems (Fig. 10).

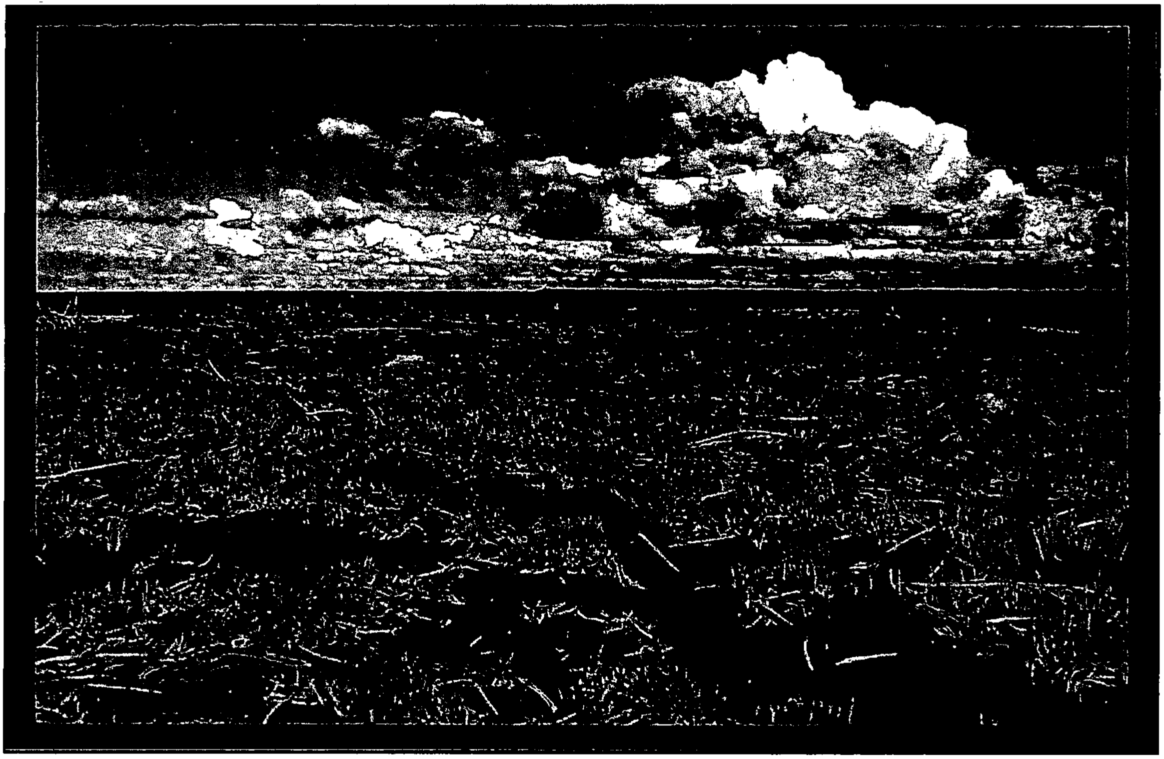

Figure 10. The Athabasca Delta and Lake Athabasca

Investigations were made of the factors effecting mercury levels in predatory fish in the NWT. The study, conducted in collaboration with Fisheries and Oceans Canada, focused on two lakes west of Fort Simpson, Cli Lake and Little Doctor Lake. Predatory fish in many lakes in the NWT have elevated levels of mercury although results show Cli Lake and Little Doctor lakes to be extreme examples. This is believed to be due to a natural feature of the watershed rather than recent human activity. The study will continue to investigate the specific reasons for the observed mercury levels. Mercury, like PCBs, DDT and toxaphene, biomagnifies in the food web. Study results show that whitefish, which feed on invertebrates, have lower concentrations of mercury than burbot and lake trout which feed on fish (Fig. 11). Fish with a muscle mercury level above 0.5 mg/g can not be sold commercially, indicating that there would be some limitation in the utilization of such lakes, including Cli Lake, for commercial fisheries. Fish with a muscle mercury level above 0.2 mg/g should not be a steady part of the human diet. Accordingly, health advisories have been issued by Health Canada regarding the consumption of fish from Cli (and Little Doctor) Lake. Therefore, from an economic perspective, communities may be less able to make use of these lakes both for domestic consumption and for tourist-based and sports fishing based commercial lodges.

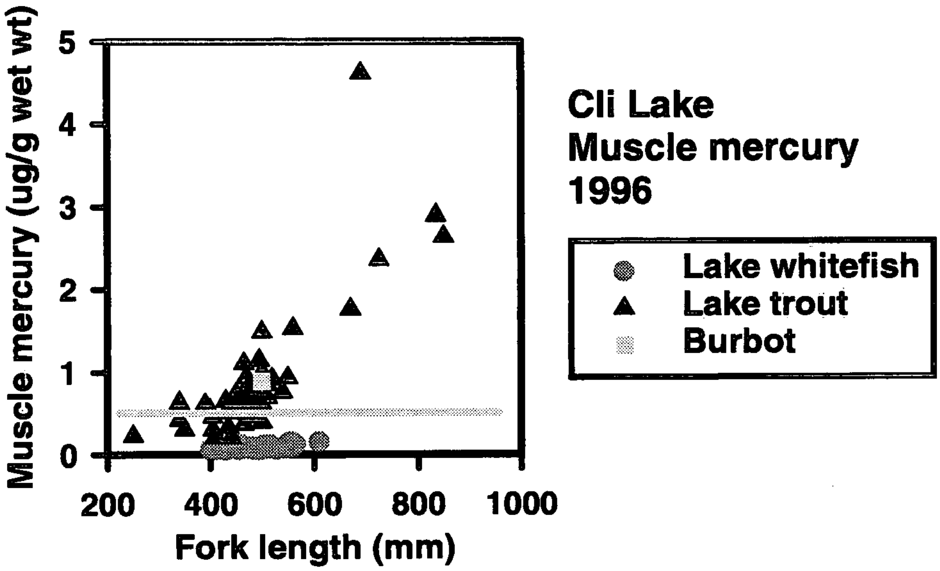

Figure 11. Chi Lake mercury in fish muscle

Haloacetic Acids

Although haloacetic acids (HAAs) are wide-spread atmospheric and aquatic contaminants they have not been extensively studied in North America. It is important that concentrations of HAAs be established in the aquatic environment since they are known to be phytotoxic and have been found in many parts of the world at concentrations likely to present a problem to aquatic organisms and terrestrial plants. Their precursors are important industrial chemicals. For example, trifluoroacetic acid (TFA) is formed in the atmosphere from the refredgerant HCFC134a which is widely used in automobile air conditioning. Trifluoroacetic acid is formed from atmospheric degradation of some chlorinated solvents. Haloacetic acids have been detected in atmospheric deposition at moderate concentrations. AECB research into this emerging issue began in 1996 with the development of a single method for analysis of 10 ubiquitous HAAs. This new practical technique allowed a Canada-wide testing of snow, rain, tap-water, groundwater and lake water for concentrations of HAAs. Preliminary survey results showed, that except for a single groundwater sample, HAAs are present in all samples at ng/L levels.

Analysis of precipitation samples, collected by the Atmospheric Environment Service from sites across Canada (Fig. 12) provided values for HAAs that ranged from below detection limits to very high.

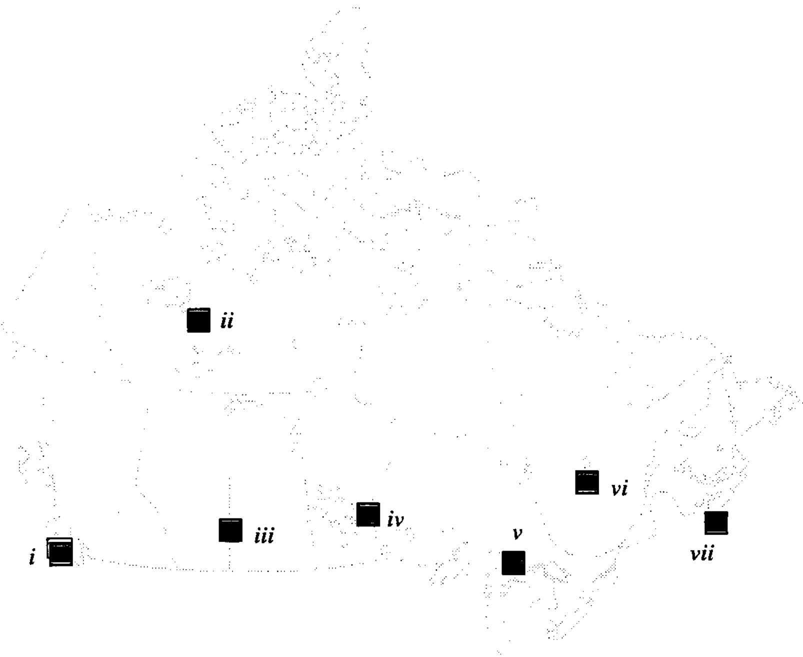

Figure 12. Precipitation sampling sites for HAAs

For a site at Saturna near Vancouver, results were variable, analyses showed appreciable concentrations (100 ng/L) of trifluoroacetic acid (TFA) only once. For this and other similar situations the back-trajectory of precipitation events were plotted using expertise from a collaboration with AES. In this case the air mass in fact passed over the San Francisco area and up the coast prior to the precipitation event. Similar observations were made for samples collected from Kejimkujik, NS in which samples with high concentrations of HAAs included precipitation events that had passed over the highly populated and industrialised New York area. Samples from the most northern site, Snare Rapids, NWT contained the lowest concentrations of HAAs. It is expected that environmental concentrations of TFA will likely increase as freon replacement compounds are released and degrade in the atmosphere.

In a study of four Canadian lakes, Loon Lake BC, Great Slave Lake, NWT, Lake Winnipeg, MB, and Kejimkujik, NS, detectable concentrations of HAAs were noted from water bodies adjacent to populated areas.

The presence of HAAs were evaluated for each of the Great Lakes both in surface surveys and depth profiles. These analyses constitute the first detailed report on HAAs in Canadian Great Lakes waters. Chloroacetic acids were found at concentrations up to 400ng/L. Lake Superior, which has some industry and low population showed TFA concentrations of about 18 ng/L and this increased though the Great Lakes system to

Lake Ontario with a TFA concentrations of ~150 ng/L (Fig. 13). These results from the Great Lakes showed a link between the concentration of TFA and areas of high population and industrialisation. To further investigate these possible links, TFA concentrations were analysed in water from Lake Malawi. This is an African lake with a high human population in the watershed but no industry about its shores. Lake Malawi was found to have a TFA concentration of only <10 ng/L , implying that the TFA in freshwater is derived from industrial sources. In addition, results were obtained for samples collected, in conjunction with Ontario Region, EC and from a number of storm-water retention ponds located north of Toronto, and Guelph. Some ponds contained HAA concentration levels close to the EC50 for phytotoxicity.

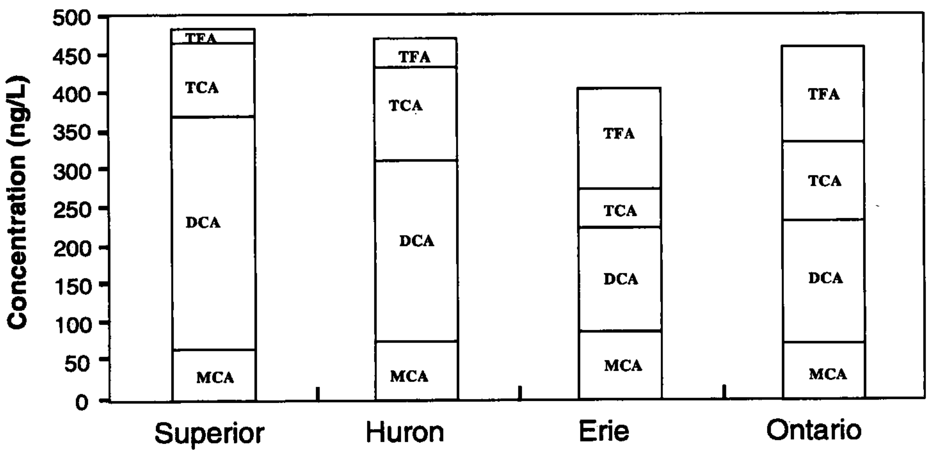

Figure 13. Average surface concentrations of HAAs in the Great Lakes

Results also showed a difference between marine and freshwater systems for the TFA. Freshwater TFA concentrations can be attributed to industrial activity within the basin, whereas in marine environments there is evidence for a natural source for this HAA. The AECB scientist who researches HAAs has been invited by representatives of the European Commission's Joint Research Centre, to participate in a global study of TFA concentrations in waters close to volcanic vents, a predicted source of natural TFA. Ocean profiles were found to have low MCA concentrations (<20ng/L) but the TFA concentrations were generally above 100 ng/L. Samples taken from the Arctic Basin at depths greater than 1500 m had concentrations greater than 120 ng/L. This water is known to have a residence time of greater than 300 years, indicating that TFA in the oceans is probably from natural sources.

POPs & Metals in the Great Lakes
Environmental concentrations of POPs are higher in the Great Lakes and St. Lawrence Basins than in the North because of proximity to sources. However, different dietary practices among the human population means that concentrations in residents of these southern regions have not matched those observed in the north where top predators such as seal and beluga are consumed as part of traditional diets. POPs of concern in Canada come largely from foreign sources through long range air transport, most notably from the USA, Mexico and Central America.

The Great Lakes aquatic ecosystem was examined for trace heavy metals and mercury. An experimental rain collector system was installed and operated for mercury analysis. Surface water samples were collected from Lake Superior and its tributaries for analysis of Hg and other trace metals. Mercury analysis was completed in cores and pore water samples. A report is available summarising the results of the study.

Mass Balance of Lake Superior
The year 1997 saw completion of the field part of a mass balance study of POPs and heavy metals in Lake Superior. A suite of analytes including most OC pesticides, PCBs, PAHs, chlorobenzenes Pb, Cd, Cu, Ni, Hg and other metals were sampled in air, water, and rain. Toxaphene was a particular focus for the study. Investigation of bioaccumulation pathways of toxaphene in Lake Superior began in 1998. This work includes examination of individual toxaphene congeners and optical isomers in order to obtain "fingerprints" for various input pathways e.g. atmosphere, sediments, rivers and local sources.

Integrated Atmospheric Deposition Network (IADN)
The Great Lakes Water Quality Agreement (GLWQA) included Annex 15 in 1987 to address the problem of airborne contaminants in the Great Lakes Basin. As a result of this agreement a Canadian Master Station was established at Point Petre in 1988. Research resulting from bi-national commitments resulting from this new Annex have had impact on development of Lake Wide Management Plans. This is particularly true for Lake Superior where IADN has reported on concentrations of Toxaphene and PAHs.

Rain and snow samples were collected from Point Petre, Lake Ontario, and Burnt Island, Lake Huron. Measurement of cadmium in precipitation at Pt. Petre show a decline over a six year period (Fig. 14). The IADN steering committee completed a major biennual report on loadings which covered sampling to 1994 inclusive. Preliminary results indicate a springtime seasonal high for the concentrations of a number of the pesticides in precipitation, and a detectable downward trend for PCBs and industrial chemicals. The duration of the sampling period is too short to identify significant trends in the loadings or concentration data. An improved reporting schedule and data assessment is expected shortly.

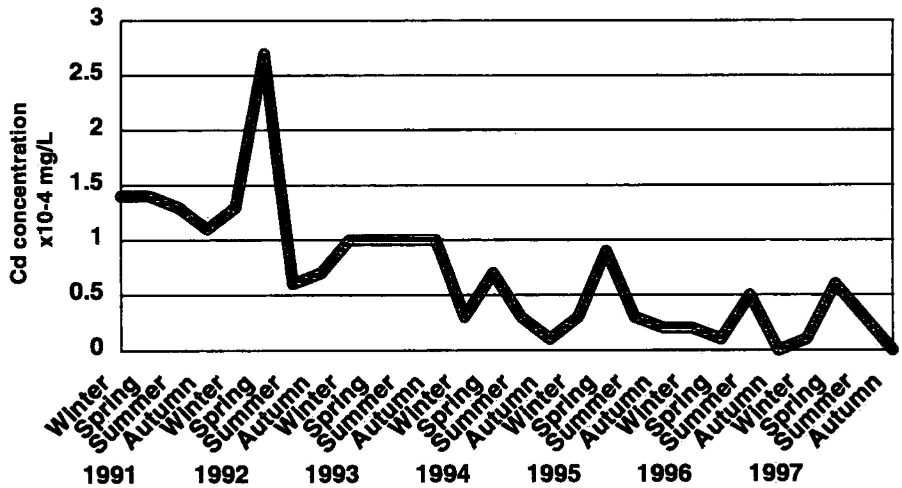

Figure 14. Cadmium in wetfall at Pt. Petre

POPs at High Altitude

The results of a study, undertaken in collaboration with Dr. David Schindler of the University of Alberta and others, show that semi-volatile POPs in snow increase in concentration with increasing altitude in the Canadian Rocky Mountains. The implication of this finding is that mountain glaciers and snow fields act as sinks for semi-volatile contaminants and can gradually release them back to the aquatic environment. This has ramifications for populations dependent on water supplied from mountain sources (for example, western Canada, the Swiss Alps, Mexico City, Denver). While levels of POPs in water from the Canadian Rockies are not especially elevated, there is evidence of increased concentrations of some compounds. For example, toxaphene in lake trout has been shown to increase with increasing altitude in western Canada.

New POPs

AECB developed an improved analytical method for the determination of brominated diphenyl ethers (BDPEs) in environmental samples in collaboration with scientists from DFO. The method is based on gas chromatography with high resolution mass spectrometry.

BDPEs are fire retardants used in the manufacturing of plastics, paint, textile and electrical devices. They are relatively persistent and bioaccumulative. BDPEs were first reported in the Swedish environment during the 1980s. Recently, they have been detected in North America. This study found detectable levels in Canadian biota and air samples, e.g., in lake trout from the Great lakes, marine mammals from the Arctic, and air samples from Alert, NWT (Fig. 15).

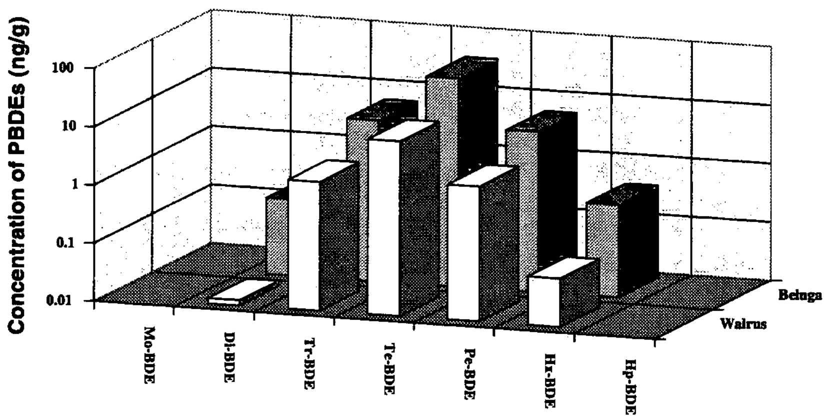

Figure 15. Concentration of BDPEs in Beluga and Walrus Samples from Arctic

Acid Rain

Acid Rain became a Canadian environmental issue in the 1970s. Although natural sources of SO_2 and NOx do exist, more than 90% of emissions occurring in North America are anthropogenic. Once released into the atmosphere, acidic pollutants may be transported great distances by prevailing winds and weather systems before being deposited. Acidic pollution is one of the most serious threats to biodiversity since reduced pH negatively affects many forms of aquatic biota. Furthermore, the effects of acidification may combine with other perturbations, like climate change, increased ultra violet radiation or mercury, to produce even broader scale deleterious effects to the ecosystem. The Long Range Transport of Air Pollutants (LRTAP) program defines the present and predicts the future scope of these effects in the Canadian environment.

In order to predict the effectiveness of reductions in acid rain that have occurred during the last decade, AECB research has focused on interpretation and assessment of monitoring data. These data were collected to recognize and quantify acidification trends; to assess the chemical and biological recovery of aquatic ecosystems; to development and apply models simulating acidification effects, and to evaluate the role of nitrogen-based pollutants in ecosystem acidification. These studies provided information which was incorporated in the Canada/US Air Quality Agreement Progress Report. Results show that many Canadian lakes are yet to respond to reduced levels of acid rain, and in fact, many aquatic ecosystems remain gravely impacted.

An integrated assessment model was used to predict the eventual status of lake chemistry and biology after the SO_2 controls, required by the AQA, are fully implemented. Results predict that the percentage of damaged lakes (pH<6) will decline as the effects of emission controls are felt. Similarly, declines in biological damage are expected. Nevertheless, significant aquatic effects will remain after full implementation of all planned SO_2 controls in North America, and further controls will be needed to achieve lower damage levels (Fig. 16). These kinds of predictions for water quality and ecological impact were used to evaluate control options for acidifying emissions when developing the federal-provincial Canada-Wide Strategy on Acid Rain.

The acid rain component of EC's Clean Environment Table review of the Department's air issues monitoring program was lead by AECB. The review identified several short-comings in the monitoring program that inhibit delivery of some results required to meet commitments made under the Canada/US Air Quality Agreement (AQA) and the UN-ECE Sulphur and No_x Protocols.

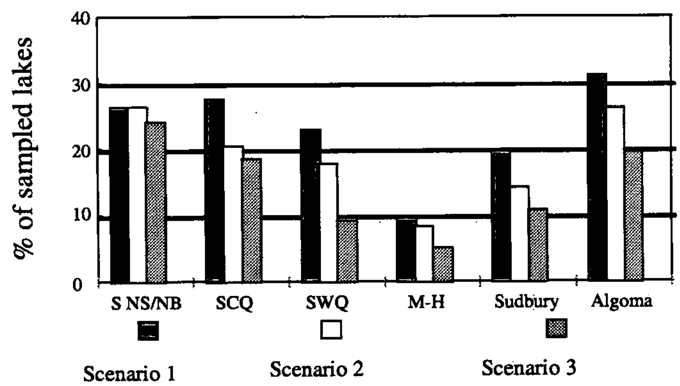

Figure 16.
Percent of lakes predicted to be damaged in 6 regions of southeastern Canada for 3 SO_2 control scenarios. Regions: Southern Nova Scotia/New Brunswick, South-central Quebec, Southwest Quebec, Muskoka-Haliburton Ontario, Sudbury Ontario, and Algoma Ontario. Scenario 1 is prior to AQA controls. Scenario 2 is Canadian controls only. Scenario 3 is Canadian plus U.S. controls.

Sediment Dating: Radionuclide Dating Services

A radionuclide facility marketing study was initiated in September, 1998. The study involved examination of the facility history (technical and financial) as well as present and projected future need. Project Chiefs from a number of NWRI branches were interviewed to gather data on their radionuclide interests. Information collected was summarized in a final report which included suggestions for the marketing strategy. The facility will be restructured to undertake the following analyses:

- Cs - 137
- Be - 7
- Ra - 226
- non-destructive Pb - 210

Future actives will include cores from peats, the Arctic, the Great Lakes and the Turkey Lakes watershed.

Twelve sediment cores have been analyzed through the radionuclide dating service since its re-opening in August of 1998. ^{210}Pb dating has described depositional history of 10 Canadian cores: two cores from Lake Superior, two from Lake Ontario, one from Lake Huron, one from Kamloops Lake, BC, three from the St. Lawrence river and one arctic core from Char Lake. Two international cores, one from Lochnagar, Scotland, and the other from Matano Lake, Indonesia were also analyzed.

FUTURE DIRECTIONS

Plans for the Project encompass expanding the research program to include cycling of the chemicals within food webs in freshwater and marine environments. Specifically, can the length of the food chain as measured by N^{15} explain some of the variability in levels of some chemicals in biota, across the regions of Canada? An increased capability to look at the plankton and fish/mammal compartments has recently been added to the Project. Detailed studies into the behaviour and retention of POPs, HAAs and Hg delivered to a watershed via atmospheric pathways are also planned at Turkey Lakes.

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Aquatic Ecosystem Health Assessment Project (EHAP)

GOALS AND OBJECTIVES

Anthropogenic activities impact the health of Canadian aquatic ecosystems. The Project develops strategies and tools for the assessment of ecosystem health and the diagnosis of impaired health. The Project develops diagnostic indicators and predictive bioassays, identifies causative agents and explores the mechanisms by which chemical stressors exert deleterious effects on ecosystem health. This knowledge supports regulatory and monitoring activities of the Environmental Effects Monitoring programs under the *Fisheries Act,* chemical assessments under the *Canadian Environmental Protection Act* and contributes to Environment Canada's Ecosystem Initiatives. Combinations of field and laboratory studies link impaired ecosystem health to chemical exposure of aquatic biota. Field studies describe effects on biota. Laboratory studies establish cause-effect relationships, explore underlying mechanisms and develop biomarkers of exposure and effect.

PROJECT RESEARCH TEAM

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Endocrine Disruptors: Field Effects.
Several studies of the EHA Project evaluate the responses of aquatic ecosystems to chemical exposures, particularly to point source effluents that cause endocrine disruption. Chemicals that alter endocrine homeostasis are commonly referred to as EDCs. Scientists in the Project also develop methods to evaluate endocrine effects resulting from non-point source inputs and develop tools for Environmental Effects Monitoring (EEM) programs.[2]

Field studies were undertaken in six watersheds in PEI to investigate the presence of intersex (males with eggs in testes) in wild fish. Intersex has been observed in the UK downstream of sewage outfalls and is associated with exposure to estrogenic chemicals. The research undertaken in PEI is a first evaluation of whether the same effects are manifested in fish exposed to agrochemical runoff. Histological analysis of gonadal tissues from brook trout showed no evidence of intersex in any of the fish collected. Blood samples collected in September from brook trout at four sites in potato regions and two reference sites on the north east side of PEI are currently being

[2] Concepts are explained in the book: Rao, S.S. 1999. *Impact Assessment of Hazardous Aquatic Contaminant.* Boca Raton, Fl.: Lewis Publishers, pp. 219.

analysed for sex steroids, and for sex determination, to see if modulation of circulating steroids is associated with the use of pesticides in potato farming. The fish were released after the blood samples were taken. Bile and blood samples will also be analysed from rainbow trout that were caged during the summer (collaboration with Atlantic Region). In a related study, no evidence of intersex was evident from gonad histological analysis of Brook trout collected from Black Creek, Acton ON approximately 1km below a sewage outfall.

Fish collected near pulp mills have consistently shown induction of the hepatic mixed function oxygenase (MFO) detoxification system. In addition to increased MFO activity, several other types of changes have been seen in fish exposed to effluent from bleached Kraft pulp mills. These include delayed sexual maturity, smaller gonads, altered reduced secondary sexual characteristics, and increased liver size. The pulp and paper industry has been required to conduct Environmental Effects Monitoring (EEM) of their receiving environment in order to evaluate the effectiveness of existing regulations. Following cycle one, it was clear that some new methods were required at specific sites. Through collaborations with the pulp and paper industry, scientists have been developing new techniques such as the use of forage fish in EEM monitoring programs. Reproductive techniques and assays are also of potential use in these EEM programs and are being developed within the Branch. Site evaluations have been conducted at a number of locations in collaboration with the mills and studies are continuing at other sites to further develop this program. These studies will also be used in the development of the fish program for an EEM program for the metal mining industry.

Long-term studies are underway using fish populations to develop health assessment tools to determine the cumulative effects of developments on aquatic systems. These studies are in collaboration with the Canadian Electrical Association, Ontario Hydro, Fisheries and Oceans Canada and the Ontario Ministry of Natural Resources. The methods developed respond to current regulations which require all new developments to provide cumulative effects assessments, prior to approval. This work continues on the Moose River Basin in northern Ontario which is impacted by hydroelectric developments, the pulp and paper industry and mining activities. Completed methods will be suitable for assessing the environmental impacts of other types of industrial development.

Health indicators have been compared between longnose suckers living in the area of oil sands mining effluent with those living upstream (240km) and outside the influence of the oil sands formation. The downstream site was below the Suncor wastewater discharge and 40km downstream of Fort McMurray. It receives oil sands effluent, input from the town of Fort McMurray as well as natural oil sands related compounds from exposure to the oil sands formation. Longnose sucker from the downstream site had MFO levels 10 times higher than fish living above the upstream site (Fig. 17). MFO is a measure of liver enzymes that metabolize foreign chemicals. At the oil sands site larger (older) fish showed lower levels of MFO than smaller (younger) fish. Condition factors showed that the fish from the oil sands site were significantly thinner than upstream fish. The lower body weights of the oil sands fish may indicate poor health. There were also changes in sex hormone levels in fish that lived in the oil sands area. Male longnose sucker had higher testosterone concentrations than upstream fish, while female longnose sucker had lower testosterone concentrations than upstream fish. The number of eggs in each female was found to be lower in oil sands fish with fewer eggs per gram of ovary compared to upstream fish. Vitellogenin (Vg) concentrations were lower in the oil sands fish. The study showed differences in the fish health parameters of oil sands exposed fish. Metabolic bioindicators (MFO) and reproductive bioindicators (testosterone concentrations) showed differences between oil sands and reference site fish. Continuing studies will focus on the relative contributions of anthropogenic natural oil sands compounds in determining these biological effects.

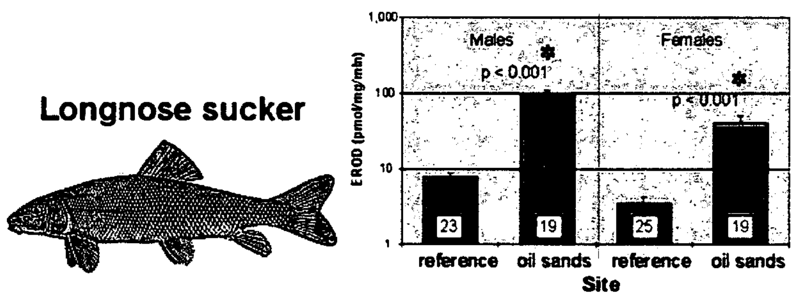

Figure 17. EROD over 10 fold increase in liver enzyme activity

The effects of environmental endocrine disruptors on reproductive function in fish have also been studied in the Canadian environment at sites affected by municipal sewage discharges and agricultural runoff. New tools and techniques have been developed to evaluate this issue through collaborations with industry, university and other government departments in both Canada and the United States.

***In vivo* bioassays: Physiological indicators.**
MFO induction is a sensitive tool to measure fish exposure to potentially toxic contaminants from a variety of anthropogenic sources. Laboratory bioassays are most useful in toxicity identification and evaluation and for the detection of sources, identities, and potencies of inducing compounds.

Phase one of a joint project between NWRI and the pulp mill sector was completed. The project involved assessing the steroidal effects of final effluents and in-mill process streams from several paper mills across Canada. Laboratory bioassays were used to test four final effluents, and an on-site bioassay was used to test final effluent and 13 in-mill process streams, from a bleached sulphite mill in New Brunswick. The goldfish steroid assay measured changes in blood steroids in the fish as well as changes in steroid production by minute pieces of gonad tissue removed from the fish and incubated in media. The goldfish assay was further developed by exploring how the exposure length (16 vs. 21 days), and the effluent renewal rate (every 2 or 4 days) could be adjusted to maximize the sensitivity of the assay (Fig. 18). In preparation for phase two of the pulp mill impact study, a re-testing of final effluents from four mills was completed to assess seasonal differences in potency.

Goldfish testes secretion of 11-Ketotestosterone decreases in response to 21 day pulp mill effluent exposure.

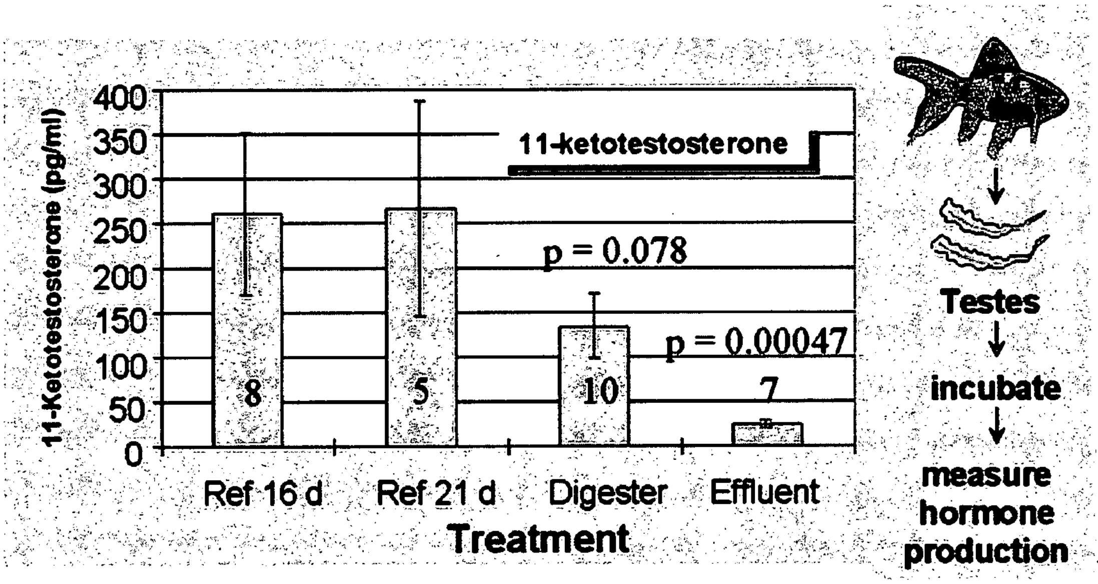

Figure 18. Endpoint: Sex Hormones in Testes

Modification of the U of Guelph rainbow trout steroid bioassay uses immature rainbow trout exposed for 21 days, and measures modulation of blood steroid levels to indicate exposure to chemicals capable of steroid disruption. Trout exposed to estradiol, retene or final effluent from a bleached sulphite mill showed changes in blood steroid levels. Standardisation of the test will continue. It appears that immature trout respond differently from mature fish. Steroid increases are seen in immature fish, while steroid decreases are observed in the most mature fish.

EHA scientists were joined by Sault College students and faculty in a study to measure hormonal effects of sewage treatment plant (STP) effluent on immature rainbow trout. This collaboration is the first successful research collaboration under the Upper Lakes Environmental Research Network (ULERN). Within this collaboration, EHA scientists taught Sault College students how to perform the rainbow trout 21-day fish bioassay, currently under development at NWRI. The project used Sault College's model scale sewage treatment facility, to expose rainbow trout to primary and secondary treated sewage. The students were trained in fish handling, exposure and maintenance, and were given instruction on detailed dissection and tissue sampling. The research team found elevated blood testosterone in fish exposed to both primary and secondary treated sewage, while estradiol was only found in secondary effluent. Estradiol exposure caused increases in blood estradiol but had no effect on blood testosterone levels. MFO enzymes were not affected by exposure to the effluents or estradiol.

A collaborative project with scientists from AEPB - NWRI showed small trout exposed to road run-off for 4 days to have highly elevated EROD activities (MFO detoxification enzymes). Elevation persisted with length of rainfall. Rain water collected during a summer storm was as potent as the water collected at the beginning of the event. The project represents the first phase of a collaboration to assess the effects of this diffuse source of PAHs and other toxics. Unlike industrial effluents which appear as point sources, the magnitude and influence of diffuse but ubiquitous non-point sources are still more difficult to assess.

***In vitro* Bioassays: Biochemical Indicators**

Biological or biochemical tests can be used to assess the estrogenicity of pure chemicals and complex mixtures. For example, the induction of the egg yolk precursor vitellogenin (Vg) in male fish is used as a bioindicator of exposure to estrogenic chemicals. Vg is normally produced in the liver of female teleosts and is not normally found in high levels in male plasma, although low levels of Vg have been reported to occur. The cause or function, if any, of low Vg induction in males is not currently known. Bioassays used to screen samples and ambient waters for estrogenicity are based on the induction of Vg in brown trout and rainbow trout. The Vg is measured by Enzyme-linked Immunosorbent Assay (ELISA).

Two whole fish bioassays for the detection of environmental estrogens were developed and optimized. The bioassays are based on the induction of Vg in brown trout and rainbow trout and are used to test ambient water, complex effluents, and pure chemicals (Fig. 19). The following routes of exposure have been evaluated: injection of pure chemicals and extracts of complex mixtures; water borne exposure under static renewal conditions in the laboratory; and caged exposure of fish to ambient water. For the static renewal bioassay the duration of exposure and the solution renewal rate were found to affect the size of the response signal and the assay threshold concentration. Using a daily full renewal regime the rainbow trout bioassay had a threshold of 10 ng/L 17ß-estradiol. The rainbow trout bioassay was used to detect an estrogenic response in effluent from a petroleum refinery.

Monoclonal antibodies specific to rainbow trout Vg were produced in a successful collaboration between researchers at NWRI, and the Technical Universities of Berlin and Munich. The monoclonal antibodies (MAB) have been incorporated into a sensitive ELISA for the measurement of Vg in rainbow trout plasma. Vitellogenin induction in male fish is an important indicator of exposure to environmental estrogens. The MABs were tested for the ability to cross react with Vg from other fish species. A western blotting technique was developed to confirm the specificity of the MABs for Vg. The western blotting technique was also used to confirm the results of the ELISA assay. A polyacrylamide gel electrophoresis technique was developed for detecting and quantifying Vg in the plasma of dace and long nose sucker. Vg was raised in carp and purified by column chromatography to be used as a reagent in an ELISA for carp Vg and also as an immunogen against which antibodies could be raised.

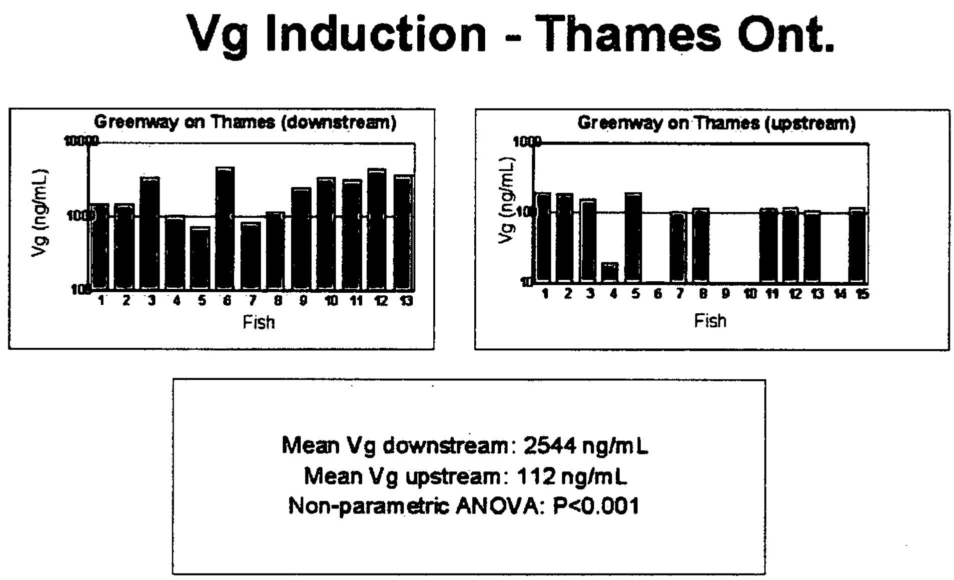

Figure 19. Estrogenic Response in Fish caged near STP

Methods were developed for fractionating refinery effluent into particulate, neat aqueous, and concentrated aqueous fractions for subsequent testing in bioassays based on cultured fish cells. A method was refined to test the toxicity of the neat effluent to cultured fish cells with minimal dilution of the sample. The methods were used in a joint study with the U. Waterloo to test effluent from three Ontario refineries for cytotoxicity, photocytotoxicity, and MFO inducing activity in cultured liver, gill, and dorsal cells from fish. Cytotoxicity and MFO inducers were detected in all samples. For some effluents toxicity was enhanced by exposure to UV light.

An in vitro bioassay based on primary cultures of trout liver hepatocytes was developed for the detection of estrogenic chemicals. The assay can also be used to detect MFO inducers and toxic chemicals. Cultures of trout liver hepatocytes are prepared weekly by culture in multiwell plates for 24-h exposed to the test chemical(s). The hepatocytes respond to estrogens by secreting Vg into the culture medium. This bioassay was optimized and has been used to detect estrogenic responses in black liquor from the pulping process, in selected alkyl phenols, in water from some Milli-Q units, and in chemicals that were extracted from Scotch Pine. The hepatocyte assay is currently supporting collaborations with several other department scientists.

In an interlaboratory steroid hormone comparison study involving Canadian and United States laboratories, rainbow trout from Jackfish Bay, Lake Superior were either injected with Oviprim to increase steroid levels in the blood or were left without treatment. Blood taken from these fish was separated into 10 samples per fish and sent by courier to the participating laboratories. The results of the analyses were collated and analysed and are currently being prepared for publication.

To evaluate the effects of exposure to ambient water at contaminated sites in Hamilton Harbour fish were caged at 5 sites in Hamilton Harbour and at one site on Lake Ontario for 1, 2 or 3 weeks. The following short-term responses were monitored in the caged fish: Vg induction, modulation of immune parameters, modulation of circulating steroids, thyroid hormones, and MFO induction. To evaluate the effectiveness of SPMD-cell line bioassay techniques to predict whole fish response, semi-permeable membrane devices (SPMD) were also deployed. Fish and SPMD uptake of selected contaminants such as PAHs, alkylphenols, and estradiol were measured. Concentrations of these contaminants were also measured in the water and sediment. Assessment of the effect of PAHs on fish present a new challenge, as these toxicants are non-persistent, and non-bioaccumulative. However, a nine-fold induction of vitellogenin, compared to reference sites in the Harbour and in nearby Lake Ontario, was measured in fish caged in the Windermere Arm of Hamilton Harbour. The Vg induction was statistically significant and indicates that the caged fish were exposed to an estrogenic chemical. Water, sediment, and fish concentrations of alkylphenols were highest in the fish from the Windermere Arm, although this does not mean there was a cause-effect relationship. Immune system modulation was also observed in the Harbour caged fish. Again, the strongest effects were associated with the Windermere Arm, although responses were also seen at other Harbour sites, such as Randle Reef. MFO activity was induced at some of the Harbour sites, being highest in the fish caged in the Windermere Arm. There was good agreement between the level of MFO activity in the livers of the caged fish and the amount of activity induced in a fish cell line by the SPMD extracts, indicating that for this parameter the SPMD-cell line may be a good predictor of whole fish responses. The study included collaborators from other Branches of NWRI and from Waterloo and Guelph Universities (Fig. 20).

Under the Canada-Germany Bilateral Agreement and with the Ecosystem Health Network several German scientists visited EHA laboratories at NWRI in Burlington. Sediments from the Elbe River in Germany were evaluated in conjunction with those collected from Hamilton Harbour, Lake Ontario. Typically, these sediments contain a mixture of compounds of which some cause biological effects. This research involved extraction of the sediments and dosing of fish and fish cells to determine potency for causing biological effects such as liver enzyme changes or steroid disruption. Sediments causing effects have been fractionated and re-tested to identify which compounds or classes of compounds caused the effects in fish and fish cells. A scientist from the UFZ in Leipzig visited NWRI to participate in the Hamilton Harbour studies. This scientist compared the ability of *in vitro* and *in vivo* bioassays to detect estrogenic responses in the water. Vg mRNA was measured in samples of tissue from caged and bioassay exposed fish. Branch scientists visited the Technical University of Berlin and analysed steroid hormone levels in fish collected from Berlin waterways. Fish plasma samples were collected in the North Sea and the Baltic Sea as part of an endocrine disruptor program. *In vitro* bioassays were used to detect estrogenic effects in extracts of refinery effluent and chemicals isolated from Scotch Pine.

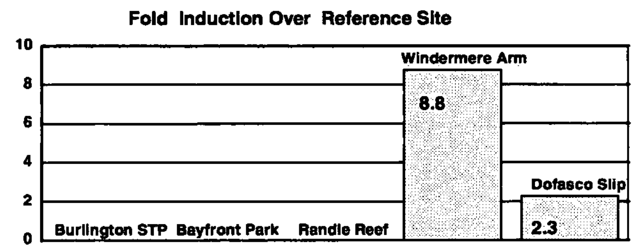

Figure 20. Estrogenic Response in Fish Caged in Hamilton Harbour

Chemistry

Stressors seen to cause an effect in the field are isolated, synthesized and identified in the laboratory (see above for practical examples). Figure 21 describes this process in a simplified diagrammatic form.

Performance characterisation of a multidimensional HPLC system was initiated in an ongoing study. Experiments investigating response characteristics associated with different solvents and solvent mixtures on *in vitro* assays to be used for Toxic Identification Evaluation (TIE) were undertaken. A TIE method was developed and applied to isolate and characterise bioactive compounds accumulated in fish caged in pulp mill effluent. MFO induction in rat liver cells was used to develop chemical fractionations and lipids were found to be toxic to the cells. Dose-response experiments determined dose levels for subsequent TIE fractionations and bioactive contaminants were characterised. Multiple inducers were found and it was determined that some are hydrophilic and metabolize rapidly while other hydrophobic contaminants are excreted at a slower rate. A collaboration with Dr. Van Der Kraak at the U. of Guelph also showed that ligands for fish androgen receptors are accumulated in these exposures.

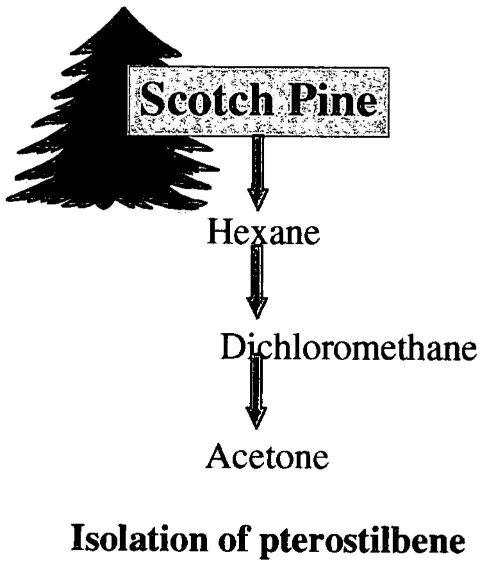

Figure 21. A diagrammatic representation of processes leading to the isolation of estrogenic compounds from the Scotch Pine

The Great Lakes Fishery Commission (GLFC) in Ann Arbor, MI requested help to determine levels of dioxin impurities in a lampricide formulation to be applied to the Bad River which flows through an Indian reservation of the Bad River Band in Wisconsin. In 1994 the Bad River Band became seriously concerned about the potential for lampricides to be contaminated with dioxin impurities. At this time, the Band allowed treatments to proceed only on the condition that the lampricide, fish and sediment showed no levels of one potentially toxic dioxin impurity, 2,7-dichloro-3,8-bis (trifluoromethyl)dibenzo-p-dioxin. In 1998 the Bad River was again scheduled for treatment, and the Band stipulated similar conditions. The GLFC procures lampricide from a different manufacturer and requests analysis to be conducted on the specific batch of lampricides proposed for the Bad River treatment. After extensive cleanup and analysis by gas chromatography-high resolution mass spectrometry, no detectable levels of 2,7-dichloro-3,8-bis(trifluoromethyl)dibenzo-p-dioxin (<14 pg/g formulation) were observed. These results were provided to the to the GLFC, to the tribal chair, and the tribal biologist.

FUTURE DIRECTIONS

The existing studies on endocrine problems in wild organisms will be expanded, as will studies into the petrochemical, agriculture and domestic sewage issues. Research on ecological effects, mechanisms of action, and innovative methods for detecting and monitoring effects will continue.

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APPENDIX I

Biographies

John Lawrence, Director
Aquatic Ecosystem Conservation Branch
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After receiving his PhD (chemistry) from Bristol University in 1967, Dr. Lawrence held post doctoral fellowships at the University of Ottawa and Colorado State University. Following a brief period with Bell Northern Research he joined Environment Canada in 1973 as a Research Scientist working on water and wastewater treatment issues. He subsequently moved to research on toxic substances in aquatic environments. In 1980 Dr. Lawrence was appointed research manager of the Analytical Methods Division at the National Water Research Institute, and in 1987 became Director of the Research and Applications Branch. Presently, Dr. Lawrence is the Director of the Aquatic Ecosystem Conservation Branch. Dr. Lawrence's current interests and responsibilities include aquatic impacts of UV radiation, LRTAP/POPs, acid rain, the Arctic, aquatic ecosystem health, environmental effects monitoring and QA/QC. Dr. Lawrence is a member of the Board of Directors, Canadian Association for Environmental Analytical Laboratories (CAEAL) and Upper Lakes Environmental Research Network (ULERN).

Janet K. Cooley, Science Liaison Officer, Aquatic Ecosystem Conservation Branch (Acting). E-mal: Janet.Cooley@ec.gc.ca
After receiving her PhD (Paleolimnology) from the University of Wales, Bangor, UK, in 1977 Janet Cooley moved to Canada. Her first research program in Canada was funded by CANUSA to evaluate the impact of the forest pesticide, Matacil^{TM}, on freshwater ecosystems, including the biodiversity of the aquatic microbial community. Prior to joining the Federal government, Fisheries and Oceans Canada in 1987 and NWRI in 1990, Dr. Cooley worked in the private sector where she held the position of senior scientist in a large company. Following this experience she founded and operated her own company to provide environmental assessment and advice on resource management issues, by using her expertise in paleo-ecology. For example, the company evaluated the impact of stressors, like acid rain, on aquatic ecosystems and provided analysis of sediment cores during an energy exploration phase of the Beaufort continental shelf. A published author, Dr. Cooley has written on topics as diverse as paleo-ecology, impact of pesticides on aquatic biota and the sexual behaviour of crustaceans. Together with her interest in biological indicators, stemming from work undertaken in the early 1970s, Janet Cooley's present assignment as Science Liaison Officer with AECB represents a return to long-standing research interests./

Rick Bourbonniere, Project Chief
UV Impacts on Aquatic Ecosystems Project (UVIP).
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Rick Bourbonniere joined the National Water Research Institute in 1979 after receiving his PhD in Organic Geochemistry at the University of Michigan in Ann Arbor. His current research interests relate to the general area of Biogeochemistry of Aquatic Systems and include such topics as: UV degradation of dissolved organic matter (DOM), carbon cycling and sequestration in wetlands, impact of multiple atmospheric stressors on aquatic ecosystems, effect of watershed disturbances on DOM character and biogeochemistry, and climate influences on trace gas exchange in aquatic and wetland ecosystems. Dr. Bourbonniere is an Adjunct Professor in the School of Geography and Geology at McMaster University, and in 1995 was a Senior Research Associate with the US Environmental Protection Agency at the National Exposure Research Laboratory in Athens, Georgia.

Derek Muir, Project Chief
Atmospheric Contaminants Impacts Project (ACIP).
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Derek Muir joined National Water Research Institute in 1997 after 20 years as a Research Scientist with Fisheries and Oceans Canada at the Freshwater Institute in Winnipeg. He received his PhD in Agricultural Chemistry from McGill University in 1977. His research interests include understanding transfer of persistent organic contaminants and metals in marine and freshwater food webs, air-water and air-plant exchanges of organics and watershed contributions of airborne contaminants to lakes and rivers. This work involves detailed measurements of persistent organohalogen contaminants in biological and abiotic samples. His recent work has been mainly in the Arctic and in western Canada but it is now also encompassing the Great Lakes and the tropics. Dr. Muir holds Adjunct professorships at University of Guelph, University of Alberta and University of Manitoba. He serves on a committee for Indian and Northern Affairs Canada, and is a member of the Northern Contaminants program Technical Committee - 1997 and 1998, and since 1996 he has been a member of the Alberta Health, Science Advisory Committee. Dr. Muir currently holds a three year Fellowship from the Pew Foundation for Marine Conservation for work on contaminants in the Russian arctic marine environment.

Jim Sherry, Project Chief
Aquatic Ecosystem Health Assessment Project (EHAP).
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Jim Sherry received his PhD from the National University of Ireland, University College Dublin. His current research interests at NWRI relate to using the induction of vitellogenin (Vg) in fish as a bioindicator of exposure to estrogenic substances. The egg yolk precursor Vg is a female protein that can be detected in the plasma of male fish after exposure to estrogenic chemicals. In vivo bioassays are used to measure the estrogenic potencies of ambient water, industrial and municipal waste waters, and pure chemicals. The estrogenic potencies of frationated mixtures are

measured using an vitro assay based on primary cultures of trout liver hepatocytes. Dr. Sherry is also exploring the replacement of conventional tests that use live fish for the detection of sublethal responses by tests based on fish cell lines. Further interests include the sublethal effects of waste waters from petroleum refineries and oil sands operations on the biota in recipient environments.

Mehran Alaee (ACIP)
After receiving his PhD in Analytical Chemistry from the University of Guelph in 1991 Dr. Alaee accepted a Visiting Fellowship at the National Water Research Institute where he worked on the Henry;s law Constants and Mass transfer velocity of POPs. Subsequently he joined the National Water Research Institute as a research scientist working on the Northern Contaminants Program in the Arctic. In 1997, Mehran accepted an assignment with the National Laboratory for Environmental Testing where he managed the Research Support and Methods Development Project. Current research interest are related to long range atmospheric transport of emerging persistent organic pollutants such as Brominated Diphenyl Ethers to the Great Lakes and Arctic. He is also working on a joint project with DFO scientists on bioaccumulation of PBDEs in the Great Lakes. Dr. Alaee is a member of the Special Graduate Faculty at the Department of Environmental Biology at the University of Guelph.

Michael Arts (UVIP)
Michael Arts received his PHD in Zoology from the University of Toronto. His scientific research relates to the fate of lipid in energy transfers in aquatic ecosystesm, the development of lipids as indicators of stress, measurement of dissolved and particulate lipids in water and the relationship of these energy sources to microbial/primary production. He also researches the role of lipid in the bioaccumulation of pesticides. Currently, Dr. Arts research interests include the effect of UV-B radiation on the allocation carbon to the main macromolecular pools in algae, and the use of mesocosms as a research tool in the determination of contaminant fate and effects in wetlands. In 1988 Dr. Arts was a Senior Research Fellow with the National Institute of Environmental Science in Tsukuba, Japan, an presently he is an Adjunct Professor with the Toxicology Research Centre at the University of Saskatchewan.

Spyros Beltaos (UVIP)
Spyros Beltaos received his PhD from the University of Alberta in 1974. Dr. Beltaos is a noted authority on river ice science, and extensively consulted on related research and engineering projects in Canada and abroad. He has written, edited, or contributed to the production of, 140 papers, reports and books, and since 1992 he has been the Chair of the Canadian Committee on River Ice Processes and the Environment (CGU-HS). Dr. Beltaos is currently with the Aquatic Ecosystem Protection Branch (AEPB).

A. Ghosh Bobba (UVIP)
A. Ghosh Bobba received his PhD in Water Resources Engineering from Lund University, Sweden. His principal research interests include the development and application of numerical surface and subsurface contamination transport models. The focus of Dr. Bobba's research is on the understanding of bio-geochemical processes affecting the fate of contaminants in the surface and subsurface environment. Dr. Bobba is presently with the Aquatic Ecosystem Impacts Branch.

Max Bothwell (UVIP)
Max L. Bothwell received his PhD in Limnology from the University of Wisconsin at Milwaukee in 1975. Dr. Bothwell's current research activities centre on the effects of ultraviolet radiation caused by clear-cut logging on the structure, function, and productivity of shallow freshwater ecosystems and how these changes impact the habitat of stream-rearing fishes. Dr. Bothwell is also exploring the effects of increased UVB levels caused by global ozone depletion on freshwater ecosystems, nutrient spiralling and food-web dynamics in river systems, and the assessment of pulp mill impacts on the benthic ecocogy of rivers. Other research activities include eutrophication and primary productivity of lakes and rivers, nutrient water chemistry, nutrient dynamics, and the physiological ecology and biochemistry of algae.

Robert P. Bukata (UVIP)
After receiving his PhD in physics and mathematical physics from the University of Manitoba in 1964, Dr. Bukata spent seven years at the Southwest Center for Advanced Studies in Dallas, Texas as Principal Investigator and Project Scientist of solar and galactic cosmic ray studies on the NASA deep-space probes Pioneers 6 to 10 and Earth-orbiting satellites Explorers 35 and 41. He joined the national Water Research Institute in 1972 as a Research Scientist where he has served in both research and management capacities. His research activities include aquatic optics, bio-optical modelling, physical limnology, remote sensing of optically-complex waters, shoreline dynamics and beach generation/regeneration, and the non-linear impacts of climate change, ultraviolet radiation, and atmospheric stressors on aquatic organisms and ecosystems. He holds an adjunct professorship at York University and, in addition to numerous publications, has authored a solicited text-book/monograph for CRC Press on the optical properties and remote sensing of inland and coastal waters.

Marlene Evans (ACIP)
Marlene Evans has been working as a research scientist at t the National Water Research Institute since 1988. Her research program has been and continues to be diverse. In the prairies, she has investigated plankton-nutrient dynamics in saline lakes, including commercially-harvested *Artemia* (brine shrimp). In the boreal region, she is investigating impacts of anthropogenic perturbations on lake ecosystem health. Most of her research focuses on contaminants in the north including: the influence of the Slave River on contaminant loading and food web biomagnification to Great Slave Lake; an investigation of factors affecting high mercury concentrations in predatory fish in certain lakes in the NWT; and

hydrocarbon transport into the Peace-Athabasca delta and Lake Athabasca. With local community participation, she will begin a long-term monitoring study of contaminant trends in Great Slave Lake fish. Dr. Evans earned her B. Sc. (Honours Biology) from Carleton University and her Ph. D. (Oceanography and Zoology) from the University of British Columbia. She conducted postdoctoral studies at the Arctic Biological Station and then worked for 14 years at the Center for Great Lakes and Aquatic Studies, University of Michigan focusing on various aspects of zooplankton communities in Lake Michigan. While there, she served on the Science Advisory Board of the International Joint Commission and on the Board of Directors of the International Association of Great Lakes Research, including a term as President. Dr. Evans is an adjunct professor with the Biology Department, University of Saskatchewan, and supervises graduate students. She is Associate Editor of the Journal of Great Lakes Research. Community service projects include the Saskatoon Regional Science Fair, the Innovators in Schools Program and, more recently, the Connaught Student Biotechnology Exhibition.

Mark Hewitt (EHAP)
Mark Hewitt received his PhD in Pesticide Chemistry/Toxicology from the Univeristy of Guelph in 1997. Prior to joining the Ecosystem Health Assessment Project in 1998 Dr. Hewitt was an NSERC Visiting Fellow with the National Water Research Institute. His research interests relate to the isolation and identification of biologically active environmental contaminants in aquatic ecosystems. Currently, Dr. Hewitt's research is focusing on characterizing endocrine disruptors in pulp mill effluents and in runoff associated with agrochemical spraying activities.

Dean S. Jeffries (ACIP)
Dean S. Jeffries received his PhD (Geochemistry) from McMaster University in 1976. Prior to joining the National Water Research Institute in 1981 he worked for the Ontario Ministry of Environment His research focuses on understanding the biogeochemical processes that regulate ecosystem retention and release of acidifying pollutants. He has led national assessments that quantified and predicted the aquatic effects of acid rain, both at a small ecosystem scale (in the Turkey Lakes Watershed) and at a regional scale. Dr. Jeffries is the ECS representative on the Canada/US Air Quality Agreement Science Committee, the UN Economic Commission for Europe International Cooperative Program on Acidification of Lakes and Rivers, and the Regional Water Quality Working Group convened under the Conference of New England Governors and Eastern Canadian Premiers.

John Jerome (UVIP)
John Jerome joined the National Water Research Institute in 1972 and immediately began working on research related to aquatic optics and remote sensing. A published author, he has written or contributed to over eighty scientific papers and reports including co-authoring a book titled, Optical Properties and Remote Sensing of Inland and Coastal Waters. John's current research involves quantifying the effects of stratospheric ozone depletion on the underwater ultraviolet environment and the resultant impacts to physical, chemical, and biological processes occurring within aquatic ecosystems. John received his B. Eng. In Engineering Physics from McMaster University in 1971.

Jagmohan Kohli (EHAP)
After receiving his PhD from Aligarh University, Aligarh , India Dr. Kohli worked as a Research scientist with the Council of Scientific & Industrial Research, India, and the Institute of Ecological Chemistry, Bonn , Federal Republic of Germany. His research work in Germany included the uptake, distribution and identification of chlorinated pesticides metabolities in plants and soil using radiotracer methodology. Dr. Kohli joined the National Water Research Institute as Research Chemist in 1984, and in 1997 was promoted to Research Scientist. He is currently working on the isolation and identification of environmental endocrine disruptors for bioassessment ; and also the synthesis of compounds associated with biological responses. Dr. Kohli has also worked in the private sector with consulting firms, industries, government, and academia in environmental related issues. A published authored, Dr. Kohli has to his credit, 31 research papers in referred journals.

Mark McMaster (EHAP)
After receiving his PhD in reproductive endocrinology from the University of Guelph in 1995 Dr. McMaster was a Visiting Scientist Fellow with the Department of Fisheries and Oceans at the Grealt Lakes laboratory for Fisheries and Aquatic Sciences. He joined the National Water Research Institute in 1996 as a Research Scientist and began his research into the field of endocrine disprutors, specifically examining the effects of contaminants on reproductive function in fish.

Kelly Munkittrick (EHAP)
After receiving his PhD in Toxicology from the University of Waterloo in 1988, Dr. Munkittrick spent several years in private industry, academic and consulting environments before joining the Federal Government in 1990. Dr. Munkittrick has co-chaired interdisciplinary working groups related to Environmental Effects Monitoring, and co-chairs both the Environment Canada and the Interdepartmental Endocrine Disruptor working groups. He is currently a Canadian representative to an OECD working group for developing screening protocols for endocrine disruptors. Dr. Munkittrick's research include environmental health assessment, environmental effects monitoring, cumulative effects assessment and the impacts of industrial discharges on wild fish populations.

Joanne Parrott (EHAP)
Joanne Parrott joined the National Water Research Institute in 1993 after receiving her PhD from the University of Waterloo. Dr. Parrott's scientific research examines the effects of toxicants on fish health. She is interested in the ways chemicals affect fish, and in particular on biochemical indicators of effects. In her capacity as a research scientist Dr. Parrott studies the impact of pulp mill effluents on oil sands wastewaters on fish, and is developing new laboratory tests of fish reproduction that link to effects seen in the field. She is Adjunct Faculty at Queen's University and Associate Faculty at the University of Guelph, where she supervises Master's and PhD students.

Richard Robarts (UVIP)
Richard Robarts received his PhD in limnology specialising in microbial ecology from Rohodes University in South Africa. Following his return from Africa in 1988 he joined the National Water Research Institute. Dr. Robarts current research interests relate to the general area of biogeochemistry and microbial ecology of aquatic systems, but particularly the wetlands and saline lakes of the prairies. His research includes: UV degradation of dissolved organic matter (DOM), carbon cycling and sequestration in wetlands, impacts of UV radiation and land-use activities on microbial processes and the composition and character of DOM. Dr. Robarts is an Adjunct Professor in the Department of Applied Microbiology, University of Saskatchewan, the Department of Biological Sciences at the University of Alberta, and in the Department of Biological Sciences, Napier University, U.K. He is Chairman of the International Committee of SIL's and INTERCOLS working group on aquatic primary productivity, and Chair of the American Society of Limnology and Oceanography's Finance Committee. He is the Editor of SILNEWS, an Associate Editor for the Canadian Journal of Fisheries and Aquatic Sciences, and a member of the Advisory Board of the Japanese Journal of Limnology. In addition to his scientific research with the Aquatic Ecosystem Conservation Branch, Dr Robarts also holds the position of Director of the UNEP-WHO GEMS/Water Collaborating Centre.

William Schertzer (UVIP)
William Schertzer joined the National Water Research Institute in 1975. He received his M.Sc. from McMaster University specialising in Physical Climatology with post-graduate studies in Water Resources Engineering. He is a certified Professional Hydrologist (PH) by the American Institute of Hydrology. He has been active in professional responsibilities with the Executive of the CMOS, and has conducted basic and multi-disciplinary research in national programs with IFYGL, UGLRS, UGLCCS, GL2000-Climate and international programs such as; Canada-Russia MOU, Forecasting Environmental Change - IIASA; Climate and Lake Hydrodynames - ASCE; and the Global Energy and Water Cycle Experiment - GEWEX. Current interests are climate impacts on lake physical, water quality and ecosystem responses. William Schertzer is currently a Research Scientist with the Aquatic Ecosystem Impacts Branch (NWRI).

Brian Scott (ACIP)
After earning his Ph.D. in physical-organic chemistry from the University of Toronto and completing a post-doctoral fellow at University College, London, Dr. Scott joined the Inland Waters Branch of the Department of Energy Mines and Resources. Initially he performed semi-empirical mathematical calculations on ice-like and substituted ice-like structures. Next were studies on the fate and effects of oil and oil-dispersent mixtures using small lakes and mesocosms. This was followed by fate and effect studies of 2,4-D on *Myriophyllum spicatum* and fate and effect of TFM, both studies utilizing mesocosms. Investigations on toxaphene analysis was followed by developing an automated computer-assisted PCB congener method of analysis. This led to broad spectrum analysis which utilized new technologies such as gc/atomic-emission detection and combining this with older technologies to optimize the information available for a sample undergoing gas chromatographic analysis. Dr. Scott then headed a study on the effects of refinery effluents and then he investigated various aspects of black liquor, a component of kraft paper mill operations. Finally Dr. Scott has been involved in the analysis of haloacetic acids in the Canadian environment and comparing these results to other areas of the globe.

Raymond Semkin (ACIP)
Ray Semkin received his B.Sc. (Honours Geology) from the University of Toronto and his M.Sc. (Geochemistry) from McMaster University. Following his M.Sc. graduation, he worked for the Ontario Ministry of Environment as a surface and groundwater evaluator, and later in the oil fields in the Gulf of Mexico and in Saudi Arabia. This experience led to employment with the Environmental Protection Service in Yellowknife as a project engineer for energy development in the Arctic. Ray joined the National Water Research Institute in 1979 in Sault Ste. Marie where he helped to set up the Turkey Lakes Watershed study, a calibrated research basin where the aquatic effects of acidic deposition are investigated. Current research activities relate to the hydrogeochemistry of small watersheds and, in particular, to the impact of air-borne contaminants on aquatic and terrestrial ecosystems.

William Strachan (ACIP)
William Strachan received his PhD from Queens University and joined the National Water Research Institute as a research scientist in 1970. Dr. Strachan's research studies relate to the impacts of atmospherically transport contaminants on aquatic systems. Under the Great Lakes Water Quality Agreement, Integrated Atmospheric Deposition Network, Dr. Strachan evaluates precipitation for trace metals and persistent organic pollutants in the Great Lakes. He also performs rain and snow measurements for these same compounds across Canada and in Arctic regions. In the Great Lakes, Arctic and Russian rivers flowing to the Arctic Dr. Strachan evaluates mass balance assessments. During his years with the National Water Research Institute he served on various committees such as; the committee for Canada's Northern Contaminants Program, Canada-Ontario Agreement Air Toxics Committee, International Expert Group of Advisors to the Swedish government on test systems for the evaluation of chemicals in the aquatic environment, and the Great Lakes Water Quality Toxic chemicals Committee responsible for developing Environment Canada's study and review funding.programmes.

Hague Vaughan (SLO/AECB, 1988 to 1998)
Hague H. Vaughan, Science Liaison Officer for the Aquatic Ecosystem Conservation Branch (AECB),

coordinates the planning and communication of AECB research programs. In 1997-1998 this research was related to Climate Change, Toxic Chemicals, UV-B and Endocrine Disrupting Compounds. Prior to taking this position Dr. Vaughan was involved with Environment Canada's water quality monitoring programs on the Prairies and in the NWT, and held positions with the Nova Scotia Department of Environment, Canadian Wildlife Service, the University of Maine, the Florida State Museum and various consulting firms. Dr. Vaughan received his PhD (ecology) from the University of Florida and is a published author on water quality monitoring, water management, organic analytical methods, acid rain, UV-B, and climate change. Dr. Vaughan is presently the Director of the Ecological Monitoring and Assessment Network (EMAN).

For further information please contact the Project Chiefs by e-mail (listed in biographies) or at the mailing address given below.

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APPENDIX II

Acronyms

ACIP	Atmospheric Contaminants Impacts Project
AECB	Aquatic Ecosystem Conservation Branch
AEPB	Aquatic Ecosystem Protection Branch
AES	Arctic Environmental Strategy
AES	Atmospheric Environment Service
AMAP	Arctic Monitoring and Assessment Programme
AQA	Canada/US Air Quality Agreement
BDPE	brominated diphenyl ether
BOREAS	Boreal Ecosystem Atmosphere Study
CACAR	Canadian Arctic Contaminants Report
CAEAL	Canadian Association for Environmental Analytical laboratories
DCA	dichloroacetic acid
DOC	dissolved organic carbon
DOM	dissolved organic matter
DU	Ducks Unlimited
EEM	Environmental Effects Monitoring
EFA	essential fatty acid
EHAP	Aquatic Ecosystem Health Assessment Project
ELISA	enzyme-linked immunosorbent assay
EROD	Ethoxyresorufin-O-deethylase assay
GIS	geographic information system
GLFC	Great Lakes Fishery Commission
GLWQA	Great Lakes Water Quality Agreement
HAA	haloacetic acid
HM	heavy metals
IADN	Integrated Atmospheric Deposition Network
IWWR	Institute for Wetland and Waterfowl Research, Ducks Unlimited
LRTAP	Long Range Transport of Air Pollutants
MAB	monoclonal antibodies
MCA	monochloroacetic acid
MFO	mixed function oxygenase
NCP	Northern Contaminants Program
NHRC	National Hydrology Research Centre
NSF	National Science Foundation
NWRI	National Water Research Institute
OCs	organochlorine contaminants
PAH	polynuclear aromatic hydrocarbons
PCB	polychlorinated biphenyls
PERD	Program for Energy Research and Development
POES/AVHRR	Polar Orbiting Environment Satellites/Advanced Very High Resolution Radiometer
POPs	persistent organic pollutants
QA/QC	Quality Assurance/Quality Control
RAN	Representative Areas Network

SHEBA	Surface Heat Budget of the Arctic Ocean
SPMD	semi-permeable membrane device
TCA	trichloracetic acid
TFA	trifluroacetic acid
TIE	Toxic Identification Evaluation
ULERN	Upper Lakes Environmental Research Network
UVA	Ultraviolet Radiation from 320nm to 390nm
UVB	Uttraviolet Radiation from 280mn to 320nm
UVIP	UV Impacts on Aquatic Ecosystems Project
UVR	Ultraviolet radiation
Vg	Vitellogenin

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