Trends in Levels and Effects of Persistent Toxic Substances in the Great Lakes

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Edited by Michael Gilberston, Glen A. Fox, amd William W. Bowerman

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PREFACE

The International Joint Commission was set up under the Boundary Waters Treaty of 1909. The purpose of the Treaty was to prevent disputes regarding the use of boundary waters between the United States and the Dominion of Canada. In 1972, after the International Joint Commission had reported on the pollution of the Lower Great Lakes, the United States and Canadian governments negotiated a Great Lakes Water Quality Agreement with provisions for the International Joint Commission to assist in the implementation of the Agreement. In 1978, the Great Lakes Water Quality Agreement was renegotiated and the Parties to the Agreement included a new policy that 'the discharge of any or all persistent toxic substances be virtually eliminated'. In 1995, the International Joint Commission asked the Great Lakes Science Advisory Board to undertake an evaluation of progress in reducing or eliminating the effects of persistent toxic substances in wildlife and humans. In September 1996, the Board held a Workshop on Environmental Results, in Windsor, Ontario, and assembled a group of scientists who presented data on the monitoring of trends in the concentrations of persistent toxic substances in biotic and abiotic samples from the Great Lakes basin. Other scientists presented evidence of the incidence and trends in effects of persistent toxic substances on populations of organisms, including humans.

The research and monitoring on persistent toxic substances in the Great Lakes basin is among the most extensive that has been undertaken anywhere in the world. This volume of the Environmental Monitoring and Assessment Journal contains several of the papers that were presented at the Workshop on Environmental Results. The purpose of publishing these papers in the peer-reviewed literature is not only to bring this monitoring information to the attention of scientists and administrators in other parts of the world, but also to draw attention to the continuing need, in these days of budgetary constraints, to focus attention on a core group of indicators by which the Parties can reliably demonstrate whether their policy concerning the virtual elimination of discharges of persistent toxic substances is being achieved.

We should like to thank those who participated in the International Joint Commission's Workshop on Environmental Results and those who have contributed papers to this publication.

Michael Gilbertson
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Abstracts

TRENDS IN CONCENTRATIONS AND EFFECTS OF PERSISTENT TOXIC CONTAMINANTS IN THE GREAT LAKES: THEIR SIGNIFICANCE FOR INFERRING CAUSE-EFFECT RELATIONSHIPS AND VALIDATING MANAGEMENT ACTIONS

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Abstract. This paper summarizes a workshop on temporal trends in levels and effects of persistent toxic contaminants in the North American Great Lakes. Information on trends in contaminant levels is reasonably good for sediments, fish, and birds, but is scanty or absent for other ecosystem components. Information on trends in effects has been reported for birds, but is scanty or absent for other groups of organisms. In principle, information on differential trends in effects of contaminants could be used to validate or improve hypotheses about cause-effect relationships and to verify the effectiveness of management actions. However, little or no useful information on differential trends appears to be available. Use of trend data for these purposes will require collection of more detailed information and greater attention to conceptual formulation of hypotheses.

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DESIGNING THE ENVIRONMENTAL RESULTS WORKSHOP: HISTORICAL CONTEXT, CAUSALITY AND CANDIDATE SPECIES

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Abstract. During the past thirty years, researchers have been documenting the concentrations and effects of persistent toxic substances, such as DDT, PCBs, dioxins and furans, in populations of Great Lakes organisms. In designing the International Joint Commission's Workshop on Environmental Results, the organizers on the Great Lakes Science Advisory Board started from the premise that the selection of indicator organisms for long-term trend analysis requires that the causal relationships between the observed effects and the putative cause should be demonstrated and believed. However, the causal relationships that have been documented have generally been met with skepticism by fellow scientists and by regulatory officials resulting in no agreement on valid indicator organisms. To overcome this skepticism, wildlife, fisheries and human health researchers have adapted the epidemiological criteria used by medical and veterinary researchers for synthesizing the

causal evidence. Brief reviews of several candidate species and of their suitability as long term monitors are presented, and the adequacy of monitoring programs for determining trends in the incidence of chemically-induced effects is assessed.

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CURRENT STATUS AND TEMPORAL TRENDS IN CONCENTRATIONS OF PERSISTENT TOXIC SUBSTANCES IN SPORT FISH AND JUVENILE FORAGE FISH IN THE CANADIAN WATERS OF THE GREAT LAKES

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Abstract. This paper presents a summary of the current status and temporal trends over the past 15 - 20 years in contaminant levels in sport fish and juvenile forage fish in the Canadian waters of the Great Lakes. Fish consumption advisories summarized from the 1995 Guide to Eating Ontario Sport Fish showed that 67% of the 1736 consumption advisories in the Canadian waters of the Great Lakes had no restrictions. In the remaining 33% of the advisories, consumption of sport fish was restricted to 4 meals per month or less. Lake Erie had the fewest consumption restrictions (19%) and Lake Ontario the most (45%). PCBs were the principal contaminants of concern responsible for 47% of the consumption restrictions in the Canadian waters of the Great Lakes and caused the most consumption restrictions in each of the Great Lakes except Lake Superior where toxaphene caused 69% of the consumption restrictions. Concentrations of PCBs in sport fish declined in Lake Huron and Lake Ontario over the period 1976-1994. A decline in mirex concentrations in sport fish from Lake Ontario was also observed over the same time period. Concentrations of Hg in sport fish from Lake St. Clair declined over the period 1970-1994, but mercury in sport fish showed no trend over time in Lake Huron or Lake Ontario over the period 1981-1994. Contaminant levels in juvenile forage fish collected in 1993 and 1994 at 44 locations in the lower Great Lakes were assessed against wildlife protection guidelines. Concentrations that exceeded the Forage Fish Contaminant Index were observed at 17 locations with PCBs being the principal contaminant of concern. PCB concentrations in spottail shiners declined at 12 of 16 locations monitored in the lower Great Lakes over the period 1975-1994.

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ORGANOCHLORINE CONTAMINANTS IN HERRING GULL EGGS FROM THE GREAT LAKES, 1974-1995: CHANGE POINT REGRESSION ANALYSIS AND SHORT-TERM REGRESSION

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Abstract. The temporal trends (1974-1995) of 11 organochlorine contaminants in herring gull eggs from 13 colonies throughout the Great Lakes were statistically analyzed using two regression methods on logarithmically transformed data on contaminant concentrations. Change point analysis was used to determine if there had been significant year to year fluctuations in contaminant levels and/or changes in long-term trends, or if there were no significant fluctuations and constant rates of change over the sampling period. In addition, short term regressions were conducted on 6 major compounds for two time periods to compare recent rates of decline to an earlier time period. Change point analyses indicated that most (75%) of the comparisons required a change point in the model. Temporal trends indicated that in 67% of the comparisons the rate of decline was the same or faster than seen previously in the sampling period, this was most common for dieldrin and heptachlor epoxide at certain locations; in 19% of the comparisons the rates of decline had slowed or stabilized, this was most common for PCB and pentachlorobenzene; in 14% of the comparisons there were no significant temporal trends, this was most common for photomirex, mirex and heptachlor epoxide. Results for short-term regression showed that out of 78 comparisons for each time period, 2 were declining significantly in the early 1990s and 10 were declining significantly in the early 1980s. Both types of regression indicated that, for most of the herring gull egg contaminant database, recent logarithmic rates of decline were similar to those seen previously in the sampling period. Nonetheless for PCB, a compound of particular toxicological importance, recent results indicated that the rate of decline was slower at the western Lake Ontario and at the Niagara River colonies than at most other colonies. In contrast, in recent years, PCB concentrations in eggs from both colonies on Lake Superior showed no pattern of declining concentrations.

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REPRODUCTIVE AND PHYSIOLOGICAL EFFECTS OF ENVIRONMENTAL CONTAMINANTS IN FISH-EATING BIRDS OF THE GREAT LAKES: A REVIEW OF HISTORICAL TRENDS

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Abstract. During the 1950s and 1960s, reproductive failures and population declines were observed in fish-eating birds such as gulls, terns, cormorants, herons, and eagles in the Great Lakes. DDE-induced eggshell thinning contributed to these declines, but other factors such as embryo toxicity also were implicated. With reduced releases of many pollutants, reproduction recovered in some species. However, biomonitoring during the 1980s and 1990s indicates continuing effects at highly contaminated sites. Improved analytical techniques and bioassays have allowed the assessment of the total dioxin-like toxicity of complex mixtures of organochlorines (TCDD-equivalents). Developmental defects such as embryo mortality, deformities, and edema have been associated with dioxin-like PCBs in

several avian species. Improved biochemical techniques have allowed the measurement of biomarkers that detect physiological alterations associated with contaminants. Specific biomarkers studied in Great Lakes birds include cytochrome P-450 monooxygenases, highly carboxylated porphyrins, thyroxine, vitamin A, and immune function. Reproductive and physiological alterations are associated with population-level effects in Caspian terns and bald eagles that feed on highly contaminated fish. Biomonitoring using biomarkers and population-level measures in fish-eating birds will continue to be important for assessing the effects of contaminants on the Great Lakes ecosystem.

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MONITORING THE ELIMINATION OF PERSISTENT TOXIC SUBSTANCES FROM THE GREAT LAKES; CHEMICAL AND PHYSIOLOGICAL EVIDENCE FROM ADULT HERRING GULLS

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Abstract. To assess progress towards virtual elimination of PCBs, DDE, dieldrin and Mirex and their associated physiological effects, we compared their concentrations in pooled livers of adult herring gulls (Larus argentatus) repeatedly sampled at 8 Great Lakes colonies and a reference colony on the Atlantic coast between 1974 and 1993. We measured the relative thyroid mass and concentrations of highly carboxylated porphyrins and retinyl palmitate in the liver of each individual. PCBs, dieldrin and mirex declined in 7 of 8 colonies while DDE decreased in six. The greatest decreases occurred pre-1985. PCBs and DDE did not decrease in gulls from Middle Island in western L. Erie. Middle Island and Saginaw Bay had the highest concentrations of PCBs of 11 Great Lakes colonies in the 1990s. Thyroids of gulls from Great Lakes colonies were slightly enlarged but the degree of enlargement has decreased over time. In 1991, gulls from Great Lakes colonies had slight to moderately elevated concentrations of highly carboxylated porphyrins. In the early 1990s, hepatic stores of retinyl palmitate were very seriously depleted in gulls from the Detroit River, western basin of Lake Erie, and Lake Ontario, reflecting decreased availability and altered storage. We conclude that PCBs and/or other persistent toxic substances in the food of herring gulls have not been virtually eliminated.

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SPATIAL AND TEMPORAL TRENDS IN ORGANOCHLORINE CONTAMINATION AND BILL DEFORMITIES IN DOUBLE-CRESTED CORMORANTS (PHALACROCORAX AURITUS) FROM THE CANADIAN GREAT LAKES

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Abstract. The levels of organochlorine contaminants (OCs) in the eggs of double-crested cormorants (Phalacrocorax auritus) from the Canadian Great Lakes, Lake Nipigon and Lake-of-the- Woods were monitored between 1970 and 1995. PCBs and p,p'-DDE were present at the highest concentrations. Significant declines in OC concentrations on the Great Lakes were observed over this period for Lake Ontario, Lake Superior, Georgian Bay and North Channel but not Lake Erie where levels remained relatively stable. In the early 1970s, the greatest OC levels were generally observed in cormorant eggs from nesting sites in Georgian Bay and North Channel of Lake Huron. Between 1984 and 1995 mirex and PCB levels were consistently highest in samples from Lakes Ontario and Erie, respectively. Similar levels of PCDDs and PCDFs were observed from all regions of the Canadian Great Lakes in 1989. In general, OC levels in cormorant eggs between 1984-95 were ranked as follows: Lake Erie>Lake Ontario Lake Superior>Lake Huron. In 1995, eggshell thickness in Canadian Great Lakes cormorants, ranged from 0.423 to 0.440 mm and was on average only 2.3% thinner than pre-DDT era values. Between 1988 and 1996, 31 cormorant chicks with bill defects were observed at 16 different colonies (21% of all colonies surveyed) in Lakes Ontario and Superior, Georgian Bay and North Channel, and the main body of Lake Huron. No bill deformities were observed at reference sites in northwestern Ontario (Lake Nipigon and Lake-of-the-Woods). For the period 1988-96, the prevalence of bill defects in cormorant chicks (0.0 to 2.8/10,000 chicks) did not differ significantly ($P > 0.05$) among most regions in the Canadian Great Lakes. Georgian Bay was the only region to show a significant decrease in the prevalence of bill defects between the periods 1979-87 and 1988-95.

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TRENDS OF CONTAMINANTS AND EFFECTS IN BALD EAGLES OF THE GREAT LAKES BASIN

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Abstract. Bald eagle (Haliaeetus leucocephalus) numbers in North America have increased since the ban of DDT and other organochlorine compounds in the 1970s. The decrease in the environmental concentrations of p,p'-DDE has lead to the lessening of egg-shell thinning and has been a major reason for the current resurgence of bald eagle populations in temperate North America, however, this recovery has not been uniform. Eagles nesting along the shorelines and islands of the Great Lakes have continued to experience impaired productivity. In order to examine some of the reasons for the current recovery of bald eagles in the Great Lakes Basin and the potential use of eagles as a bioindicator species of Great Lakes water quality, we analyzed trends in reproductive activity, concentrations of PCBs and p,p'-DDE in unhatched eggs, and rates of developmental deformities. Numbers of occupied nests, fledged young, and yearly productivity rates have increased across the basin. No trends have been observed in changes in the concentrations of p,p'-DDE nor Total PCBs in unhatched eggs. An increasing rate in the incidence of developmental deformities in nestlings has been observed in Michigan. The recovery of the bald eagle population along the Great Lakes is most likely due to immigration of relatively uncontaminated adults from Interior regions.

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LONG TERM TRENDS IN LIVER NEOPLASM EPIZOOTICS OF BROWN BULLHEAD IN THE BLACK RIVER, OHIO

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ABSTRACT. Since 1980, liver neoplasms in brown bullhead and polynuclear aromatic hydrocarbons (PAH) in sediment have been researched in a series of studies on the Black River in Lorain, Ohio. In the early 1980s the liver cancer prevalence in fish of age 3 and older was high, ranging from 22% to 39% of the adult population. These high cancer rates corresponded to high levels of PAHs in the sediment resulting from long-term releases by an upstream coking facility (USX). In 1983 this coking plant was closed, and by 1987 the PAH in sediment had declined by about two orders of magnitude. Coincidentally the tumor

prevalence in 1987 was only about one- fourth of that in the early 1980s. In 1990, the most contaminated sediments were dredged. Neoplasm surveys in 1992 and 1993 found liver tumor frequencies in mature bullhead were as high as or higher than in the early 1980s. However liver tumor incidence declined in 1994, especially among age 3 fish, where neoplasm incidence was zero. These age 3 fish were the first group sampled that were not present during the 1990 dredging. These data are consistent with a hypothesis that the increase in tumor prevalence in 1992 and 1993 was caused by exposure to buried PAH-contaminated sediments released by the dredging. This research points out the insight provided by long term effects studies.

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REPTILES AND AMPHIBIANS: SHY AND SENSITIVE VERTEBRATES OF THE GREAT LAKES BASIN AND ST. LAWRENCE RIVER

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Abstract. Bioaccumulation of environmental contaminants has been documented in amphibians and reptiles inhabiting the Great Lakes, St. Lawrence River and elsewhere. The effects of pollutants on the physiology and reproduction of amphibians and reptiles has also been reported but this research has largely been restricted to laboratory studies. Much less work has been conducted to quantify the effects of toxic chemical exposures on these cryptic animals in the wild. In the Great Lakes basin and St. Lawrence River, this work has only been performed in detail since 1981 although some samples collected in 1974 indicated a high level of contamination. Results in the 1990s on aquatic salamanders, frogs and turtles indicate that adults and embryos are currently experiencing toxic effects and, in some species and locations, there are indications that population declines are influenced by environmental pollution exposure. In this review, we describe the existing literature on contaminant levels and effects in reptiles and amphibians of the St. Lawrence River and Great Lakes basin.

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HUMAN HEALTH EFFECTS OF ENVIRONMENTAL POLLUTANTS: NEW INSIGHTS

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Abstract. While a variety of effects of toxic chemical are known in animals exposed both in the laboratory and in situ, it has proven more difficult to obtain definitive information relating harm to humans resulting from environmental contamination. Until quite recently it has been generally assumed that cancer was the human disease of greatest importance. In fact, the majority of regulations of exposure to toxic chemicals by most governments are designed on the basis of presumed cancer risk. The evidence that hazardous chemicals can cause cancer is strong, and concern of cancer risks is appropriate. However, recent evidence has triggered a reevaluation of the assumption that cancer is the sole disease of concern. New evidence has emerged suggesting that exposure to hazardous chemicals may lead to a variety of non-cancer endpoints, and that these effects may occur at low concentrations. Of particular concern is evidence for irreversible effects on the embryo and very young children which influence intelligence, attention span, sexual development and immune function. Some of these actions appear to be direct effects on the brain and other organ systems while others are mediated via disruption of endocrine systems. While these effects are subtle and difficult to quantify, the aggregated evidence is sufficiently compelling as to necessitate reevaluation of those health outcomes upon which regulations are based.

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