1995-97 PRIORITIES AND PROGRESS UNDER THE GREAT LAKES WATER QUALITY AGREEMENT

CHAPTER ONE: GREAT LAKES SCIENCE ADVISORY BOARD

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Figure 1. Ecological/Environmental Variability

1.1 INTRODUCTION

How do you know what you know? This was the question posed at a small workshop held May 29, 1997 to consider new evidence of the effects of chemicals found in the Great Lakes/St. Lawrence River system on human health, held in conjunction with the **Science Advisory Board's** (SAB) meeting in Hamilton, Ontario. How certain are scientists that eating contaminated Great Lakes fish prior to or during pregnancy results in neurobehavioural deficits in infants exposed *in utero*? How sure are we that the changes were caused by PCBs and not by DDE? How solid is the evidence that eating fish from the St. Lawrence River results in a loss of attention and memory in adults?

In the 19th century, philosophers played a significant role in the practice of science. In this century, philosophers and scientists have developed specialized disciplines for their spheres of interest and nowhere is this more apparent than in the environmental sciences. Is there a role for philosophers in the practice of environmental sciences and particularly in relation to bilateral approaches to transboundary pollution under the Great Lakes Water Quality Agreement?

A large part of the initiatives to manage pollutants in the U.S. and Canada is assumed under the policy of pollution prevention using well established risk-assessment methodologies. This approach is essential for addressing substances currently being released into the ecosystem or that are likely to come into commerce as new chemicals. The challenge for scientists and regulatory officials working in the Great Lakes basin however, is to address the continuing injury to human health and resources caused by past commercial practices involving persistent toxic substances. The scientific aspects of defining injury and its causes, assessing trends, and evaluating progress are the essence of the activities of SAB and central to the recommendations in this report.

Since the time of Aristotle, philosophers of science have pondered causes and effects, but only in the past 150 years have scientists applied epidemiologic methods to human health. Only in the past 40 years have health practitioners, authorities and researchers systematized the philosophical underpinnings of the knowledge of the causal relationship of certain diseases to specific pollutants. These were codified by the United States surgeon general in 1964, in relation to the causal relationship between lung cancer and cigarette smoking (U.S. Surgeon General 1964). They have been similarly codified as epidemiological criteria and applied by Sir Austin Bradford Hill to a range of occupational and environmental diseases and were addressed by SAB in its chapter of the 1993-95 Priorities Report (IJC 1995; Hill 1965). In terms of research on human health, recent initiatives have resulted in a series of definitive statements about the injury and the specific causal agents. In turn, these statements now form the specific knowledge on which regulatory officials can act to formulate new policies with confidence using existing laws to restore the integrity of the waters of the Great Lakes basin ecosystem.

In fulfilling its broad mandate to provide science advice under the Agreement, SAB's three work groups (Ecosystem Health, Emerging Issues and Parties Implementation) addressed an IJC priority for the 1995-97 biennial cycle on health, and identified several other topics upon which it developed its independent advice. While each activity has its own salience, taken together, they could also be viewed in terms of new scientific knowledge or research needs, and its relevance for policymakers in implementing the Agreement and sustaining progress.

It is clear, based on findings from the Workshop on Environmental Results: Monitoring and Trends of Effects Caused by Persistent Toxic Substances; the Workshop on PCBs, the New Equilibrium?; and Foodweb Dynamics in Aquatic Systems, that increased monitoring is needed in order to evaluate progress towards restoration. Similarly, the review of institutional performance in terms of Remedial Action Plan (RAP) progress, State of the Lakes Ecosystem Conference (SOLEC) and governance, reveals the need for a systematic approach to achieve the purpose of the Agreement, based on efficacy and accountability. As an emerging issue, ecological economics holds potential as a new way to understand the effect of man's activities by applying economic analysis to model the interaction between the economy and the ecosystem. Finally, creating a linkage between science and policy, the Workshop on Policy Implications of Evidence Regarding Toxic Substances and Human Health, held September 5-7, 1997, addressed what actions are needed to respond to the new research findings related to neurobehavioural effects of persistent toxic substances. The findings and recommendations from this workshop will be submitted to IJC as a special report from SAB.

1.2 WORK GROUP ON ECOSYSTEM HEALTH

1.2.1 Environmental Results: Trends in Concentrations and Effects of Persistent Toxic Substances

Introduction

Article IV of the Boundary Waters Treaty states that the boundary waters shall not be polluted on either side to the injury of health or property on the other. During the first half of the present century, the Great Lakes became progressively more contaminated with a variety of persistent toxic substances. In 1978, the Parties to the Great Lakes Water Quality Agreement agreed to a new policy stating that the discharges of any or all persistent toxic substances be virtually eliminated. The second half of the present century has been marked by extensive investment by governments and industries to treat and control discharges and emissions of pollutants, including persistent toxic substances. The results have been encouraging, and concentrations of many persistent toxic substances have decreased markedly during the past 25 years, though the recent data indicate little, if any, change in the concentrations of persistent toxic substances in the past decade.

There is extensive evidence that concentrations of persistent toxic substances were sufficiently high to have resulted in toxicological effects on populations of exposed organisms, including humans. The assumption has been made that with the decreasing levels of these substances in the Great Lakes, the incidence of these toxicological effects would concomitantly decline. IJC, in preparing its 1995-97 priorities for the work to be undertaken by SAB, directed it to host a workshop examining this assumption and report on the adequacy of the monitoring programs undertaken by the Parties to determine trends in the concentrations and effects of persistent toxic substances in the Great Lakes basin.

Workshop on Environmental Results

SAB held a Workshop on Environmental Results September 12-13, 1996 in Windsor, Ontario. The workshop commenced with a keynote address by Donald Tillitt describing the advances that had been made in demonstrating causal relationships between the observed effects in wild populations and exposures to a few persistent toxic substances. There were subsequent presentations on the results of monitoring for trends in concentrations of persistent toxic substances in a variety of media such as air, water and sediments, as well as in biota, such as lake trout and other fish species, herring gull eggs

and human blood. Presenters were Paul Baumann, Christine Bishop, William Bowerman, David Carpenter, Carol Edsall, Peter Ewins, Glen Fox, Keith Grasman, Diane Henshel, Raymond Hoff, Hal Humphrey, James Ludwig, Melanie Neilson, Wolf Scheider, Deborah Swackhammer, Chip Weseloh and Mike Whittle.

Presentations were made on a variety of effects noted at various levels of biological organization in populations of species that have been shown to have been affected by exposures to persistent toxic substances in the Great Lakes basin. These effects include the trends in the reproductive and population status of bald eagles, ospreys, herring gulls, double crested cormorants, lake trout and snapping turtles; differential recruitment of Caspian terns to colonies in the United States and Canada; the incidence of a variety of anomalies in physiological and biochemical markers, such as porphyrins, vitamin A storage and thyroid status in herring gulls; and the incidence of papillomas and liver tumours in brown bullheads. Populations of humans have been exposed to persistent toxic substances from Great Lakes foodwebs and a presentation was made concerning effects in humans and particularly their offspring. The detailed technical papers are to be published as proceedings in the peer-reviewed literature in *The Environmental Monitoring and Assessment Journal*.

Reasons for Monitoring for Trend

Monitoring for the observed rates of effects should be an integral part of the procedures for the assessment of toxic chemicals for environmental management and cleanup. In most cases, scientists investigating chemically-induced effects start with either an analytical finding of contaminants in the environment or a biological observation of effects occurring in wildlife. Frequently, both are found and lead to the formulation of hypotheses about possible causal relationships. The contaminant levels and the observed effects are linked in an exposure assessment from which preliminary inferences about cause and effect are made. Hypotheses are then formulated and tested through laboratory studies to determine whether the particular chemicals detected could have caused that kind of effect. These inferences about the putative causal agents can lead to further refinement and to agent identification.

Agent identification is complex in the Great Lakes environment and in many other environments because the contaminants are so strongly correlated. One of the most difficult tasks in determining causal relationships is in providing defensible evidence that contaminant A, rather than contaminant B, is the critical agent contributing to the observed effect when this is indeed the case. The identification of a critical agent is necessary to provide scientifically defensible advice on which regulatory interventions can be based. The attainment of this objective may be made even more difficult by additive and interactive effects, such as synergism or antagonism. In addition, there may be confounding factors from physical stressors such as temperature, light and humidity. Once the agents have been identified, critical sources can be identified and connected to the environmental and biotic contamination with an environmental transport model.

The information about the identification of the agent and the specific sources can be transmitted to the authorities responsible for source management. There are two kinds of source management relevant to the Great Lakes. One is a very broad scale, such as the banning of pesticides, the banning of lead in gasoline or the limitation of PCBs to closed systems. In addition, there is management of local sources, including the clean up of specific hazardous waste sites that are contributing to the general contamination of the Great Lakes. Much of this source management has been helpful. There have been changes in the levels of contamination and changes in the magnitude and nature of some of the effects. Scientists can investigate these changes to refine the process, improve the evidence for cause-effect relationships and give the managers better information to manage the sources.

Source management can lead to some changes in contamination levels that can be measured for trends which, in turn, can lead to trends in effects. With measurements showing changes in contamination levels and information on how these relate to the changes in effects, exposure assessments can be revised, and inferences about cause and effect can be verified. The question of whether the original inference that the observed effect was due to contamination with a specific chemical usually leads to additional laboratory studies.

Differential changes in contamination, when one chemical's level changes more than another chemical's level, can lead to some further verification of agent identification, an improvement in the evidence for identifying specific chemicals, improvement of source identification and in the environmental transport modelling. Finally, these findings can lead to informing the managers of the effectiveness of their actions concerning the sources, and to a reevaluation of their programs.

The elements in the process with the greatest uncertainty are the cause-and-effect inferences, and particularly in relationship to fish and mammals. In humans, the cause-and-effect relationships are difficult to establish because the various sources of exposures to substances cannot be controlled. There has been considerable difficulty in agent identification because different chemicals and possible confounding factors appear in the same places and tend to correlate with many of the effects. Similarly, there has been some difficulty with source identification, but this has improved because sources are now much better characterized. As well, there has been improvement in the verification of environmental transport models enabling managers to better understand pathways and mass balance in terms of the whole system.

Adequacy of the Parties' Programs for Monitoring for Effects

In determining the adequacy of the Parties' programs for monitoring changes in the concentrations of persistent toxic substances and in the observed rates of effects, there is a need to develop a set of criteria by which to evaluate the development of a program.

Species

The workshop participants reviewed several candidate species that have been used and that could be used for monitoring trends in concentrations and effects. The preparation of the lists of candidate species relies on accumulated knowledge of the species that should be present in the Great Lakes region and on those that were extirpated or injured due to exposures to persistent toxic substances. It is assumed that as the concentrations of persistent toxic substances decline, the injured populations will recover and extirpated species can be reestablished. A series of review papers has been published relating the various outbreaks of disease in the Great Lakes to exposures to persistent toxic substances (Gilbertson 1989; Mac and Gilbertson 1990; Best, Gilbertson and Hudson 1990; Addison, Fox and Gilbertson 1991; Gilbertson 1992; Schneider 1991). There are several databases of effects and exposures that could be used to compile further linkages between causes and effects on a retrospective basis and taking potential confounding factors into consideration, particularly for fish and mammals.

In evaluating the adequacy of the Parties' programs, there is a need to review the selected species in relation to the geographic and temporal scale being indicated. There should not be only species sampled to report on large-scale trends, such as declines in the incidence of pollutant effects in an entire lake, but also adequate sampling of species to reflect changes at the local or regional level. Similarly, the program should be sufficiently flexible to respond to the possibility that the introduction of new species into the Great Lakes may create new critical pathways of pollutants to indigenous species. For example, the introduction of the zebra mussel to the Great Lakes has led to

the increased contamination of scaup and old squaw ducks while on their Great Lakes wintering grounds, and there are indications that these species are experiencing reproductive anomalies at their breeding grounds in the Arctic.

Observational, Sampling, Archiving and Analytical Protocols

In the evaluation of the Parties' programs there is a need to evaluate the degree of standardization of the various protocols for observation of the rates of effects in the field or, in the case of humans, in clinical examinations. With declines in the concentrations of persistent toxic substances in the past 25 years, more sensitive biological measurements have been developed. Similarly, the sampling strategies, including sampling frequency, for the collection of biological materials for analysis and archiving should be assessed. The evaluation should include consideration of the quality assurance/quality control for the chemical analytical determinations.

The adequacy of systems to store, retrieve and process information on the concentrations of pollutants and on the outbreaks of chemically-induced disease and deformities should be assessed. Similarly, trends in the concentrations of persistent toxic substances and in the observed rates of effects that can be reported on a regular basis, in the scientific literature or on a web site, should be investigated.

Interpretation of Results

The purpose of the Parties to the Agreement is "to restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem." To help achieve this end, the policy, in part, states "the discharge of any or all persistent toxic substances be virtually eliminated." The evaluation should consider whether the Parties have formulated realistic biological objectives by which to judge whether the policy has been achieved.

Funding

The implementation of a program to determine long-term trends in the concentrations of persistent toxic substances and in the incidence of biological effects requires committed long-term funding. Thus, the Parties' programs should be evaluated in terms of a long-term commitment to funding.

Assessment for Trend

The most reliable means for the retrospective assessment of contamination in the Great Lakes basin with persistent toxic substances is from analysis of radiodated sediment cores. Sampling of other abiotic materials, such as air and water, and of biological materials, such as fish and wildlife, started after the peak concentrations of persistent toxic substances occurred in the early 1970s. Sediments can be recovered from a period before the contamination with most of the pollutants of concern. About seven sites have been analyzed and show that Lake Ontario was generally more contaminated than Lake Michigan, which was more contaminated than Lake Superior. The sediment data show that the period of greatest contamination occurred between about 1958 and 1973. Levels declined significantly until the early 1980s, since which time declines in concentrations have generally become progressively smaller or nonexistent.

There have been extensive sampling and analysis of water samples since 1986 to determine the long-term changes in concentrations, particularly in the connecting channels. The available data are consistent with the evidence from the sediment samples and show that the concentrations have been decreasing slowly in the past decade. The program to monitor the concentrations of persistent toxic

substances in air was started in 1990, and thus the air data are even more recent than the water data. The results from the first five years of sample collection and analysis are not inconsistent with the trends indicated by the sediment and water analyses.

Lake trout have been sampled for trend evaluation by the Canada Department of Fisheries and Oceans, since 1977 and their analyses provide a reliable data set. Samples of lake trout tissues have been archived for retrospective analysis. Concentrations have declined in the past 20 years, but there has been no perceptible change in concentration in the last decade.

There are excellent long-term data for herring gulls since the monitoring project was started in 1974 by the Canadian Wildlife Service. There is an extensive tissue archive that has been used to compare results from different analytical methodologies, to identify previously undetected substances and retrospectively to construct exposures. The results show that the concentrations of organochlorine pollutants declined rapidly between 1975 and the early 1980s, but that further declines have been slow or imperceptible.

There are no established projects to determine trends in the concentrations in Great Lakes populations of mammals, amphibians, reptiles or humans.

There are essentially no projects being undertaken to document trends in the observed rates of effects in any group of organisms except birds. There are effects documented in the reproduction of lake trout, snapping turtles and in human development, but there are no data on the trends in the observed rates of these effects in these organisms.

The evidence for the long-term trends in the observed rates of effects in birds from exposures to persistent toxic substances is remarkably well developed. The data for the status of the Great Lakes population of bald eagles originated in the mid-1960s when the concentrations of organochlorine pollutants were still increasing. The Great Lakes bald eagles were the most heavily contaminated of all the populations studied at that time, and the population was almost extirpated from throughout the Great Lakes region by 1970. With the decline in the concentrations of DDT, dieldrin, PCBs and other organochlorine compounds during the 1980s, some Great Lakes shoreline populations have been reestablished, naturally or artificially, with offspring from less-contaminated inland populations. Similarly, the decline in the organochlorine concentrations has resulted in the reestablishment of ospreys in Georgian Bay, aided by the involvement of local communities in protecting the breeding habitat and in constructing artificial nesting platforms.

There are extensive long-term data on the status of Great Lakes populations of double crested cormorants and a reliable set of causal relationships established between observations of specific effects and exposures to specific organochlorine pollutants. This species was almost extirpated from the Great Lakes basin as a result of eggshell thinning and breakage caused by exposures to DDT and metabolites. This species also is susceptible to exposures to compounds with a toxicological mode of action similar to the polychlorinated dibenzo-*p*-dioxins, including the planar PCBs and the polychlorinated dibenzofurans. The observed rates of deformities and of embryo mortality in various Great Lakes colonies is correlated with this dioxin-like activity on a colony basis. With the decline of concentrations of these organochlorine compounds in the Great Lakes, the populations of double crested cormorants have dramatically increased. Similarly, there are data showing that the incidence of deformities in cormorant chicks has declined, but there are still areas of the Great Lakes, such as Green Bay and Saginaw Bay, where the incidences of deformities are high.

One of the longest data sets on Great Lakes birds is the banding of Caspian terns. Caspian terns can be successfully recaptured in their colonies with the use of cannon nets. Analysis of banding returns has suggested that chicks fledged from Canadian colonies tend to be less contaminated than United States colonies, are more viable and are recruited as adults into the breeding colonies at a higher rate. In addition, birds fledged in Canadian colonies tend to be recruited as breeding adults into the United States colonies at a much greater rate than United States birds. The most recent data, collected for 1990-92, do not indicate that the young from the United States colonies are yet being recruited into the U.S. breeding colonies at a comparable rate.

Findings and Recommendations

Trends in Concentrations in Organisms and the Environment

SAB finds that the Parties to the Agreement have adequate long-term monitoring projects to document gross trends in the concentrations of organochlorine pollutants in Great Lakes biota. These monitoring projects include the annual sampling, analysis and tissue storage of herring gull eggs and lake trout. SAB recommends the following.

- **The Parties commit to the long-term funding of herring gull egg and lake trout monitoring projects and formalize these projects as programs by naming them in the Agreement.**

SAB finds that the removal of addled eggs and sampling of bald eagle blood and their analysis and storage have been a valuable means for documenting the trends in the concentrations of organochlorine pollutants in locations where the Great Lakes population was not extirpated by organochlorine pollutants or where the population has reestablished territories. SAB recommends the following.

- **The Parties formalize the use of addled eggs and sampled bald eagle blood as biological materials suitable for establishing trends in the concentrations of organochlorine pollutants in Great Lakes biota.**

The use of radiodated sediment cores as a means of reconstructing the history of contamination of the Great Lakes is a recent technological advance. Based on the few available results, the period of most severe contamination occurred between about 1958 and 1973. The concentrations of persistent toxic substances declined markedly between 1975 and 1980 but since then, trends have been less evident. SAB recommends the following.

- **The Parties make funding available to sample, radiodate and analyze representative sediment cores for persistent toxic substances from each Great Lake and results be made available to researchers undertaking retrospective injury assessment.**

Based on the available evidence from long-term monitoring of the concentrations of persistent toxic substances in the eggs of herring gulls and tissues of lake trout and from radiodated sediment cores, SAB finds that the concentrations of organochlorine compounds declined between the mid-1970s and the early 1980s, but decline since the mid-1980s has been less evident.

Trends in Effects in Great Lakes Organisms

SAB finds that, while the Parties to the Agreement have several projects investigating the potential use of various species and toxicological measurements, there is no formal program for monitoring the

long-term changes in the observed rates of the effects of organochlorine pollutants on any Great Lakes species. Reliable causal links have been established between toxicological measurements at various levels of biological organization and exposures during this century to a few specific organochlorine pollutants in a few species. These measurements included the rates of deformities, reproductive failure, biochemical or behaviourial anomalies or the demise and recovery of populations of several Great Lakes species. These few species include the bald eagle, herring gull, double crested cormorant, Caspian tern, Forster's tern and snapping turtle. These persistent toxic substances include DDT and metabolites, dieldrin, PCBs, dibenzo-*p*-dioxins and dibenzofurans. These persistent toxic substances are both embryotoxic and structural and functional teratogens. SAB recommends the following.

- **The Parties formally name species to be used as indicators in relation to the virtual elimination policy contained in the Agreement and devise and implement a formal bilateral program for long-term monitoring of the changes in the observed rates of embryotoxic and functional teratogenic effects.**

SAB finds that there is a noteworthy lack of case studies relating effects in Great Lakes fish and mammal populations to exposures to persistent toxic substances and, thus, no fish or mammal species can be recommended at this time as an indicator of changes in the observed rates of effects of persistent toxic substances. In the Gulf of St. Lawrence, the status of the beluga whale population has been related to exposures to persistent toxic substances, some of which come from the Great Lakes. SAB recommends the following.

- **The Parties request the Great Lakes Fishery Commission and fish and wildlife agencies to consider whether population declines and extirpations of certain Great Lakes fish and mammals during this century might be attributable, in part, to exposures to persistent toxic substances.**

Observed rates of effects on populations of Great Lakes species exposed to persistent toxic substances have been surveyed. Based on available evidence, SAB finds that embryonic deformities and mortality in gulls, terns and cormorants still occur in highly contaminated areas. The rates have declined compared with the rates in the 1970s, and are highest in the areas that are most contaminated with compounds with dioxin-like activity. The reestablishment of subpopulations of bald eagles on Great Lakes shorelines still contaminated with persistent toxic substances has resulted in increased reports of deformed eaglets.

Trends in Concentrations and Effects in Humans

The evidence from a limited number of epidemiological studies shows that the consumption of Great Lakes fish by humans has resulted in elevated levels of persistent toxic substances. SAB finds that there is no formal program under the Agreement to document trends in concentrations of persistent toxic substances in the Great Lakes population.

Prenatal exposure of human infants to persistent toxic substances from maternal consumption of Great Lakes fish has resulted in effects on neurological development, though the scale of the occurrence and severity of this phenomenon within the Great Lakes population has not been documented. SAB finds that the Parties do not have a formal program to monitor the long-term trends in the incidence of teratogenic effects in human infants. SAB recommends the following.

- **The Parties investigate the feasibility of devising and implementing a formal program pursuant to the Agreement to document trends in the observed rates and severity of functional teratogenic effects on humans caused by exposures to persistent toxic substances.**

The documentation of observed rates in the incidence of teratogenic effects on human health from exposures to persistent toxic substances may not be feasible in the immediate future. Thus, there is a need for an indicator of structural and functional teratogenesis in humans. PCBs are the major persistent toxic substances causing structural deformities in various species of fish-eating birds in the Great Lakes basin and suspected to be causing functional anomalies in neurological development in humans. SAB recommends the following.

- **The Parties use information from studies of the structural teratogenic effects of contaminants in populations of wildlife as sentinels for teratogenic effects in humans.**

1.2.2 Persistent Toxic Substances: Neurobehavioural Toxicology and Policy Implications

Introduction

During the past 15 years, the scientific community has expressed a growing awareness and interest in the effects of persistent toxic substances on neurological structure and function of exposed Great Lakes organisms. In October 1995, IJC assigned a priority of addressing human and ecosystem health to SAB that comprised three elements:

- assemble and consider new evidence, particularly pertaining to the disruption of the endocrine system of wildlife and humans, by the 11 critical pollutants and other persistent toxic substances and the effect of these substances on the neurobehaviour of animals and humans;
- organize an international scientific meeting to identify what is known regarding factors that normally affect neurobehaviour and the effects of persistent toxic substances through the endocrine system, especially gender-specific neurobehaviours; and
- hold a workshop with invited experts on the policy implications on behalf of IJC.

SAB directed its Work Group on Ecosystem Health to undertake these assignments.

Within the past five years, several international conferences have been held addressing various aspects of the neurotoxicological effects of persistent toxic substances and particularly those that have disrupted endocrine systems in humans. In June 1993, a workshop was held at Berkeley, California on perinatal exposure to dioxin-like compounds (Golub and Jacobson, 1995). An extensive review of the functional aspects of polyhalogenated aromatic hydrocarbons, based on a workshop held May 1994 in Wageningen, Netherlands, and organized by the European Environmental Research Organization, has recently been published (Brouwer et al. 1995). Many of the leading researchers studying neurobehavioural toxicology convened at a workshop held November 5-10, 1995 in Erice, Sicily and reached a consensus that the dioxin-like compounds can and have affected the neurobehavioural development of human infants. They produced a consensus statement that detailed their concerns (Colborn et al. in press).

Epidemiological Evidence and Review of Neurobehavioural Effects

The first epidemiological evidence of neurobehavioural injury to infants from prenatal exposure to Great Lakes pollutants was reported in 1984 from a cohort established in 1980 in western Michigan

(Fein et al. 1984). Infants of mothers who had eaten Lake Michigan fish prior to and during pregnancy had higher levels of PCBs in the cord blood, lower birth weight and a smaller head circumference than those infants whose mothers reported eating no fish. The exposed infants had a shorter gestational age and had poorer neuromuscular development. In subsequent testing at seven months, the more highly exposed infants exhibited poorer visual recognition memory and were smaller than the reference group (Jacobson et al. 1985). At four years, there was an inverse exposure dependent relationship with verbal and numerical memory and short-term memory processing ability (Jacobson et al. 1990). At 11 years, the strongest effects related to memory and attention. The most highly exposed children were three times as likely to have low IQ scores and twice as likely to be at least two years behind in reading comprehension (Jacobson and Jacobson, 1996a).

Another cohort, the Oswego cohort, was established in 1990 through 1994 in New York. The objective was to investigate the neurological effects of maternal consumption of Lake Ontario fish on offspring (Lonky et al. 1996). The more highly exposed group of infants showed the same psychomotor deficits at birth as those documented in the western Michigan cohort in the 1980s. An additional assessment showed the infants habituated poorly to an aversive stress.

In addition to these Great Lakes epidemiological studies of the neurobehavioural effects of PCBs, relevant studies have been undertaken in other parts of the world, including the North Carolina cohort in the United States (Rogan et al. 1986), the Yu-Cheng cohort in Taiwan (Lai et al. 1993) and a cohort of infants in the Netherlands (Huisman et al. 1995).

Since the original research was reported there has been lively discussion because of the social, economic and political implications of the findings. Schantz (1996), in her review of the evidence of teratogenic effects in humans, raised questions relating to research methodology and to differences in the effects observed between studies. Jacobson and Jacobson (1996b) responded to these methodological issues in relation to potential confounding factors, unmeasured control variables and selection of the participants in the cohort. In addition, they reviewed four possible factors involved in the reported variability of the effects between the various studies and commented on the similarity to the variability of the effects reported in studies of prenatal exposures to alcohol and lead on infant development. These four factors were: 1) the pattern and timing of the exposure; 2) the socioeconomic status of the cohort; 3) the reliability of the outcome measures assessed; and 4) the procedures followed in administration of the assessments.

The Health Conference '97 - Great Lakes/St. Lawrence River

Since the late 1980s, the Parties have spent more than $30 million for various investigations on the effects of pollutants on human health under the Agreement. In the United States, Congress amended the Great Lakes Critical Programs Act in 1990 and supported a program of health research on persons residing in the Great Lakes basin. The **Agency for Toxic Substances and Disease Registry** was designated as the responsible agency for overseeing the Great Lakes Human Health Effects Research Program. This program was designed to investigate and characterize the potential for short- and long-term health effects, particularly in susceptible populations, from exposures to Great Lakes contaminants. In 1989, as part of the Great Lakes Action Plan, Health Canada undertook a program to study the impact of the region's environment on the health of the human population in the Great Lakes basin. In 1993, Health Canada and the Quebec Ministry of Health and Social Services jointly implemented the St. Lawrence 2000 Action Plan as a federal-provincial research program with five years of funding. These agencies held a conference in Montreal, May 12-15, 1997, to enable the various scientists involved in the research to present their results. Research relevant to the interpretation of this information and the risk communication issues related to it also was presented.

SAB was one of several sponsors of the conference, thereby fulfilling its responsibility under the IJC priority, to convene an international scientific meeting. Its support was provided so that researchers who had relevant data on neurodevelopmental effects from outside the Great Lakes/St. Lawrence River basin could present their information. A roundtable discussion on the Public Health Implications of Neurobehavioural Effects specifically addressed the current human research in this area. The panelists were Joseph Jacobson, Corine Koopman-Esseboom, Walter Rogan and Thomas Darvill. The discussants were Deborah Rice and Renate Kimbrough. The session was facilitated by Susan Schantz. The results of the studies on five human cohorts exposed to PCBs/dioxins *in utero* were briefly presented. Discussion of the limits of epidemiologic studies and the role of mercury as a possible confounder occurred. The majority opinion on the panel was that the weight of evidence supports PCBs (or more specifically a set of PCB congeners) as the agent responsible for neurodevelopmental effects (dioxin in the Dutch cohort) and that, taken together with the Michigan, North Carolina, Dutch, Yu-Cheng and Oswego cohorts provide a coherent epidemiological picture of neurodevelopmental effects related to PCBs/furans/dioxins. There is ongoing research with Inuit communities and with the Oswego cohort that will help determine which PCB congeners are involved in neurobehavioural effects and what role other persistent toxic substances may play in an additive or interactive fashion.

In other studies reported at the conference, one showed a dose-response correlation between Lac St-François and Lac St-Louis fish consumption and motor slowing and attention deficits in adult fish consumers (Mergler et al. 1997). However, another study's preliminary results indicate that fine motor slowing in older fish eaters in a Michigan cohort was not evident (Schantz et al. 1997). Preliminary research also was presented that shows consumption of contaminated fish may affect fertility. A negative effect on fertility on retrospective assessment was found in a Michigan cohort (Courval et al. 1997), but not in a New York cohort (Buck et al. 1997). Research on both cohorts is ongoing and these studies may provide very important information once the final results of the prospective assessments are in.

General Assessment

Earlier research found an increase in birth weight associated with PCBs related to fish consumption, but at exposure levels lower than the Jacobson cohort that found a negative effect (Dar et al. 1992). Another study failed to find evidence of fetal death related to PCB exposure through fish consumption (Mendola et al. 1995). The growing body of animal evidence, from both the laboratory and from wild populations in the field and from mechanistic research, indicates that dioxin-like compounds are definitely neurotoxic for mammals and birds. Developmental effects found in reptiles, amphibians and fish are consistent in implicating the same chemicals although the effects are not specifically neurotoxic. This work indicates that changes in thyroid hormones and neurotransmitters individually or together at critical periods of *in utero* development are involved in the observed neurological changes. These effects have been found in wildlife and experimental animals at levels of exposure that overlap the range of exposures and body burdens found in the North American human population (Brouwer et al. 1995; Henshel et al. 1997a,b, and in press; DeVito et al. 1995).

Human health effects, including a reduction in IQ for the children exposed *in utero*, are clearly evident in the Yu-Cheng cohort exposed to PCBs and associated polychlorinated dibenzofurans and quaterphenyls (Chen et al. 1992). A similar reduction has been found in the Michigan cohort for whom PCB exposure was much lower (Jacobson et al. 1996a). Neurodevelopmental effects have been reported in the Oswego cohort at even lower levels of exposure (Lonky et al. 1996; Darvill et al. 1997).

There is coherence of the epidemiological evidence among the various studies and a corroboration of that evidence with the findings in wildlife and laboratory experimental studies. This coherence and corroboration provide support for the conclusions of the researchers undertaking the studies of the Michigan and North Carolina cohorts and of the preliminary conclusions from the Oswego cohort, that PCBs/dioxins or a specific subset of congeners are the agents responsible for at least part of the observed difference in neurobehavioural outcomes for the infants exposed to these teratogenic agents *in utero*.

Despite the limits and weaknesses of individual pieces of research, the collective weight of evidence indicates that certain PCB/dioxin-like compounds found in fish in the Great Lakes/St. Lawrence River basin, and elsewhere, can cause and have caused neurobehavioural deficits of Great Lakes fish consumers. The evidence indicates that these compounds have produced some effects in the offspring highly exposed *in utero*. The importance of these effects at current levels of PCBs in fish, either to the individual or a population basis, is not known.

There may be a threshold at which these effects are not significant even as a population-wide effect. However, there is the possibility of widely based, though subtle effects, on fish consumers that would be very difficult to demonstrate conclusively by epidemiological methods. The weight of evidence indicates there also may be reproductive and immunological effects. Public health and other policy responses are therefore warranted. Similar conclusions were reached by the Agency for Toxic Substances and Disease Registry. As a consequence, this agency cooperated with U.S. EPA Region 5 in distributing 1.5 million fish-consumption advisories in Michigan.

The effects on individuals are likely to be in terms of subtle functional deficits, such as a decrease in IQ, and do not represent a severe public health danger even for high-risk populations in the Great Lakes basin. The public health case for action is based on the change in a measure of functional capacity, such as IQ, within the exposed population. In terms of a distribution curve, the proportions of the population that fall into the high and low ends of the curve could be significantly altered. Thus, in an exposed population, there could be a reduced number of potentially gifted individuals and an increased number of disabled individuals. The case for action also is based on the rights of individuals and communities to know the risks to which they are exposed. These risks are addressed in part through fish-consumption advisories.

The research at the Montreal Conference highlighted other relevant factors.

- There is significant variation in exposure to PCBs and methyl mercury, depending on where the fish were caught and which fish species consumed.
- There are considerable health benefits from fish consumption that can be demonstrated in human populations with "background" exposure to persistent toxic substances through other dietary sources.
- Wildlife consumption is important economically and culturally for many communities in the Great Lakes/St. Lawrence River basin, especially American Indian/First Nation communities.

The research presented at the conference has provided much better estimates of the patterns of fish consumption in the Great Lakes/St. Lawrence River region and on the size of the population exposed. It is, however, not clear what the exposure threshold is for human-health effects related to PCBs/dioxins in the fish. It is also clear that mercury exposure for some communities is the more significant concern. A broad range of chemicals has been identified as potential endocrine disruptors but only lead, mercury, PCBs and dioxins have been shown epidemiologically to actually affect the neurobehavioural development of human infants.

The weight of evidence accumulated through the research efforts of the Parties and the public health interventions taking place through fish consumption advisories make it imperative to have a fuller exploration of the policy implications of the presence of these toxic substances in Great Lakes/St. Lawrence River basin fish.

Policy Goals

Issues in several areas need to be articulated into a series of practical options to address the following policy goals.

- The reduction of inputs of mercury, PCBs and dioxins into airsheds and watersheds wherever possible (e.g. the effort to eliminate incineration of medical polyvinyl chloride waste in the United States (Thornton et al. 1996).
- The clean up of hazardous waste sites and destruction of stored PCBs in order to reduce the leakage of PCBs into the environment.
- Fish-consumption advisories that communicate the right message effectively. These messages must balance risks and benefits and be based on personal/community choices as much as possible in order to reduce the consumption of the most contaminated fish species and fish populations.

Policy Implications Workshop

The Work Group on Ecosystem Health hosted a workshop on Policy Implications of Evidence Regarding Toxic Substances and Human Health. The workshop was held at the Wingspread Conference Center in Racine, Wisconsin, September 5-7, 1997. The workshop comprised a select group of approximately 35 persons from diverse sectors of the Great Lakes community. The action-oriented discussion from the workshop will produce information to help IJC fulfill its Agreement obligations. The results from the Montreal conference were integrated and made accessible for the participants of this workshop to help ensure that all participants shared a common base of information about the scientific underpinnings of related policy issues. The policy implications workshop was therefore the link between scientific findings and the identification of policies and actions that are warranted.

1.3 WORK GROUP ON PARTIES IMPLEMENTATION

1.3.1 Workshop on PCBs, the New Equilibrium?

A workshop entitled PCBs, the New Equilibrium? was held September 10, 1996 in Windsor, Ontario, under the auspices of the Work Group on Parties Implementation. Work Group members and 19 invitees gathered to hear a number of presentations and to discuss issues around the question of whether PCB concentrations in the Great Lakes are reaching a new equilibrium. Presenters were Ross Norstrom and Craig Hébert, Paul Mac Berthoeux, Stephen Carpenter, Daniel Smith, Craig Stow and Leland Jackson. John Giesy served as moderator.

The term "new equilibrium" as applied to the lack of change in concentration of PCBs in the Great Lakes was brought to light in 1993 by a discussion in the preamble to proposed U.S. EPA rules widely referred to as the Great Lakes Initiative (U.S. EPA 1993). That discussion centred on PCB and DDT concentration trends in lake trout and salmon that seem to indicate a slowing in the rate of decline. The discussion highlighted the policy implications by concluding that, " ... if a new

equilibrium is being reached, given current mass loadings, then substantial further reductions in mass loadings to the lakes will be necessary to eliminate fish advisories." It is noteworthy that quite early in the workshop, objection was raised to the use of the term "equilibrium" in this context because of the theoretical thermodynamic connotations. There was consensus that a better term, such as "steady state" or "quasi-steady state," would be more appropriate, and these terms were used throughout the remainder of the workshop.

The impetus for the workshop came from a debate emerging in the literature over whether PCB concentrations in Great Lakes biota are indicating the establishment of a steady state with existing loadings. Dr. Stow was the main presenter in support of the position that a steady state is being approached. His focus was on sophisticated regression analysis of data from biota. Dr. Smith was the main presenter of an alternative view that available data from biota are not very useful for addressing the question, and that other data tend to refute the steady-state hypothesis. He supported his position using a combination of mathematical and mechanistic reasoning. Mr. Hébert made a presentation partially corroborating this position by presenting one possible foodchain mechanism in operation. Because many of the analyses presented at the workshop were based on herring gull egg data collected by the Canadian Wildlife Service, Dr. Norstrom described the nature of the data and the implications of trying to analyze them. As Dr. Stow's work is heavily rooted in statistical regression modeling, Dr. Berthoeux presented a primer on this topic with an emphasis on the challenges environmental data can present. Professor Carpenter and Dr. Jackson discussed aspects of monitoring and management of PCBs in the Great Lakes. A variety of reference materials were distributed to the attendees in advance of the workshop (Smith 1995a,b,c; Jeremiason et al. 1994; Stow 1995a,b; Stow et al. 1994, 1995).

Findings and Recommendation

There was clear consensus that when this issue is discussed in the future, the term "steady state" should be used to characterize the hypothesized phenomenon rather that the term "equilibrium."

While there was no consensus on the main question, there was general agreement by the participants that PCB levels will continue to decline. Dr. Smith suggested a reasonable estimate for biota in lakes Ontario and Superior over the next 10 years might be 5 percent average annual decline. Dr. Stow declined to make a quantitative estimate, preferring to characterize the likely declines in the near future as small or nearly zero.

There was also general agreement that even the most optimistic assumption of a constant percentage annual decline will mean lower and lower absolute declines every year. This will make the detection of those declines even more difficult.

Given the likelihood of ever-decreasing absolute declines in PCB concentration, the importance of continued and increased monitoring, not only of biota, but also of abiotic (i.e. air, water and sediment) components will grow. Current decreases in funding of such monitoring are opposite of what is needed if there is to be any hope of understanding how PCB concentration trends are proceeding.

Options for the abatement of PCB levels in biota on a basinwide scale are limited by the widespread and diffuse nature of the major sources (e.g. atmospheric input and sediment recycling). This does not mean that abatement is necessarily impractical in localized areas, such as Areas of Concern, or other areas where sources are well characterized and can be controlled.

Factors that cause perturbation of the foodchain (e.g. weather effects, population collapse, exotic species introductions, stocking programs) can cause fluctuations in biota PCB levels that are unrelated to system loadings and concentrations. Consequently, biota trends cannot be assumed to reflect trends in loading (see discussion in section 1.4.3).

Changes in analytical methodologies over the years can confound the ability to discern trends in PCBs in the environment. Some workshop participants suggested that researchers should analyze for trends, both with and without early portions of the data record to learn if this confounding is significant.

As the workshop produced no clear answer to the question of PCBs in the Great Lakes approaching steady state, no recommendations on such a finding are forthcoming. However, based on the conclusions from the workshop, SAB recommends the following.

- **The Parties increase funding for monitoring of PCBs and other persistent toxic substances in Great Lakes biota, air, water and sediment.**

Without such expanded monitoring, the scientific basis for policy decisions regarding persistent toxic substances in the Great Lakes will continue to erode. The workshop made it clear, moreover, that monitoring of biota alone is insufficient to elucidate trends.

1.3.2 RAP Progress: Site Visits to Two Areas of Concern

The mandate of the Work Group on Parties Implementation is to assess the activities of the Parties in meeting their obligations under the Agreement. Fundamental among those obligations are the Remedial Action Plans (RAPs) for the Areas of Concern. In the past two years, there have been major reductions in government funding for RAP activities. The Work Group previously expressed concern regarding the potential for these cuts to reduce the effectiveness of RAPs, but also has sought to meet with selected RAP participants to learn firsthand about progress under RAPs and how budget reductions might affect that progress.

The first meeting was held in Detroit, Michigan, November 20, 1996. The Detroit River RAP, like other connecting channel RAPs, includes participation from both countries, and thus two frameworks for legislation, administration and infrastructure. The second meeting was held in Burlington, Ontario, May 27-28, 1997, to discuss the Hamilton Harbour RAP.

The objective of these meetings was to focus on the scientific issues associated with RAPs, particularly examining the research challenges related to contaminated sediments, airborne deposition and biological effects. Each meeting offered an opportunity to hear invited presentations by scientists currently working on RAP-related research, advisory committee members and other interested parties.

The Work Group heard a variety of evidence. The complexity of each RAP and the diversity of information available pointed to the need for a systematic basis of comparison. Without such a basis, the Work Group concluded that a direct comparison of any one RAP with another and with its own stated goals would be almost impossible. Conclusions from the presentations follow.

- Each RAP was able to demonstrate progress in some respects (e.g. reductions in the volume and frequency of combined sewer overflows in both areas, improved quality and extent of wildlife habitat in Hamilton Harbour). Progress on remediation of contaminated sediments has, however, been slow in both RAPs. The reasons for this appear to relate to delays in source controls, incomplete or inconsistent scientific evidence regarding the source of the problem and

the efficacy of proposed remedial measures, and the need to share clean-up costs among public and private sources.

- Progress in some areas may be constrained by highly variable sources (e.g. sewage treatment plant effluents, combined sewer overflows) and by continuing population growth within the RAP areas. Indeed, the present and historic sources of persistent toxic substances and the current status of those sources may be unknown.
- Funding cuts are having a local impact and affecting RAP progress. In relation to binational RAPs, such as the Detroit River, these cuts may constrain the ability of the RAP to sustain a binational public process to complete the plans. Funding cuts also have affected the availability of research funding, particularly in Canada, and thus the availability of research in key areas that would support implementation choices/decisions with confidence.
- Sometimes, funding cuts are achieved by reducing funding for independent (e.g. university-based) research and relying solely on government research. This can result in the loss of outside peer review, a process that is essential for the preservation of scientific integrity and the maintenance of the scientific credibility of the conclusions and recommendations of RAP developers. Reduction of independent research funding and peer evaluation also may limit the dissemination of scientific knowledge which could be applied elsewhere in the basin.
- The Detroit River RAP has defined a scope based on political, rather than watershed boundaries. As a result, broader ecosystem, including foodweb, impacts resulting from local air emissions and cumulative effects may be overlooked or underestimated. This may limit the utility of the "ecosystem approach" as envisaged under Annex 2 of the Agreement. In contrast, the Hamilton Harbour RAP has taken a watershed approach.
- A positive, trust-based relationship was evident in Hamilton among government agencies, university researchers, members of the general public and other interested stakeholders. This relationship appears to be central to the development of consensus about the importance of individual sources and the urgency of remedial measures. Good communication among stakeholders also may facilitate risk communication and risk management where sources and mechanisms of impact are complex.
- Where communication problems do exist among stakeholders, as appears to be the case in the Detroit River RAP, dispute resolution procedures may be helpful in restoring trust among the participants.

See Chapter 6 for additional discussion of the Detroit River and Hamilton Harbour RAP reviews.

Recommendation

SAB recommends the following.

- **IJC develop a systematic framework for evaluating RAPs.**

The framework should include elements such as:

1. clear goals and objectives;
2. resource inputs (e.g. human and fiscal resources for administration, contractors, government and university/other research);
3. number of peer-reviewed publications related to the program and its goals;
4. number and type of activities (e.g. public outreach, industrial and municipal liaison);
5. total and annual number of participants in program activities;
6. nature and extent of volunteer participation;

7. nature and number of stakeholders who consistently decline to participate and their expressed reasons;
8. total and annual funding for monitoring and surveillance activities since program initiation;
9. reactions in the community directly attributed to the program including, for example, measurable changes of knowledge, practice and skills; and
10. changes in environmental condition (i.e. movement toward delisting goals) directly attributable to RAP activities.

This framework should be applied by IJC and its advisers when undertaking RAP site assessments and also would be beneficial as guidance during the development of the RAPs.

1.3.3 State of the Lakes Ecosystem Conference

The 1978 Agreement, as amended in 1987, marked a major shift in how both IJC and the Parties interpreted and responded to the terms of the Agreement. The most evident shift was in the manner in which planning, data acquisition, analysis and reporting took place to assess the state of the Great Lakes basin ecosystem and to evaluate the Parties' progress under the Agreement.

The most significant reporting initiative by the Parties since 1987 has been a biennial State of the Lakes Ecosystem Conference (SOLEC) with the most recent taking place in November 1996. Two objectives of the first conference, SOLEC '94, " ... were to promote better decision-making through improved availability of information, and to review current information and to find out where there were data gaps" (United States and Canada, 1995). The process adopted involved the preparation of topical background papers that became the focus for discussion at the conference itself. Six papers were prepared and distributed prior to the conference: aquatic health, human health and health risks, aquatic habitat and wetlands, toxic contaminants, nutrients and economy-environment linkages. A summary integration document also was prepared. The Parties selected a number of indicators to assess the health of and stresses on various components of the ecosystem. Of particular note is the continuing success the Parties have achieved in addressing the nutrient stresses in the lakes. The Parties highlighted the continuing loss of both the quantity and quality of habitat and wetlands.

While SOLEC '94 spanned both nearshore and open-lake issues, but was limited in its objectives, SOLEC '96 was more limited in geographic scope, but broader in its objectives. SOLEC '96 identified five objectives:

- inform local decisionmakers of environmental issues affecting nearshore areas of the Great Lakes basin;
- provide information on the state of the nearshore ecosystem to help strengthen decisionmaking and management within the basin;
- develop support for an integrated environmental information system and help direct plans and programs;
- provide information on existing Great Lakes strategies and build cooperative actions needed to strengthen and complement them; and
- provide a forum for improved communication and network building for involved groups and individuals within the basin.

Five background discussion papers were prepared addressing nearshore waters, coastal wetlands, nearshore terrestrial (land by the lakes), land use, and information and information management. The Parties acknowledged that land use continues to be the major source of stress on the nearshore

ecosystem. The prevailing pattern of development of urban sprawl consumes vast areas of land and destroys natural habitat and farmland.

While the two conferences provided forums for presentation of a range of technical papers and discussions related to the Great Lakes basin ecosystem, neither conference provided a comprehensive assessment of the state of the lakes. By scheduling the conferences between the issuance of IJC biennial reports under the Agreement, and by titling the conferences "State of the Lakes Ecosystem," it was assumed by some members of the Great Lakes community that SOLEC was intended to be a mechanism for Party reporting under the Agreement.

Prior to amending the Agreement in 1987, biennial reporting of the state of the Great Lakes basin ecosystem and progress under the Agreement was carried out mainly through a committee infrastructure under the Water Quality Board (WQB). The Great Lakes International Surveillance Plan provided the basis for responding to the requirements specified in Annex 11 of the Agreement. Surveillance and monitoring data and information collected by the Parties and jurisdictions, sometimes raw but most often already interpreted, were provided to IJC's Great Lakes Regional Office. Here they were assembled and draft state-of-the-lake reports prepared by WQB's Surveillance Work Group. Data provided included facilities' compliance records from municipal and industrial sources, nonpoint source pollution, airborne toxic substances, radioactivity and other monitoring data related to the Great Lakes basin ecosystem. WQB subsequently reported biennially to IJC on such areas as "Progress under the Agreement" and "State of the Lakes." The last such report to IJC took place in 1989 as responses to the 1987 amendments were evolving. While WQB's reports were brief summaries of the surveillance and monitoring data available to the Surveillance Work Group, a more comprehensive appendix was prepared to support the findings, conclusions and recommendations of the WQB's report.

In 1989, subsequent to the 1987 amendments to the Agreement, WQB's committee infrastructure was dissolved. The Parties committed to the biennial preparation of state-of-the-lakes reports and also the development of a binational surveillance and monitoring program for the Great Lakes. The 1987 amendments also added new annexes and revised existing ones. The new annexes focused on such areas as RAPs and LaMPs, pollution from nonpoint sources, contaminated sediment, airborne toxic substances, pollution from contaminated groundwater and research and development. Many annexes specified that the Parties would report to IJC biennially their progress in implementation.

While committed to reporting biennially on the state of the lakes, as well as on specific annexes, reporting by the Parties has remained sporadic and inconsistent. The last U.S. report to IJC, in September 1995, was not responsive to the reporting requirements addressing the state of the lakes. Canada also reported in 1995, submitting its "First Progress Report Under the 1994 Canada-Ontario Agreement respecting the Great Lakes Basin Ecosystem." Again, the report was essentially a program overview responsive to the Agreement targets and not an assessment of the state of the lakes. In each case, the reports were not coordinated binationally nor did they report on the requirements for a joint surveillance and monitoring program. WQB's 1989 report to IJC, supported by the Surveillance Work Group's 1987 Appendix B (GLWQB 1989a,b) still remains as the most recent and most comprehensive assessment of the status of the Great Lakes basin ecosystem and, therefore, progress under the Agreement.

Finally, the problem of assessing the status of the Great Lakes basin ecosystem and reporting on progress towards the goal of sustainability was considered by the National Roundtable on the Environment and Economy in their report "Pathways to Sustainability: Assessing Our

Progress" (Hodge et al. 1995). The National Roundtable noted three criteria for effective assessment and reporting on progress as:

- the freedom and resources to function independently;
- the stature and capability to link successfully with any appropriate element of the existing institutional web; and
- assured longevity of existence to ensure that an institutionalized memory is created and assessment is undertaken periodically.

It concluded that IJC was the only existing mechanism that has the potential of meeting these criteria.

SOLEC '98 will focus on the issue of indicators, providing an opportunity to build on the report, "Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement," prepared by IJC's Indicators for Evaluation Task Force (IETF 1996). As noted in the report, "The development of indicators and evaluation of progress are dynamic, interactive and evolving processes that will require coöperation between the governments and the Commission. The Task Force hopes this report will provide the Commission with useful guidance to encourage governments and others to consider a set of desired outcomes and associated indicators, as well as the data and information necessary and sufficient to evaluate progress under the Agreement." SOLEC '98 would be an excellent opportunity for IJC to collaborate with the Parties in determining the process for measuring, reporting and evaluating Agreement progress and for ensuring that the data and information needs necessary for the success of the process are identified. IJC, however, must ensure that its role as an independent evaluator is not compromised as a result of this collaborative initiative.

Recommendations

SAB recommends the following.

- **The Parties clarify to IJC, the role of SOLEC in fulfilling their obligation to report on the status of the Great Lakes basin ecosystem.**
- **The Parties invite IJC's collaboration in the preparation of SOLEC '98 and that IJC clarify how it proposes to fulfil its evaluative role at the completion of that conference.**

1.4 WORK GROUP ON EMERGING ISSUES

1.4.1 Governance

Introduction

By its very nature, Great Lakes basin governance is in a continuous state of evolution, adapting to the ever-changing socioeconomic, environmental and political priorities of policy makers and opinion leaders. Basin governance must overcome the incongruency between geo-political and hydrologic boundaries -- a formidable challenge in an expansive, binational setting where the magnitude and complexity of the physical ecosystem is rivalled by that of the institutional ecosystem. Multi-jurisdictional, basin-oriented institutions play a pivotal role in this process. They provide a forum within which stakeholders can coordinate their shared implementing roles and focus on a common set of problems and opportunities. They provide a framework for nurturing new ideas and governance innovations, while functioning as a buffer to temper the impact of individual and collective change

among relevant political jurisdictions. Further, in often subtle ways, such institutions can have a substantive impact on the nature and direction of basin governance.

Great Lakes basin governance is in the midst of profound change, brought on by equally profound changes in jurisdiction philosophies and approaches toward environmental protection and resource management. As a preeminent binational institution operating under the authority of the Boundary Waters Treaty of 1909 and the Agreement, IJC must demonstrate vision and leadership in this time of change. To succeed, the IJC must be open to change itself and to a fundamental rethinking of its mission and procedures and a willingness to adopt any resultant structural and operational innovations.

SAB, through its Work Group on Emerging Issues, emphasizes the importance and timeliness of an objective review and reassessment of IJC roles and procedures in the context of basin governance. SAB further recognizes that a window of opportunity has presented itself. An IJC strategic planning process is presently underway, affording an excellent opportunity for the governments, Commissioners, board members, staff and constituents to assess current efforts and prepare for the future. Further, following release of the next IJC biennial report, Article X of the Agreement calls on the Parties to "conduct a comprehensive review of the operation and effectiveness of this Agreement." And, finally, in April 1997, President Clinton and Prime Minister Chrétien requested that IJC "examine its important mission" and advise on how it "might best assist the parties to meet the environmental challenges of the 21st century."

The following discussion presents an overview of the evolution of Great Lakes basin governance, the role of IJC, an acknowledgment of institutional analyses conducted in recent years and findings and recommendations SAB has endorsed.

The Evolution of Great Lakes Basin Governance

Great Lakes basin governance might best be characterized as a century old experiment in institutional design. Both individually and collectively, the myriad political jurisdictions in the binational basin are constantly reorienting themselves to reflect the ever changing socioeconomic, environmental and political priorities of their constituents. Multi-jurisdictional, basin-oriented institutions must adapt accordingly to ensure that progress in meeting established goals is maintained.

The present era of basin governance, with its roots in the early to mid-1980s, features the transition from a top-down, command and control, government-dominated approach to a bottom-up, partnership-based, inclusive approach. The evolution to this new era was not the product of a single, orderly, calculated strategy. It was the outcome of multiple -- and not necessarily mutually compatible -- developments. For example, the past decade has seen a pronounced change in both U.S. federal/state and Canadian federal/provincial relationships. Devolution of authority has placed additional management responsibilities on state and provincial governments that, in turn, have looked to local governments to share those responsibilities. At the federal level, the regulatory emphasis of past years is tempered by a growing emphasis on voluntary compliance and less-prescriptive means of achieving standards. Fiscal constraints, downsizing and the "reinvention" of government are commonplace. And, a rising ethic of self-determination, stewardship and collaboration at the local level has seen a growth in community empowerment and watershed-based institution building.

To some, transformation to this new era is regarded as a step backward: an era of declining budgets, a compromised regulatory framework, a research infrastructure at risk and government downsizing that does little more than pass the burden of stewardship from one level of government to the next. To

others, the transformation is regarded as a step forward: management responsibilities are assumed by the level of government closest to the resource and the people; limited funds promote added efficiency; state, provincial and local governments are empowered; and an overly prescriptive regulatory framework is tempered by voluntary compliance.

While both perspectives offer legitimate arguments, ready agreement is reached on one point. All basin stakeholders, within government and out, need to develop and pursue creative approaches to basin governance that ensure efficiency and effectiveness in a time of change and uncertainty. Binational basin institutions have an obligation to meet this challenge, to shape an evolving governance regime in response to changes within individual political jurisdictions. To accommodate and influence change within the broader institutional ecosystem, basin institutions must be open to internal change as well. This is a critically important consideration for IJC, given its role in basin governance.

The International Joint Commission and its Role in Basin Governance

IJC is a permanent bilateral body created under the auspices of the Treaty to prevent disputes relating to boundary water usage and to settle questions arising along the "common frontier." IJC provides the framework for binational cooperation on questions relating to water and air pollution and the regulation of water levels and flows.

IJC's three principal functions are as follows.

- Quasi-judicial: Approves/disapproves applications from governments, companies or individuals for obstructions, uses or diversions of water that affect the natural level or flow of water on the other side of the international boundary.
- Investigative: Investigates questions on matters of difference along the common boundary, undertaking references that are presented by the two federal governments that entail fact finding and recommendations.
- Surveillance/coordination: Monitors and coordinates implementation of recommendations accepted by the governments, monitors compliance with Orders of Approval for structures in boundary waters and evaluates the governments' progress in meeting goals of programs established under the auspices of IJC.

IJC has specific Great Lakes responsibilities under the 1978 Agreement as amended. The Agreement calls on the two governments to "restore and maintain the chemical, physical, and biological integrity of the waters of the Great Lakes Basin Ecosystem."

The Agreement is a comprehensive bilateral arrangement that functions both as a framework for cooperation and an instrument for implementation. As a framework for cooperation, the Agreement explicitly affirms the intent of the Parties to restore and protect the world's largest freshwater resource. IJC plays a credible and important role among citizens, industry and the scientific research establishment in the basin in promoting binational cooperation. This role is not easily achieved by governments, and IJC has been highly effective in terms of contributing to progress under the Agreement by bringing together representatives from diverse Great Lakes community groups to cooperatively discuss and move forward on Agreement issues. Within its own advisory institutions, IJC facilitates a consensus-based binational process involving Commissioners, professional staff and eminent volunteers in their personal and professional capacities. The Agreement also functions as an instrument aimed at achieving four central tenets:

- specific goal setting through the implementation of three policies of prevention, management and control of pollutants;
- commitments in terms of specific objectives, programs and research priorities;
- mechanisms for ongoing cooperation and reporting; and
- accountability and independent evaluation of progress through IJC, the joint institutions (i.e. WQB and SAB), the dissemination of public information and hearings.

The Agreement's 25th anniversary in 1997 is indeed an appropriate occasion to celebrate remarkable and continuing success in many areas. The Agreement has institutionalized U.S. and Canadian relationships on environmental protection and resource management concerns, offering a degree of stability and familiar, trusted mechanisms for objective analysis and advice. The Agreement pioneered the notion of an "ecosystem approach" to management and, in so doing, helped promote interdisciplinary science and collegiality among the research, management and policy communities. And, more specifically, the Agreement is rightfully credited with significantly reducing problems of phosphorus and other conventional pollutants, highlighting concerns and promoting actions for control of toxic contaminants and encouraging "place-based," partnership-oriented initiatives through RAPs and LaMPs.

IJC, along with the Agreement and its institutions, have long been subject to the highest of expectations of basin stakeholders. As such, the aforementioned successes have been tempered by other examples where Agreement language and implementation activity has been the focus of some concern. Among others, concerns include an inadequate emphasis on evaluating progress, lack of accountability for the governments, inadequate resources for monitoring and data gathering, inadequate representation of American Indians/First Nations, the need for enhanced citizen participation and the absence of a strategic approach to ensure that the governments, along with Agreement institutions, meet Agreement goals in an efficient and cost-effective manner.

Assessments of the overall performance of the Agreement and its institutions tend to be both subjective and varied. However, even those with divergent views agree, to safeguard past progress and ensure future relevance, the Agreement and its institutions must be flexible and open to change in this era of evolving basin governance.

Embracing the Environmental Challenges of the 21st Century

Over the past two years, SAB has focussed on the issue of governance as an emerging issue. Prompted by the rapid and continuing transformation into a new era of basin governance, it focused on the challenge of ensuring continuing relevance and leadership of IJC, the Agreement and its institutions. One outgrowth of this focus was a recommendation that IJC initiate a strategic planning exercise to fundamentally evaluate -- and explicitly state -- its mission and goals and the necessary structure, procedures and actions to achieve them.

More recently, the issue of governance was raised in the form of a charge by the two federal governments. In reaffirming their commitment to IJC and "its important role in fostering cooperative action," the governments also acknowledged that "the environmental challenges faced collectively by our people have grown in size and complexity, requiring strengthened collaborative action." The governments then called upon IJC "to examine its important mission in the light of relevant agreements and references, and to provide the parties ... proposals on how the Commission might best assist the parties to meet the environmental challenges of the 21st century within the framework of their treaty responsibilities."

In responding to this challenge and, more generally, to facilitate change where warranted, IJC can draw on a wealth of analyses conducted over the last decade. Among others, these include:

- The Great Lakes Water Quality Agreement: An Evolving Instrument for Ecosystem Management (National Research Council and Royal Society of Canada, 1985);
- Institutional Arrangements for Great Lakes Management: Past Practices and Future Alternatives (Donahue 1987);
- Perspectives on Ecosystem Management for the Great Lakes (Caldwell 1988);
- The International Joint Commission Seventy Years On (Centre for International Studies 1981);
- Managing North American Transboundary Water Resources, Parts 1 and 2 (Dworsky et al. 1993a,b);
- Report and Recommendations of the Reconstituted Task Force on Commission Role and Priorities under the Great Lakes Water Quality Agreement (IJC 1991);
- An Evaluation of the Effectiveness of the International Joint Commission (Environmental Law Institute 1995); and
- The Great Lakes Water Quality Agreement: Its Past Successes and Uncertain Future (Botts and Muldoon, 1996).

The extent to which these various analyses address the issue of basin governance varies from one to another, in terms of rigor, focus and comprehensiveness. Collectively, they represent a cogent analysis of the institutional opportunities and challenges facing the United States and Canada in the joint management and protection of the Great Lakes. Their analyses suggest that 25 years of binational experience is sufficient for undertaking institutional reform now to support continued progress under the Agreement into the next millennium.

Findings and Recommendations

SAB has addressed the issue of basin governance through a methodical review of the literature, a series of invited workshop presentations and continuing SAB dialogue. These exercises have yielded several statements of findings and recommendations that IJC is urged to implement in the interest of meeting the environmental challenges of the 21st century.

To ensure its continuing relevance and leadership in basin governance in an era of change and uncertainty, IJC must be open to change itself. A fundamental, introspective examination of its past and present mission, structure and processes, coupled with an assessment of future challenges, is advised. This examination is currently under way through the strategic-planning process and development of the response to the recent charge from governments. SAB recommends the following.

- **The Parties, together with jurisdictional representatives and other basin stakeholders, form an expert binational committee to review the organizational and institutional arrangements that support the Agreement and offer recommendations needed to ensure the effective implementation of the Agreement in the 21st century.**

SAB is pleased IJC is acting on its earlier recommendation to initiate a strategic-planning process. SAB emphasized that such a process afforded IJC an opportunity for a thorough and fundamental review and evaluation of its mission, procedures and performance. A strategic plan also provides an opportunity to reaffirm or enhance organization relevance through fundamental change, if warranted. SAB recommends the following.

- **IJC diligently pursue its strategic-planning exercise through an inclusive process involving Commissioners, board members, staff, governments and all basin stakeholders.**

The process should not focus on procedural or operational "fine tuning," but on a fundamental review of the performance and future relevance of IJC, the Agreement and its institutions. One product must be a concise strategic plan presenting an organizational mission, goals, objectives and strategic actions.

Progress in meeting Agreement goals has been compromised by an inadequate emphasis on IJC's role in monitoring activities under the Agreement, evaluating the adequacy of the Parties' programs and holding the Parties accountable for progress. SAB recommends the following.

- **As part of the strategic-planning process, IJC identify program evaluation as the highest priority and initiate necessary budgetary, staffing and work plan adjustments to support this priority.**
- **IJC explore and pursue measures necessary to ensure that the Parties respond publicly to all IJC recommendations in a timely and substantive manner.**
- **IJC encourage the Parties to use the biennial State of the Lakes Ecosystem Conference to provide an assessment of the state of the lakes as a basis for determining progress under the Agreement, as well as an opportunity to respond to IJC recommendations.**

Following release of the IJC's next biennial report, Article X of the Agreement calls on the Parties to "conduct a comprehensive review of the operation and effectiveness of this Agreement." SAB recommends the following.

- **The Parties conduct a review of the adequacy of the Agreement, given the evolving state of basin governance and the need for the Agreement and its institutions, to both adapt to and influence that evolution.**

A decision as to whether the Agreement needs to be modified should not be predetermined, but should be an objective outcome of the review process. If modified, current Agreement language must be maintained or enhanced and additional emphasis placed on implementation.

IJC has experienced a steady decline in U.S. and Canadian federal appropriations in recent years. This erosion of financial resources compromises the organization's ability to meet its mandate under the Boundary Waters Treaty and the Agreement. Further, it prevents IJC from evaluating the Parties' programs that support the Agreement. SAB recommends the following.

- **IJC document and quantify the benefits of its products and services in the form of a "return on investment" analysis for use by the Parties, legislative bodies and all basin stakeholders.**

Such an analysis could also quantify, to the extent possible, the economic and ecological consequences of program cutbacks due to budgetary constraints.

SAB recommends the following.

- **IJC aggressively pursue the feasibility of alternative sources of funding to complement its current sole reliance on U.S. and Canadian federal appropriations.**

Sources might include foundation grants, government contracts for references and studies and an endowment or trust fund. Safeguards to ensure IJC's integrity and objectivity would be required.

In offering the above recommendations, SAB emphasizes that all can be pursued in the near term. It further urges IJC, in its strategic planning and related initiatives, to think openly and objectively about its current and prospective role in basin governance, and without constraints imposed by tradition. For example, should the Agreement be replaced with a broader Great Lakes Agreement that accommodates water quality and quantity considerations? Would a single IJC secretariat be advisable and strengthen IJC's binational character? Should provisions be made for IJC to accept public petitions for references, as is the case with the Commission on Environmental Cooperation? How might American Indian/First Nation constituencies be accommodated in institutional arrangements under the Agreement? These are but a few of the provocative questions raised in recent analyses that speak to the need for a fundamental review of IJC roles and responsibilities in the interest of meeting the environmental challenges of the 21st century.

1.4.2 Ecological Economics as an Emerging Issue

At its 16th meeting, the Work Group on Emerging Issues met with three experts in the field of ecological economics: Robert Costanza, Tony Friend and Ellie Perkins. Each is actively engaged in teaching, consulting and research in ecological economics and has published in economics literature.

In the view of some, neoclassical economics does not adequately deal with environmental issues. The Work Group on Emerging Issues has reviewed the emerging discipline of ecological economics. The following explains the discipline and suggests its relevance.

Ecological economics is based on the premise that the natural world, including local ecosystems, has a natural carrying capacity and finite resources and, in the long run, human activities must work within these constraints. Ecological economics involves evaluating the material economy in conventional terms, but also evaluating interactions with the ecosystem. Ecological economics incorporates neoclassical economics but holds that neoclassical economics is too limited. Ecological economics expands the analysis to incorporate the stocks and flows of natural resources and environmental pollutants and to model the interaction between the economy and the ecosystem. Some aspects of ecological economics involve systems modelling.

Neoclassical economics examines the satisfaction of human wants from a set of finite resources and seeks to achieve an efficient allocation of those resources to maximize consumer satisfaction. Ecological economics sets three additional goals: sustainable scale, fair distribution and efficient allocation. Sustainable scale means conducting economic activities on a scale that can be sustained eventually given the real limitations of natural resources and the ecosystem within which we live. Fair distribution deals with dividing the output of the economy and enjoyment of the natural environment, including consideration of which groups are adversely affected by resource consumption or pollutant discharge. Efficient allocation is the portion of the problem that is dealt with by neoclassical economics and refers to the use of available resources in a way that maximizes the consumer satisfaction that can be achieved from them or, to put it another way, minimizes the resources needed to achieve a given level of output.

In neoclassical economics, it is assumed that consumer satisfaction depends on the consumption of material goods and services. Ecological economics recognizes that individuals derive satisfaction out of doing useful work and out of living in harmony with the surrounding ecosystem. While the latter

elements are not inconsistent with neoclassical economics, they are generally not included in neoclassical models.

Neoclassical economics assumes that a set of factors -- land, labour, capital -- is used to produce output. Ecological economics recognizes these three and adds two more: natural capital and organizational capital. Natural capital includes the stock of natural resources both renewable and nonrenewable. For example, when a stand of timber is harvested, neoclassical economics recognizes the economic activity involved in cutting and processing that timber while ecological economics also recognizes that the wealth of society has been diminished by the reduction in the stock of standing timber. Similarly, when fossil fuels are burned, ecological economics recognizes a reduction in the world's stock of available energy resources and the increase in air pollution levels and associated damage. Organizational capital represents the collective ability to organize for productive purposes, whether through forming corporations, government structures, or social and cultural organizations. Ecological economics recognizes that when a society has developed organizational capital, it has made a valuable investment; and when technological or social change renders those organizational forms or cultural practices obsolete, the society may lose something valuable.

Ecological economics is viewed by some as a process, not just an analysis. Supporters of this view believe strongly in the participation of stakeholders in the process of defining values, structuring the model and evaluating the results.

While ecological economics is a multi-disciplinary, systems-model approach, many of the elements that it incorporates are not unfamiliar to the economics profession. Economists have been working for over two decades to develop an expanded system of national accounts that would measure not only traditional economic activities, but also the effects of these activities on stocks of natural resources and the quality of the environment. Much effort has gone into measuring costs of environmental pollution and changes to the natural environment.

Ecological economics has its problems and limitations. Obviously data needs are far greater than those of traditional economic models. While there is more than 200 years of experience in developing the data used in the system of national accounts that measure gross natural product, inflation and unemployment, much of the data that ought to be included in an ecological economic model is not routinely gathered. Some of the data are difficult even to define. The evaluation of environmental impacts has been the subject of much research, but it is still highly contentious. There is no reason to expect that agreement will be reached on how to value many of these variables much less on what the values will be in the immediate future. This lack of agreement places serious limits on the ability to fully implement ecological economic approaches in the near term.

Ecological economics can be applied on a global, national or local scale. It is perhaps most easily understood as a world-scale modeling exercise in which the relationship of all human economic activity can be related to the world stock of resources and environmental effects. However, it is equally appropriate to apply the same principles to very local issues, such as water pollution problems in a single harbour in the Great Lakes.

It would be useful to explore the application of ecological economic principles to some of the environmental problems faced by the Parties by sponsoring at least one pilot study using ecological economics. The study might deal with a single RAP, such as the Collingwood or the Hamilton Harbour RAP; it might address a single air pollutant, water pollutant or a family of pollutants. The choice of area and pollutant would depend in part on the availability of local ecological and economic data and models that could be developed for the study. The study would examine one or more policies

for dealing with the specific environmental problem and evaluate the relative costs and benefits of those policies. The study could be conducted simultaneously with a conventional analysis so results could be compared.

Recommendation

SAB recommends the following.

- **The Parties commission a study, using the methods of ecological economics, to evaluate the practical value of utilizing the ecological economics approach.**

A particular environmental problem in a relatively small watershed within the Great Lakes could be selected. The results would include an assessment of whether further studies of this type are of value.

1.4.3 Foodweb Dynamics in Aquatic Systems as an Emerging Issue

Reducing contaminant loadings to the Great Lakes is a major goal of the Agreement. Traditional approaches to issues of water quality and contaminant loading have generally assumed that changes (i.e. reductions) in contaminant loadings would be reflected by reductions in contaminant levels in fish. It is generally assumed that organic and inorganic contaminants that reach the Great Lakes are passed through the foodweb and are increasingly concentrated in higher trophic levels. However, a growing body of evidence suggests that these assumptions are often incorrect. Thus, the research issue of how contaminants bioaccumulate in foodchains has long been of interest.

Recent data analyses and models have highlighted some of the complexities involved in contaminant cycling that can lead to counterintuitive results. Changes in the structure of the foodweb (e.g. shift in size/age distribution of prey species) can have dramatic effects on contaminant concentration levels in the fish (Jackson 1996a,b). For example, changes in the foodweb can change: the relative contribution of different sources of contaminants (e.g. sediment resuspension, atmospheric) to higher trophic levels; the relative shunting of contaminants to pelagic and benthic communities; the types of organisms likely to bioaccumulate contaminants; trophic transfer rates; and the amount and kinetics of contaminants in the water column. Structural changes in the foodweb can be induced by a number of factors, such as changes in the weather, introduction of exotic species and/or manipulation of stocking levels of predatory fish. Organic and inorganic contaminants may also directly affect Great Lakes biota and foodweb structure through toxic effects on eggs and subtle effects on biological processes. There is also an increasing body of evidence suggesting the concentrations of contaminants in the water and biota and the rates of bioaccumulation are dependent on the lakes' trophic status (i.e. eutrophic to oligotrophic) and nutrient loading and that contaminant transfer rates are affected by the relationship between production at one trophic level and predatory demand at the next higher trophic level (Taylor et al. 1991, 1996; Almond et al. 1996). Predatory demand is affected by the invasion of exotic species and fisheries management policies that can alter foodwebs and trophic transfer directions and rates. For example, changes in stocking rates of salmonids, relative to prey availability, can cause significant increases in PCB levels in fish even at the same PCB loading rates (Jackson 1997). Likewise, the zebra mussel effects on phytoplankton levels and composition can cause changes in contaminant cycling and exposure levels to different parts of the foodweb. Therefore, the relationships among contaminant loadings, contaminant recycling, contaminant levels in fish and human-health risk are not clear.

The Great Lakes foodwebs and relative species composition have changed dramatically over the past decade. These changes are due to a combination of factors including invasions of exotic species,

predator-prey imbalances and changes in habitat. Although the general character of these changes is known, there is little quantitative information on changes in abundances, predator-prey interactions or production levels in most trophic levels. Also, the effective nutrient reduction strategies in the Great Lakes will affect production levels and production dynamics at different trophic levels. Some of the top fish predators in the Great Lakes, such as lake trout and salmon, have shifted their diets in response to changing prey availabilities. What are the consequences of these diet shifts and changes in foodwebs and production dynamics to contaminant cycling and to contaminant levels in fish?

The Agreement mandate is to use an ecosystem approach to water quality issues. There is a clear interrelationship between fisheries management ("top-down" control), nutrient reduction strategies ("bottom-up" control), invasion of exotic species, contaminant cycling and habitat quality through the foodweb (Figure 1). The foodweb structure and trophic transfer rates and pathways have been modeled somewhat, but there is a clear lack of lakewide information on even the operation of the foodweb (i.e. what eats what, and when?), particularly for ecologically important species (e.g. deep water sculpin) that may not have direct economic value.

Figure 1 **Ecological/Environmental Variability**

It is critical to understand the interconnectedness of foodweb structure, nutrient loadings and contaminant cycling to better interpret changes in contaminant levels in fish relative to changes in source loadings. This understanding could result in more effective monitoring programs and promote better public awareness of the effectiveness and complexities of cleanup efforts, particularly if decreases in contaminant loadings correspond to increases in contaminant levels in fish caused by changing foodwebs. SAB recommends the following.

- **Great Lakes researchers address water quality nutrient and contaminant issues together with monitoring for a quantitative assessment of foodweb and production dynamics in the Great Lakes.**

The recently completed report of IJC's Lake Erie Task Force (Dodge and Reutter, 1997) that included development of the Lake Erie Ecological Modeling Project (LEEMP) is a good example of the type of approach recommended. This Task Force led a collaborative process that included a Core Advisory Group of Lake Erie fishery and water quality managers that "provided ongoing advice, guidance and data to facilitate model development, as well as feedback on the scope and characteristics of the model." The model developed will be used by the binational Lake Erie Committee of the Great Lakes Fishery Commission and the Lake Erie LaMP Work Group. The value of the collaborative process was highlighted in the report: "The experience in developing a model in concert with an advisory group, the learning that occurred about the uses of the model and compromise in model resolution, and heuristics of model use were all positive, and the transfer to the LaMP has occurred through the involvement of LaMP participants in the LEEMP. The Task Force has created a much larger group or nucleus of people working together on ecosystem issues and have [sic] crossed boundaries -- agencies, offices, communities, disciplines, etc." See Chapter 5 for further discussion.

SAB recommends the following.

- **IJC foster linkages and increased communication with agencies responsible for fisheries management and exotic species (e.g. the Great Lakes Fishery Commission).**

- **IJC develop an interdisciplinary task force similar to the Lake Erie Task Force to explore developments, models, monitoring and data needs on the effects of foodweb structure and nutrient loading on contaminant levels in biota.**
- **IJC encourage new research initiatives in the following areas:**
    1. **quantitative evaluation of foodweb structure and trophic transfer on a lakewide basis, including diet analysis;**
    2. **relationships of contaminant bioaccumulation in relation to size, age and condition of the predominant prey fish in the Great Lakes (e.g. bloater, alewife, rainbow smelt);**
    3. **sources (i.e. atmospheric, sediments, landfill sites) of contaminants, such as PCBs to the foodweb, to answer where do the PCBs in fish come from?;**
    4. **the consequences of changing foodweb structure on contaminant levels in fish (e.g. linkages with Lake Erie Ecological Modelling Project); and**
    5. **the development of appropriate and innovative monitoring tools (e.g. growth rates) that can be used to detect foodweb changes that have an impact on contaminant cycling.**

1.4.4 Public Survey Results

As scientific adviser to IJC and its WQB, SAB is charged with developing recommendations on matters of science pertaining to the identification, evaluation and resolution of current and anticipated problems. The Work Group on Emerging Issues invited the identification of emerging issues from the diverse public and scientific communities in the basin through a survey questionnaire published in the March/April 1997 edition of *Focus*, and also distributed to delegates attending the International Association for Great Lakes Research conference (IAGLR '97) in Buffalo, New York. Although the response was limited, a wide range of issues was submitted for consideration.

IAGLR '97 conference participants identified eight broad areas of interest:

- understanding how to quantify and measure ecosystem health and integrity;
- understanding the human health linkage to Great Lakes pollution;
- sustaining progress towards environmental quality;
- achieving sustainable development;
- atmospheric deposition, especially understanding its physical processes;
- increasing understanding of environmental responses to lake levels fluctuations;
- improving the integration of scientific findings; and
- permit trading as an economic incentive for pollution abatement.

The areas may be categorized as follows: ecological/biological, resource management, social/economic/cultural and physical process.

Thirty-one submissions (14 U.S. and 17 Canadian) were received in response to the questionnaire published in *Focus.* Respondents identified themselves as follows: civil engineer, hydrogeologist, biologist, toxicologist, ecologist, health liaison officer, mayor, economics adviser, policy analyst, writer, environmental activist, underwater archaeologist, amateur historian, computer data technician, software engineer, speech pathologist and educator.

In response to the question, "Which new issue, or understanding of an old issue is most likely to enable us to achieve [the] goals [of the Agreement]?" the following issues were identified:

Water Quality Issues

- nonpoint source pollution
- amphibian deformities
- sulfonyl urea and dieback of plants
- toxin impact on biodiversity
- agricultural chemical drift and atmospheric deposition (pesticides and nitrogen)
- dredged *versus* undredged sediment quality
- storm sewer discharge and combined sewer overflows
- importance of sediment management to ecological recovery
- linkages between pollutants and biota health
- sodium levels in Lake Michigan (near carrying capacity) and other Great Lakes
- airborne pollutants from United States to Canada (soft coal)
- deep burial of nuclear waste
- understand phosphorus cycling
- land use, impervious surfaces and runoff problems

Water Quantity Issues

- land use, impervious surfaces and runoff problems
- water diversion projects from the basin

Other Issues

- sustainable development
- biodiversity
- re-evaluate information provided to news media
- public apathy to environmental issues
- re-establish public confidence in restoration efforts
- publish a guide to sites and monuments where history of the 17th and 18th centuries unfolded (for tourism and culture)
- targeting areas for habitat restoration
- habitat relation to fisheries management
- institutional analysis and design
- government support for RAPs
- changes in roles of governments and environmental organizations
- privatization of publicly owned treatment works, drinking water systems and sewage treatment facilities
- put legal means behind goals so industry is forced to comply
- implement effective cleanup measures in times of resource constraint to implement the Agreement

The issues were categorized by respondents as predominantly social, governance or institutional problems rather than resource management, physical processes or ecology. A slight majority thought their issue(s) could be addressed through the existing or a revised Agreement, while a substantial minority indicated that another initiative would be required. Education was identified by several respondents as a specific example of another initiative.

Almost half the respondents perceived measuring progress to resolve their identified issue in terms of policy analysis and program review and evaluation. An equally strongly held position would measure

progress through environmental monitoring and assessment, though it was recognized that expanded efforts would be required. Suggestions included:

- monitor people, not just the environment: "Record of KASA (knowledge, attitude, skills, abilities) changes at the local level in officials who have decisionmaking responsibility for local land use;"
- monitor economic and social factors;
- "Reports on the State of the Great Lakes need to bring in these factors (how environmental protection applies to daily life, such as personal health, economic health, and health of culture and community) if people are to clearly understand the links between ecosystem health and human well-being;"
- survey for understanding and attitude;
- make laws enforceable;
- measure tax incentives for businesses investing in environmental improvements; and
- identify critical areas.

SAB finds that periodic surveys of this nature are helpful in identifying current and emerging issues for prospective consideration by IJC. All survey responses will be considered by SAB in developing its candidate priorities under IJC's priority planning process in the upcoming 1997-99 biennial period.

1.5 REFERENCES

Addison, E.M., G.A. Fox and M. Gilbertson (eds.), 1991. Proceedings of the expert consultation meeting on mink and otter. Ecological Committee, Great Lakes Science Advisory Board, International Joint Commission, Windsor, Ontario. 30 pp. ISBN 1-895085-32-2.

Almond, M.J.R., E. Bentzen and W.D. Taylor, 1996. Size structure and species composition of plankton communities in deep Ontario lakes with and without *Mysis relicta* and planktivorous fish. Can. J. Fish. Aquat. Sci. 53:315-325.

Best, D.A., M. Gilbertson and H. Hudson (eds.), 1990. Proceedings of the expert consultation meeting on bald eagles. Ecological Committee, Biological Effects Subcommittee, Great Lakes Science Advisory Board, International Joint Commission, Windsor, Ontario. 33 pp. ISBN 1-895085-21-7.

Borgman, U. and D.M. Whittle, 1991. Contaminant trends in Lake Ontario lake trout. J. Great Lakes Res. 17:368-381.

Botts, L. and P. Muldoon, 1996. The Great Lakes Water Quality Agreement: Its Past Successes and Uncertain Future, A project sponsored by the Institute on International Environmental Governance, Dartmouth College, Hanover, New Hampshire 175 pp.

Brouwer, A., U.G. Ahlborg, M. Van den Berg, L.S. Birnbaum, E.R. Boersma, B. Bosveld, M.S. Denison, L.E. Gray, L. Hagmar, E. Holene, M. Huisman, S. Jacobson, J.L. Jacobson, C. Koopman-Esseboom, J.G. Koppe, B.M. Kulig, D.C. Morse, G. Muckle, R.E. Peterson, P.J.J. Sauer, RF. Seegal, A.E. Smits-Van Prooije, B.C.L. Touwen, N.Weisglas-Kuperus, and G.Winneke, 1995. Functional aspects of developmental toxicity of polyhalogenated aromatic hydrocarbons in experimental animals and human infants. European Journal of Pharmacology. Environmental Toxicology and Pharmacology Section. 293:1-40.

Buck, G.M., P. Mendola, J.F. Vena, L.E. Sever, P. Kostyniak, H. Greizerstein and J. Olson, 1997. Paternal Lake Ontario fish consumption and risk of conception delay, New York State Angler Cohort. Abstracts for Health Conference '97 -- Great Lakes-St. Lawrence, Montréal, Québec, May 12-15,1997. 62 pp + 4 inserts. Proceedings in press.

Caldwell, L.K. (ed.), 1988. Perspectives on Ecosystem Management for the Great Lakes: A Reader. State University of New York Press, Albany, NY. 375 pp.

Centre for International Studies, 1981. The International Joint Commission Seventy Years On. Robert Spencer, John Kirton and Kim Richard Nossal (eds.) University of Toronto, Toronto, Canada. ISBN 7727-0801-4. 172 pp.

Chen, Y.C.J., Y.L. Guo and W.J. Rogan, 1992. Cognitive development of Yu-Cheng ('oil disease') children prenatally exposed to heat-degraded PCBs. Journal of the American Medical Association. 268:3213-3218.

Colborn, T., F.S. vom Saal and P. Short (eds.), 1997. Statement from the work session on environmental endocrine-disrupting chemicals: Neural, endocrine and behavioural effects. Toxicology and Industrial Health. In press.

Courval, J.M., J.V. DeHoog, A.D. Stein, E.M. Tay, J.P. He, N. Paneth, H.E.B. Humphrey, 1997. Sport-caught fish consumption and conception failure in Michigan anglers. Abstracts for Health Conference '97 -- Great Lakes-St. Lawrence, Montréal, Québec, May 12-15,1997. 62 pp + 4 inserts. Proceedings in press.

Dar, E., M.S. Kanarek, H.A. Anderson and W.C. Sonzogni, 1992. Fish consumption and reproductive outcomes in Green Bay, Wisconsin. Environmental Research, 59:189-201.

Darvill, T., E. Lonky, J. Reihman and P. Stewart. 1997. Effect of recency of maternal consumption of Lake Ontario sport fish on neonatal coping behavior and infant temperament. Abstracts for Health Conference '97 -- Great Lakes-St. Lawrence, Montréal, Québec, May 12-15,1997. 62 pp + 4 inserts. Proceedings in press.

DeVault, D.S., R. Hesselberg, P. Rodgers and T. Feist, 1995. Contaminant trends in lake trout and walleye from the St. Lawrence Great Lakes. J. Great Lakes Res. 22:884-895.

DeVito, M.J., Birnbaum, L.S., W.H. Farland and T.A. Gasiewicz, 1995. Comparisons of estimated human body burdens of dioxin-like chemicals and TCDD body burdens in experimentally exposed animals. Environ. Health Persp. 103:9.

Dodge, D.P. and J.M. Reutter, 1997. The Lake Erie Ecological Modelling Project (LEEMP). Report of the Lake Erie Task Force to the International Joint Commission, Windsor, Ontario. 22 pp.

Donahue, M. J. 1987. Institutional Arrangements for Great Lakes Management: Past Practices and Future Alternatives. Michigan Sea Grant, Ann Arbor, Michigan 397 pp.

Dworsky, L.B., J.A. Mauer and A.E. Utton (eds.), 1993a. Managing North American transboundary water resources: The International Joint Commission and the International Boundary and Water Commission, Part 1. Natural Resources Journal, University of New Mexico School of Law. Vol. 33, No. 1. 231 pp.

Dworsky, L.B., J.A. Mauer and A.E. Utton (eds.), 1993b. Managing North American transboundary water resources: The International Joint Commission and the International Boundary and Water Commission, Part 2. Natural Resources Journal, University of New Mexico School of Law. Vol. 33, No. 2. 539 pp.

Environmental Law Institute, 1995. An evaluation of the effectiveness of the International Joint Commission. Project #93322-00. ELI, Washington, DC. ISBN 0-911937-61-7. 117 pp.

Fein, G.G., J.L. Jacobson, S.W. Jacobson, P.M. Schwartz and J.K. Dowler, 1984. Prenatal exposure to polychlorinated biphenyls: Effects on birth size and gestational age. Journal of Pediatrics. 105:315-320.

Gilbertson, M. (ed.), 1989. Proceedings of the Workshop on Cause-Effect Linkages. Council of Great Lakes Research Managers, International Joint Commission, Windsor, Ontario. 45 pp.

Gilbertson, M. (ed.), 1992. Proceedings of the third expert consultation meeting on bald eagles in the Great Lakes basin. Biological Effects Subcommittee, Ecological Committee, Great Lakes Science Advisory Board, International Joint Commission, Windsor, Ontario. 25 pp. ISBN 1-895085-42-X.

Golub, M.S. and S.W. Jacobson, 1995. Workshop on perinatal exposure to dioxin-like compounds. IV. Neurobehavioural Effects. Environmental Health Perspectives. 103 (Suppl. 2):151-155.

Great Lakes Science Advisory Board. 1991 Report to the International Joint Commission, Windsor, Ontario. 126 pp.

Great Lakes Water Quality Board, 1989a. 1989 Report on Great Lakes Water Quality. Great Lakes Water Quality Board, International Joint Commission, Windsor, Ontario. 128 pp.

Great Lakes Water Quality Board, 1989b. 1987 Report on Great Lakes Water Quality. Appendix B. Great Lakes Surveillance. 3 volumes. International Joint Commission, Windsor, Ontario.

Guy, M., W.D. Taylor and J.C.H. Carter, 1994. Decline in total phosphorus in the surface waters of lakes during summer stratification and its relationship to size-distribution of particles and sedimentation. Can. J. Fish. Aquat. Sci. 51:1330-1337.

Henshel, D.S., J.W. Martin, R.J. Norstrom, J. Elliott, K.M. Cheng and J.C. DeWitt, 1997a. Morphometric brain abnormalities in double crested cormorant chicks exposed to polychlorinated dibenzo-*p*-dioxins, dibenzofurans and biphenyls. Journal of Great Lakes Research. 23:11-26.

Henshel, D.S., J.W. Martin and J.C. DeWitt, 1997b. Brain asymmetry as a potential biomarker for developmental TCDD intoxication: A dose-response study. Environmental Health Perspectives. 105:2-9.

Henshel, D.S., 1997. Developmental neurotoxic effects of dioxin and dioxin-like compounds on domestic and wild avian species. Environmental Toxicology and Chemistry. In press.

Hill, A.B., 1965. The environment and disease: Association or causation. Proceedings of the Royal Society of Medicine, 58:1217-19.

Hodge, T., S. Holtz, C. Smith and K.H. Baxter (eds.), 1995. Pathways to Sustainability: Assessing Our Progress. National Round Table Series on Sustainable Development, National Round Table on the Environment and the Economy, Ottawa, Ontario. 245 pp.

Huisman, M., C. Koopman-Esseboom, V. Fidler, M.Hadders-Algra, C.G. van der Paauw, L.G.M. th. Tuinstra, N. Weisglas-Kuperus, P.J.J. Sauer, B.C.L. Touwen and E.R. Boersma, 1995. Perinatal exposure to polychlorinated biphenyls and dioxins and its effect on neonatal neurological development. Early Human Development. 41:111-127.

Indicators for Evaluation Task Force, 1996. Indicators to Evaluate Progress under the Great Lakes Water Quality Agreement. International Joint Commission, Windsor, Ontario. 82 pp. ISBN 1-895085-85-3.

International Joint Commission, 1991. Report and Recommendations of the Reconstituted Task Force on Commission Role and Priorities under the Great Lakes Water Quality Agreement. Unpublished. Windsor, Ontario. 14 pp + 5 annexes.

International Joint Commission, 1995, 1993-95 Priorities and progress under the Great Lakes Water Quality Agreement. Windsor, Ontario. 184 pp. ISBN 1-895085-83-7.

Jackson, L.J., 1997. Piscivores, predation, and PCBs in Lake Ontario's pelagic food web. Ecological Applications, 7:991-1001.

Jackson, L.J., 1996a. How will decreased alewife growth rates and salmonid stocking affect sport fish PCB concentrations in Lake Ontario? Environ. Sci. Technol. 30:701-705.

Jackson, L.J., 1996b. A simulation model of PCB dynamics in the Lake Ontario pelagic foodweb. Ecol. Modelling, 93:43-56.

Jackson, L.J. and D.E. Schindler, 1996. Field estimates of net trophic transfer of PCBs from prey fishes to Lake Michigan salmonids. Environ. Sci. Technol. 30:1861-1865.

Jackson, L.J. and S.R. Carpenter, 1995. PCB contents of Lake Michigan invertebrates: reconstruction based on PCB contents of alewives and their bioenergetics. J. Great Lakes Res. 21:112-120.

Jacobson, J.L., S.W. Jacobson and H.E.B. Humphrey, 1990. Effects of *in utero* exposure to polychlorinated biphenyls and related contaminants on cognitive functioning in young children. J. Pediatr. 116, 38-45.

Jacobson, J.L. and S.W. Jacobson, 1996a. Intellectual impairment in children exposed to polychlorinated biphenyls *in utero*. New England Journal of Medicine. 335:783-789.

Jacobson, J.L. and S.W. Jacobson, 1996b. Sources and implications of interstudy and interindividual variability in the developmental neurotoxicity of PCBs. Neurotoxicology and Teratology. 18:257-264.

Jacobson, J.L., G.G. Fein, S.W. Jacobson, P.M. Schwartz and J.K. Dowler, 1985. The effect of intrauterine PCB exposure on visual recognition memory. Child Development. 56:853-860.

Jeremiason, J.D., K.C. Hornbuckle and S.J. Eisenreich, 1994, PCBs in Lake Superior, 1978-1992: Decreases in water concentrations reflect loss by volatilization. Environ. Sci. Technol. 28:903-814.

Lai, T.J., Y.C. Chen, W.J. Chou, Y.L. Guo, H.C. Ko, and C.C. Hsu, 1993. Cognitive development in Yucheng children. Organohalogen Compounds. 14:247.

Larsson, P., L. Colvvin, L. Okla and G. Meyer, 1992. Lake productivity and water chemistry as governors of the uptake of persistent pollutants in fish. Environ. Sci. Technol. 26:346-352.

Lonky, E., J. Reihman, T. Darvill, J. Mather, Sr. and H. Daly, 1996. Neonatal behavioral assessment scale performance in humans influenced by maternal consumption of environmentally contaminated Lake Ontario fish. Journal of Great Lakes Research. 22:198-212.

Mac, M. and M. Gilbertson (eds.), 1990. Proceedings of the roundtable on contaminant-caused reproductive problems in salmonids. Biological Effects Subcommittee of the Ecological Committee, Great Lakes Science Advisory Board, International Joint Commission, Windsor, Ontario. 45 pp. ISBN 1-895085-41-1.

Madenjian, C.P., S.R. Carpenter and P.S. Rand, 1994. Why are the PCB concentrations of salmonine individuals from the same lake so highly variable? Can. J. Fish. Aquat. Sci. 51:800-807.

Madenjian, C.P. and S.R. Carpenter, 1993. Simulation of the effects of time and size at stocking on PCB accumulation in lake trout. Trans. Am. Fish. Soc. 122:492-499.

Mendola, P., G.M. Buck, J.E. Vena, M. Zielezny and L.E. Sever, 1995. Consumption of PCB-contaminated sport fish and risk of spontaneous fetal death. Environmental Health Perspectives. 103 (5):498-502.

Mergler, D., S.Belanger, F. Larribe, M. Panisset, R. Bowler, J. Lebel, K. Hudnell, 1997. Early nervous system dysfunction in adults associated with eating fish from the St. Lawrence River system. Abstracts for Health Conference '97 -- Great Lakes-St. Lawrence, Montréal, Québec, May 12-15,1997. 62 pp + 4 inserts. Proceedings in press.

National Research Council of the United States and Royal Society of Canada, 1985. The Great Lakes Water Quality Agreement: An Evolving Instrument for Ecosystem Management. National Academy Press, Washington, DC. 224 pp.

Rasmussen, J.B., D.J. Rowan, D.R.S. Lean and J.H. Carey, 1990. Foodchain structure in Ontario lakes determines PCB levels in lake trout (*Salvelinus namaycush)* and other pelagic fish. Can. J. Fish. Aquat. Sci. 47:2030-2038.

Rogan, W.J., B.C. Gladen, J.D. McKinney, N. Carreras, P. Hardy, H. Thullen, J. Tinglestad and M. Tully, 1986. Neonatal effects of transplacental exposure to PCBs and DDE. Journal of Pediatrics. 109:335-341.

Rowan, D.J. and I. Rasmussen, 1992. Why don't Great Lakes fish reflect environmental concentrations of organic contaminants? An analysis of between lake variability in the ecological partitioning of PCBs and DDT. J. Great Lakes Res. 18:724-741.

Schantz, S.L., J.C. Gardiner, D.M. Gasior, K.R. Srikanth, A.M. Sweeney, H.E.B. Humphrey and R.J. McCaffrey, 1997. Fine motor function in aging Great lakes fish eaters. Abstracts for Health Conference '97 -- Great Lakes-St. Lawrence, Montréal, Québec, May 12-15,1997. 62 pp + 4 inserts. Proceedings in press.

Schantz, S.L., 1996. Developmental neurotoxicity of PCBs in humans - What do we know and where do we go from here? Neurotoxicology and Teratology. 18:217-227.

Schneider, S. (ed.), 1991. Cause-Effect Linkages II Symposium Abstracts. Workshop held September 27-28, 1991, Traverse City, Michigan. Michigan Audubon Society. 46 pp. Available from International Joint Commission, Windsor, Ontario.

Seegal, R.F., 1996. Can epidemiological studies discern subtle neurological effects due to perinatal exposure to PCBs? Neurotoxicology and Teratology. 18:251-254.

Smith, D.W., 1995a. Are PCBs in the Great Lakes approaching a new equilibrium? Environ. Sci. Tech. 29:42A-46A.

Smith, D.W., 1995b. Synchronous response of hydrophobic chemicals in herring gull eggs from the Great Lakes. Environ. Sci. Tech. 29:740-750.

Smith, D.W., 1995c. Current and near future trends of PCBs in the Great Lakes: Report completed for the PCB panel of the Chemical Manufacturers Association. Available from CMA, Washington, DC.

Stow, C.A., 1995a. Great Lakes herring gull egg PCB concentrations indicate approximate steady-state conditions. Environ. Sci. Technol. 29:2893-2897.

Stow, C.A., 1995b. Factors associated with PCB concentrations in Lake Michigan salmonids. Environ. Sci. Technol., 29:522-527.

Stow, C.A., S.R. Carpenter, L.A. Eby, J.F. Amrhein and R.J. Hesselberg, 1995. Evidence that PCBs are approaching stable concentrations in Lake Michigan fishes. Ecological Applications, 5(1):248-260.

Stow, C.A., S.A. Carpenter and J.F. Amrhein, 1994. PCB concentration trends in Lake Michigan coho (*Oncorhynchus kisutch*) and chinook salmon (*O. tshawytscha*). Can. J. Fish. Aquat. Sci., Vol. 51:1384-1390.

Taylor, W.D., J.H. Carey, D.R.S. Lean and D.J. McQueen, 1991. Organochlorine concentrations in the plankton of lakes in southern Ontario and their relationship to plankton biomass. Can. J. Fish. Aquat. Sci. 48:1960-1966.

Taylor, W.D., E. Bentzen, B. DeLucca, B.E. Hickie, D.R.S. Lean, D. Mackay and G. Patterson, September 1996. Presentation at international conference on interaction of nutrients and contaminants in Utrecht, Netherlands. Unpublished.

Thornton, J., M. McCally, P. Orris and J. Weinberg, 1996. Dioxin prevention and medical waste incinerators. Public Health Reports 111(4):298-313.

[United States and Canada, 1987]. Revised Great Lakes Water Quality Agreement of 1978 ... as amended by Protocol signed November 18, 1987. Consolidated by International Joint Commission, Windsor, Ontario.

United States and Canada, 1995. State of the Great Lakes 1995. Prepared by Environment Canada and U.S. Environmental Protection Agency. 56 pp. ISBN 0-662-61887-4.

United States Environmental Protection Agency, 1993. Great Lakes Water Quality Initiative. Federal Register, Vol. 58, No. 72, April 16, 1993.

United States Surgeon General, 1964. Report of the Advisory Committee of the U.S.P.H.S.: Smoking and Health." PHS Pub No. 1103, Supt. Of Documents, Washington, DC.

1.6 BOARD AND WORK GROUP MEMBERSHIP LIST

Dr. Edward Addison [2]
Ontario Ministry of Natural Resources
(Temporary Address at Trent University)
300 Water Street, P.O. Box 7000
Peterborough, Ontario K9J 8M5

Dr. Anders W. Andren [1,3]
Sea Grant Institute
University of Wisconsin - Madison
1800 University Avenue
Madison, Wisconsin 53705-4094

Mr. Bruce L. Bandurski *(Liaison)*
International Joint Commission
United States Section
1250-23rd Street, N.W. Suite 100
Washington, D.C. 20440

Dr. William W. Bowerman [1,2]
Gale Gleason Environmental Institute
School of Science and Natural Resources
Lake Superior State University
Sault Ste. Marie, Michigan 49783

Mr. Peter C. Boyer [1,4]
(*Board & Work Group Secretary)*
International Joint Commission
Great Lakes Regional Office
100 Ouellette Avenue, Eighth Floor
Windsor, Ontario N9A 6T3

Dr. Stephen B. Brandt [1,4]
(Work Group Co-chair)
Great Lakes Center for Environmental Research and Education
SUNY College at Buffalo
1300 Elmwood Avenue
Buffalo, New York 14222

Dr. John L. Clark [3]
(Work Group Secretary)

Dr. Mark T. Goldberg [2]
GlobalTox International Consultants Inc.
367 Woodlawn Road West, Suite 805
Guelph, Ontario N1H 7K9

Dr. Magda Havas [1,4]
(To June 1997)
Environmental Research Studies
Trent University
P.O. Box 4800, 3351 Nassau Mills
Peterborough, Ontario K9J 7B8

Dr. Isobel Heathcote [1,3]
(Work Group Co-chair)
School of Engineering
University of Guelph
Thornborough Building, Room 202
Guelph, Ontario N1G 2W1

Dr. Diane Henshel [1,2]
Environmental Neurotoxicology
Indiana University
School of Public Health and Environmental Affairs
Bloomington, Indiana 47405-7802

Dr. Daland R. Juberg [2]
Eastman Kodak Company
1100 Ridgeway Avenue, Bldg. 320
Rochester, New York 14652-6253

Dr. Barbara Knuth [1,2]
(To November 1996)
Cornell University
Ferrow Hall
Ithaca, New York 14853-3001

Dr. George H. Lambert, M.D., Director [1,2]
(Work Group Co-chair to April 1997)

International Joint Commission
100 Ouellette Avenue, Eighth Floor
Windsor, Ontario N9A 6T3

Dr. Theo Colborn [2]
The World Wildlife Fund
1250 - 24th Street, N.W., Suite 6019
Washington, D.C. 20037

Dr. Harold J. Day [1,3]
(Work Group Co-chair)
College of Environmental Science
University of Wisconsin-Greey Bay
2200 Nicolet Drive
Green Bay, Wisconsin 54311-7001

Dr. Christopher DeRosa [2]
Director, Division of Toxicology
Agency for Toxic Substances and Disease Registry
Mail Stop E-29, 1600 Clifton Road
Atlanta, Georgia 30333

Dr. Donald N. Dewees [1,4]
Professor, Department of Economics
Acting Dean, Faculty of Arts and Science
University of Toronto
100 St. George Street, Room 2020
Toronto, Ontario M5S 1A1

Dr. Michael J. Donahue [1,4]
(Board U.S. Co-chair)
Great Lakes Commission
The Argus II Building, 400 Fourth Street
Ann Arbor, Michigan 48103-4816

Dr. Michel Fournier [1,2]
(Work Group Co-chair)
Université du Québec
Institut National de la Recherche Scientifique
INRS-SANTÉ
245 Boulevard Hymus
Pointe-Claire, Québec H9R 1G6

Mr. Glen Fox [2]
National Wildlife Research Centre
Environment Canada

Environmental and Occupational Health Sciences Institute (EOHSI)
681 Frelinghuysen Road, P.O. Box 1179
Piscataway, New Jersey 08855-1179

Mr. Henry Lickers [1,4]
Department of the Environment
Mohawk Council of Akwesasne
St. Regis Environmental Division
P.O. Box 579
Cornwall, Ontario K6H 6T3

Dr. Suzanne McMaster [1,2]
Health Effects Research Laboratory, MD-51-A
U.S. Environmental Protection Agency
Research Triangle Park, NC 27711

Dr. Milagros S. Simmons [2]
Department of Environmental and Industrial Health
The University of Michigan
2534 School of Public Health
109 Observatory Street
Ann Arbor, Michigan 48109-2029

Mr. Geoffrey Thornburn *(Liaison)*
International Joint Commission
Canadian Section
100 Metcalfe Street, 18th Floor
Ottawa, Ontario K1P 5M1

Mr. Jay P. Unwin [1,3]
National Council of the Paper Industry for Air & Stream Improvement, Inc.
Central-Lake States Regional Center
Western Michigan University
2041 McCracken Hall
Kalamazoo, Michigan 49008-3844

Mr. E. Tony Wagner [1,3]
(Board Canadian Co-chair)
Waterfront Regeneration Trust
207 Queen's Quay West, Suite 580
Toronto, Ontario M5J 1A7

Dr. George N. Werezak [1,4]
(Work Group Co-chair)
Environmental Health and Safety
Dow Chemical Canada Inc.

100 Gamelin Boulevard
Ottawa, Ontario K1A 0E7

Dr. Brian Louis Gibson, M.D. [1]
LAMP Occupational Health Program
185 Fifth Street
Etobicoke, Ontario M8V 2Z5

Mr. Michael Gilbertson [2]
(Work Group Secretary)
International Joint Commission
100 Ouellette Avenue, Eighth Floor
Windsor, Ontario N9A 6T3

P.O. Box 1012, 1086 Modeland Road
Sarnia, Ontario N7T 7K7

Dr. Michael Zarull [1,3]
National Water Research Institute
Canada Centre for Inland Waters
P.O. Box 5050, 867 Lakeshore Road
Burlington, Ontario L7R 4A6

[1] Science Advisory Board

[2] Work Group on Ecosystem Health

[3] Work Group on Parties Implementation

[4] Work Group on Emerging Issues

1.7 SCIENCE ADVISORY BOARD SCHEDULE OF MEETINGS FOR THE PERIOD 1995-97

- 100th Meeting, December 6-7, 1995, Washington D.C., hosted by the Water Science and Technology Board of the National Research Council.
- 101st Meeting, February 28-29, 1996, Windsor, Ontario.
- 102nd Meeting, May 22-23, 1996, Windsor, Ontario.
- 103rd Meeting, September 10-11, 1996, Windsor, Ontario.
- 104th Meeting, November 20-21, 1996, Detroit, Michigan, in association with a public meeting on scientific issues of relevance to the Detroit River Remedial Action Plan.
- 105th Meeting, February 19-20, 1997, Windsor, Ontario
- 106th Meeting, May 28-29, 1997, Hamilton, Ontario, at Canada Centre for Inland Waters, involving a tour of the Harbour and briefing on the status of the Hamilton Harbour Remedial Action Plan.

URL: http://www.ijc.org/rel/boards/sab/pr9597.html