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Evaluating Ecosystem Results of PCB Control Measures Within the Detroit River-Western Lake Erie Basin

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EVALUATING ECOSYSTEM RESULTS OF PCB CONTROL MEASURES WITHIN THE DETROIT RIVER-WESTERN LAKE ERIE BASIN

Based on a Canada-United States Workshop
Held at University of Windsor's Great Lakes Institute

June 18-19, 2002
Windsor, Ontario, Canada

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TABLE OF CONTENTS

EXECUTIVE SUMMARY

A workshop was held at the Great Lakes Institute in Windsor, Ontario on June 18-19, 2002, to address PCB monitoring, modeling, research, remediation actions and ecosystem impacts within the Detroit River-western Lake Erie basin. The workshop brought together approximately fifty technical experts to present and discuss important results from their research. These same experts then participated in one of three different breakout sessions to develop important recommendations and advice for future monitoring, modeling and management of PCBs within the basin.

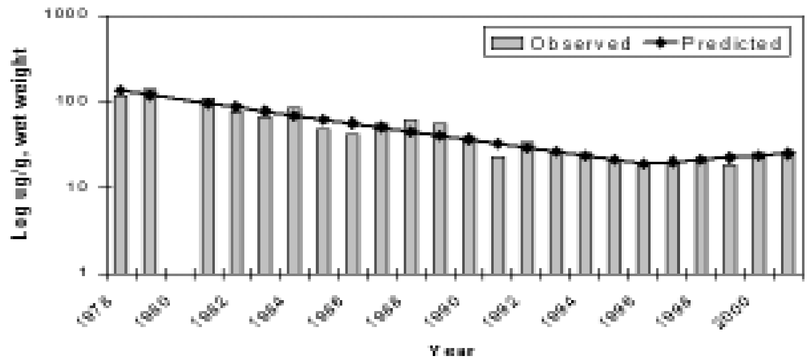
Although the focus of this report is to provide a comprehensive overview of the major findings and recommendations developed at the workshop, participants and members of the project steering committee also identified a few critical issues which warrant special emphasis at the outset, i.e., issues germane to future efforts in developing an effective approach for management of PCBs and other contaminants within the Detroit River-Western Lake Erie region. Perhaps the most significant of these is the lack of a formal system or mechanism to effectively integrate extensive and sometimes inconsistent information pertaining to the local ecosystem. Integrating results of diverse research programs focused on different ecosystem components is a key to extending our understanding of cause and effect, as well as problems and solutions. Effective integration is necessary to provide scientifically-sound explanations of observed changes within the ecosystem, to make sense of apparent inconsistencies in research findings, and to expand our overall knowledge base. The absence of a well-defined system to evaluate and integrate information reflecting different time frames, different locations, and different ecosystem indicators remains a formidable obstacle to expanding our state-of-knowledge pertaining to PCBs and other threats to the Detroit River and Western Lake Erie. In recognition of this deficiency, a framework is needed to ensure binational coordination of current and future monitoring efforts, research programs and management activities within the region.

A second issue of significance to the findings and recommendations presented in this report is the need to distinguish between monitoring for assessment of near-field vs. far-field ecosystem conditions and effects. The scale of monitoring should fit the area undergoing change. Temporally and spatially broad monitoring is crucially important for characterizing and understanding long-term trends within the overall ecosystem (far-field effects), yet the resulting data bases may not be suitable or sufficient for judging the effectiveness of specific remediation efforts within localized hotspots of PCB contamination. Alternatively, narrowly focused monitoring programs in localized hotspots provide information needed to evaluate remediation effectiveness in those areas (near-field effects), yet these same data may not offer much insight on broader ecosystem trends. This distinction between monitoring for assessment of far-field vs. near-field effects should be clearly identified and factored into the design of programs to understand trends and manage contamination threats within the region. Importantly, any and every monitoring program should be undertaken with an awareness and sensitivity to other

monitoring efforts within the region, thereby taking advantage of all available information and avoiding unnecessary redundancy whenever possible.

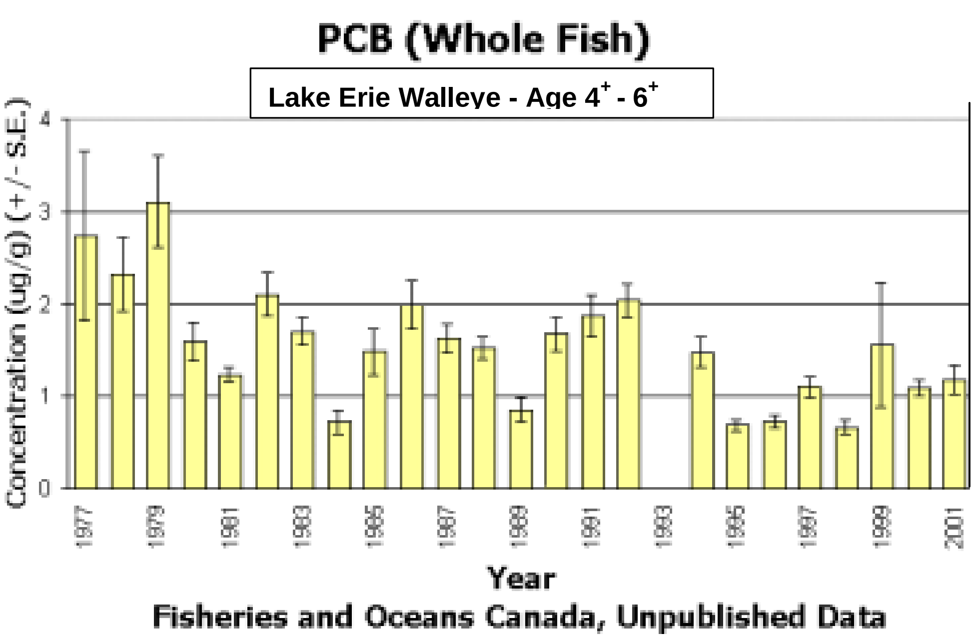
Longstanding efforts such as the Canadian Wildlife Service's herring gull monitoring program and the Canadian Department of Fisheries and Oceans' fish contaminant monitoring program are examples of scientifically-sound, far-field monitoring efforts which are important to management and an improved understanding of ecosystem trends (Figures 1 and 2). Programs of this type must be sustained in the future.

Figure 1. PCB 1:1 in Herring Gull eggs – Fighting Island in the Detroit River, 1978-2001 (Canadian Wildlife Service).



Model shows a significant decline before the change point and a non-significant trend after the change point in 1996.

Figure 2. Total PCB trends in Lake Erie Western Basin Walleye, 1977-2001 (Canada Department of Fisheries and Oceans).



On the other hand, local sediment remediation projects cannot rely on information at this scale to assess post-project conditions and overall project effectiveness (Table 1). In recognition of this fact, post-project monitoring at an appropriate temporal and spatial scale should be a mandatory component of any sediment remediation project.

Table 1. Sediment remediation projects in the Detroit River/Western Lake Erie watershed.

Sediment Project	Date	Cost (millions)	Estimated Volume of Sediment Removed	Estimated Mass of PCBs Removed
Evans Products Ditch Site - Rouge River, Michigan	1997	$ 0.75	7,300 m^3	8,000 kg
Newburgh Lake – Rouge River, Michigan	1997-1998	$11	306,000 m^3	800 kg
Carter Industrial Site – Detroit River, Michigan	1986-87 - residential; 1995-1996 - soil excavation	$7	35,100 m^3	6,268 kg
BASF Riverview Property – Detroit River, Michigan	2003	$8	No removal, only containment of waste	No accurate estimates available; estimated loading: 0.03 kg/yr
Wayne County's Elizabeth Park Marina – Detroit River, Michigan	1993	$1.3	3,100 m^3	Limited data available, rough estimate - 5 kg
Monguagon Creek – Detroit River, Michigan	1997	$3	19,300 m^3	No accurate estimate available, however, it would be very low
Conners Creek – Detroit River, Michigan	2002-2003	$4	87,200 m^3	302 kg
Black Lagoon – Detroit River, Michigan	2003	$9	23,000 m^3	38 kg
Willow Run Creek – Huron River, Michigan	1998	$70	336,400 m^3	136,400 kg
Ford Motor Company Site – River Raisin, Michigan	1996-1997	$6	20,000 m^3	20,500 kg
Fraleigh Creek – Ottawa River, Ohio	1998	$5	6,100 m^3	25,300 kg
Dura Landfill – Ottawa River, Ohio	1994	$4.8	No removal, containment wall system	No accurate estimates available, however it was believed to be a major source of PCBs

Thirdly, many workshop participants and members of the project steering committee observed that monitoring is now driven more by regulatory needs rather than efforts to characterize trends and assess remediation projects. The design of monitoring programs should be determined in large part by use impairments of the ecosystem, including fish contamination and consumption advisories, fish tumors, chick mortality, degraded and deformed benthos, and other similar conditions. Sampling methods, locations, and frequencies should be based upon the need to derive reliable estimates of contaminant loadings, to assess the impact of localized remediation projects, and to establish ecosystem trends rather than a need to determine compliance with regulatory permits and standards. Successful management of PCB contamination within the Detroit River-Western Lake Erie Basin will require an ability to quantify and compare the relative importance of point sources, contaminated sediment, atmospheric contributions, and wind-induced re-suspension events. Monitoring should be undertaken with these critical needs in mind.

A related issue of great importance pertains to PCB detection limits and the crucial role these limits play in deriving reliable estimates of PCB loadings. Reliable loading estimates are essential for tracking loading trends, comparing the relative importance of different contaminant sources, as well as calibrating and validating models used in decision-making. For known sources of PCBs like the Detroit Wastewater Treatment Plant, current detection limits are inadequate. Lower detection limits must be established. In conjunction with increased sampling frequencies and testing for a range of specific PCB congeners, lower detection limits will facilitate calculation of reliable PCB loading estimates that are needed for the applications noted above.

Finally, a shift from the current piece-meal approach to monitoring, research, and management of PCBs and other contaminants in the Detroit River-Western Lake Erie Basin to a more systematic, integrated approach will require increased funding and more coordination. One option for accomplishing this goal is to increase the visibility and support of the Monitoring Upper Great Lakes Connecting Channels Committee (MUGLCCC) under the auspices of the Four Party Agreement (U.S. Environmental Protection Agency, Environment Canada, Michigan Department of Environmental Quality, and Ontario Ministry of the Environment). MUGLCCC could work with the Lake Erie Millennium Plan to coordinate monitoring, research and management efforts directed at understanding and protecting the Detroit River - Lake Erie ecosystem. The Lake Erie Millennium Plan has established a strong foundation of successful workshops and conferences that foster coordination of research. The Plan is an excellent example of a binational, collaborative effort that has helped to identify and solve basic ecological questions relevant to the Lake Erie ecosystem.

Workshop participants strongly supported this unique effort to bring together scientists, engineers, modelers and program managers at one time and location for the purpose of sharing information, insights, concerns and ideas to help guide future management of the Detroit River-western Lake Erie basin. The recommendations and advice developed at this workshop will next be communicated to partners and stakeholders throughout the basin. It is hoped that these results will lead to an integrated strategic plan for remediation of known hot spots, more comprehensive and coordinated monitoring of the basin, improved understanding of how remediation efforts have impacted the local ecosystem, and perhaps most importantly, future bi-national workshops and investigations of this nature in support of effective monitoring, modeling and management programs.

Major Findings and Recommendations

Among the major findings identified during the workshop are the following:

- In general, long-term monitoring data indicate that significant declines in PCBs have occurred in the atmosphere, water, sediment and biota of the Detroit River and western basin of Lake Erie since the 1970s. There is limited evidence to suggest further improvements in PCB contamination levels within these systems have occurred during recent years.

- The long-term monitoring of herring gull eggs has provided one of the most complete and consistent data bases for assessing PCB levels and ecosystem trends within the Detroit River-Western Lake Erie basin. PCB concentrations in herring gull eggs collected from sites in the Detroit River and Western Lake Erie have exhibited a significant decline since the mid-1970s. Other primary data bases for fish and sediment also indicate long-term declines.

- Many ecosystem indicators have exhibited a consistent pattern of decline in PCB contamination within the upstream portion of the Detroit River. Several of these same indicators suggest less improvement has occurred in the lower River.

- The Detroit River continues to be a significant source of PCBs to Lake Erie. The Trenton Channel is the most contaminated area within the River system.

- Current programs for monitoring PCB sources are inadequate for developing reliable estimates of annual loadings to the Detroit River and western Lake Erie.

- Current funding and coordination of monitoring programs to help understand ecosystem function, assess the effectiveness of remediation, track ecosystem trends, and support development of comprehensive models are inadequate.

- An integrated monitoring, modeling, research and management plan is lacking for the Detroit River. The absence of a comprehensive plan for synthesizing information has inhibited decision-making and limited application of best management practices and best professional judgment.

- The cost of sediment remediation and disagreement on suitable disposal sites for dredged PCB-contaminated sediment remain major obstacles to the restoration of impaired beneficial uses in the Detroit River and at other locations within the Great Lakes basin.

- During 1997 and 1998, sediment remediation occurred in Evans Ditch and Newburgh Lake along the Rouge River. Over 313,000 m^3 of sediment was removed, representing an estimated 8,800 kg of PCBs. Follow-up analyses of PCBs in fish collected from Newburgh Lake during 2001 showed approximately an order of magnitude decline from levels documented prior to remediation. Such post-project monitoring is essential to document the efficacy of sediment remediation projects.

- Between 1993 and 2001 approximately $130 million was spent on 10 contaminated sediment remediation projects within the Detroit River/Western Lake Erie Basin. Total estimated volume of contaminated sediment removed was 843,500 m^3, representing an estimated 198 tonnes of PCBs. Michigan Department of Environmental Quality estimates that there remains approximately 2,293,500m^3 of sediment that impacts beneficial use impairments in the Detroit River, Rouge River, and River Raisin combined.

- Although recent remediation projects in the study area have removed a considerable amount of contaminated sediment, far-field ecosystem improvements could not be demonstrated or discerned from long-term data bases. However, evidence of improvements attributable to these projects may be more fully realized in the future. As was the experience with Newburg Lake (Rouge River, Michigan) noted just above, significant near-field improvements were observed in this system following remediation of PCB-contaminated sediment.

- Developing partnerships among all stakeholders will be essential for planning and implementing effective PCB cleanup programs in the future.

Important recommendations and advice developed during the workshop include:

- An integrated PCB monitoring program is needed to provide suitable data for calculating reliable loading estimates, evaluating short and long-term trends, supporting mass balance and ecosystem modeling efforts, as well as determining the effectiveness of specific remedial efforts from the standpoint of standards and de-listing criteria within the Detroit River-western Lake Erie basin. The monitoring program should include sampling of PCB levels in the atmosphere, sediment, water and biota at strategic locations, and should emphasize important loading sources and key indicators of ecosystem health, e.g., mayflies, fish, snapping turtles, and herring gulls.

- Control of contaminants (PCBs and other persistent bioaccumulative toxic substances) at their source remains a primary imperative for action.

- Improved monitoring is needed to calculate reliable estimates of PCB loadings to the Detroit River, especially loadings from the Detroit Water and Sewerage Department (DWSD). Improvements should include increased sampling frequency, testing for different PCB congeners, and lower detection limits. A detection limit of 1 nanogram per liter (1 ηg/L) is recommended for measuring the concentration of total PCB. When PCB loading estimates are based on testing for different congeners, the "method detection limit (MDL)" for each congener should be used.

- Expansion of the Integrated Atmospheric Deposition Network (IADN) to include a satellite station within the Detroit River-western Lake Erie basin should be considered. The additional station would provide locally-specific data for estimating atmospheric PCB loadings to the area.

- Greater effort is needed to analyze and interpret ecosystem changes and trends as suggested from available monitoring data. Trend analyses are critically important for gaining an improved understanding of ecosystem dynamics, identifying cause-effect relationships and strengthening model frameworks, as well as evaluating the long-term impact of management programs on water, sediment and biota within the basin.

- Continued support should be provided to the Great Lakes Institute at the University of Windsor to sustain its monitoring and modeling programs focused on contaminant loadings and ecosystem changes within the Detroit River-western Lake Erie basin.

- Significantly increased funding and coordination of monitoring is needed to develop and sustain a central repository for databases supportive of ecosystem modeling, research and management. The visibility and support of the Monitoring Upper Great Lakes Connecting Channels Committee should be increased and the Committee should assume responsibility for coordinating surveillance and monitoring of the basin. This step would improve the overall efficiency of current and future monitoring programs and would result in an improved scientific foundation for ecosystem-based management.

- There is a need to develop and support creative new modeling approaches that take advantage of limited data bases and existing monitoring programs to provide “best available” estimates of ecosystem health. Results of concomitant uncertainty limits and sensitivity analyses could then be used as prescriptive tools to forecast where additional data would most contribute to our understanding of Detroit River conditions and dynamics.

- Hotspots of contaminated sediments remain within the Detroit River-western Lake Erie basin and are contributing to many beneficial use impairments. Although some success has been achieved through sediment remediation projects within the basin, higher priority must be placed on remediation of known contaminated sediment hot spots within a comprehensive remediation framework.

- A protocol for funding PCB remediation projects should be established, including a rule mandating that a fixed percentage of overall project expenditures be set aside for short and long-term post-project monitoring. This “tax” on project expenditures would exclusively support monitoring to assess project effectiveness and provide data for evaluating ecosystem response, establishing trends, and enhancing modeling research.

- As our understanding of PCB contamination levels, remediation projects and ecosystem dynamics improves, a strategy is needed to articulate this knowledge and effectively share important lessons and insights with all partners and stakeholders.

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Sandra George – Environment Canada 2
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INTRODUCTION AND BACKGROUND

The Detroit River-western Lake Erie basin has historically suffered from problems of toxic contamination and ecosystem degradation due to a complex network of pollution sources located within this intensively-urbanized region. Impairments of beneficial uses in the area are well-documented, and a number of remediation activities have been undertaken to address local contamination problems (Detroit River RAP; Lake Erie LaMP). The State of the Great Lakes (2001) Report states that concentrations of PCBs remain high in the Western Basin of Lake Erie. Ecosystem changes in this part of Lake Erie are occurring rapidly while resources to monitor and effectively track them are diminishing. The report emphasizes that more research is needed to understand ecosystem changes, including the cause-effect relationships which govern them.

The National Coastal Condition Report (USEPA, 2001) has characterized the benthic condition of the Great Lakes nearshore waters as poor. The Report notes that the U.S. Environmental Protection Agency's Great Lakes National Program Office has determined that polluted sediments are the largest major source of contaminants to the Great Lakes food chain. Over 2,000 miles (20%) of the Great Lakes shoreline are considered impaired because of sediment contamination, while fish consumption advisories remain in place throughout the Great Lakes. The Report states that chemical contamination and related fish consumption advisories is one of the most significant problems facing the Great Lakes region. Fish consumption advisories have been issued for a total of five pollutants (mercury, mirex, chlordane, dioxins and PCBs). Most of the advisories (48%) have been issued for PCBs).

The National Coastal Research and Monitoring Strategy (USEPA, 2000) and the National Coastal Condition Report (USEPA, 2001) have collectively identified the importance of monitoring, modeling and research in terms of developing an effective national strategy for protecting nearshore ecosystems. The former report states that:

- "Monitoring provides information on the condition and changes in the levels of environmental properties. By comparing the patterns of the spatial and temporal distributions of different properties, monitoring results can be used to evaluate the relationships among various properties and, thus, establish hypotheses regarding the cause-effect relationships among these properties."

- "Monitoring is crucial to documenting status and assessing trends, evaluating the cause-effect relationships between stressors and impacts, and assessing the effectiveness of management actions. Research is an important part of environmental monitoring and is particularly important for improving our ability to interpret monitoring data, and improving our assessment capability. Additionally, research is key to predicting impacts as a result of emerging trends and to forecasting and assessing the impacts and benefits of management actions."

In recognition of findings and recommendations set forth in the aforementioned reports and in response to a need for integrating and understanding important information and insights gained from historical monitoring, modeling and management activities focused on PCB contamination within the Detroit River-Western Lake Erie basin, a workshop was held on June 18th and 19th of 2002 at the Great Lakes Institute in Windsor, Ontario. The workshop brought together approximately fifty international experts to present the results of their research and investigations pertaining to PCB monitoring, trends, loadings, remediation and related ecosystem effects within the basin over the past twenty years. The purpose of the workshop was to develop an improved understanding of how PCB contamination and historical remediation projects within this region have impacted the local ecosystem, and to develop a set of critical findings and advice to help guide future monitoring, modeling and management.

On the first day of the workshop, nineteen speakers presented papers summarizing results of their research on a variety of topics related to PCB loadings and ecosystem effects in the Detroit River-western Lake Erie basin. On the second day these same experts, along with an additional thirty scientists, engineers, and program managers familiar with past and present technical issues related to PCBs in the study area, divided into three separate groups to discuss information presented the previous day and to develop a set of findings and recommendations as noted above. This report contains an overview and summary of these findings and recommendations, along with a set of the extended abstracts prepared by the individual speakers (Appendices 3 - 21).

It is hoped that the information contained in this report will be helpful in designing and implementing practical, cost-effective strategies for better understanding and managing PCBs in the Detroit River-western Lake Erie basin. The workshop was intended to address and characterize much of what has been learned and accomplished through a broad range of studies and projects over the past several years, as well as identify what information gaps and critical needs still remain.

ORGANIZATION OF INFORMATION

The workshop produced a large number of findings and recommendations pertaining to a broad range of important issues on the subjects of monitoring, modeling and managing PCBs within the Detroit River-western Lake Erie basin. It is not the purpose of this report to attempt to prioritize or rank these findings and recommendations based upon their perceived relative importance. Such an undertaking is beyond the scope of the investigation and would detract from the critical guidance and advice developed through workshop deliberations. Furthermore, an attempt has been made to capture and fairly reflect both the “good news and the bad news” that was presented at the workshop, thereby providing a fair and balanced assessment of PCB contamination and ecosystem impacts within the region.

The following sections of the report highlight the important observations, major findings, and key recommendations and advice from speaker presentations, extended abstracts, and deliberations within each breakout session. Although some limited background is provided to assist in understanding the context of each major finding and recommendation, details of the underlying research and data which serve as their foundation cannot be provided in the main body of the report. However, many are linked to a specific extended abstract contained in the appendices of this report. These abstracts typically offer more detail and in-depth discussion of individual issues and topics related to PCB contamination of the local ecosystem. For those instances in which a key observation or recommendation was developed during one of the breakout sessions conducted on the second day of the workshop, no reference to a specific abstract is provided. Rather, its origin is designated by the name of the breakout session.

Results have been organized and presented according to the following format:

Important Observations and Major Findings

- Monitoring
    - Sources and Loadings
    - Ecosystem Response
    - Remediation Assessment
    - Funding and Coordination
    - Other Observations
- Modeling and Research
- Management
    - Problem Areas and Case Studies
    - Understanding and Communicating Success

Key Recommendations and Advice

- Monitoring
    - Sources and Loadings
    - Ecosystem Indicators
    - Remediation Assessment
    - Coordination and Support
- Trends and Ecosystem Understanding
- Modeling: Benefits and Needs
- Management
    - Remediation
    - Coordination and Support
- Sharing Information and Communicating Success

It should be emphasized that the order in which findings and recommendations are presented in this report does not imply their relative importance, but rather provides a logical framework for grouping information and discussing insight and advice developed by workshop participants. All of the information presented at the workshop was carefully reviewed and an attempt made to identify and articulate a set of fundamental or "core" findings and recommendations reflecting the collective opinion of those present. Each of these has been highlighted below along with a set of supporting findings and recommendations.

Summary of Workshop Results

1. Important Observations and Findings

1.1 Monitoring

As noted earlier in this report, the National Coastal Research and Monitoring Strategy (USEPA, 2000) has identified the importance of monitoring for developing an effective national strategy to protect nearshore ecosystems. Information on the temporal and spatial distributions of PCBs and other contaminant levels in water, sediment and biota of the Detroit River-western Lake Erie basin is essential for understanding and managing the local ecosystem. Monitoring data bases support a number of different objectives including calculation of reliable loading estimates, evaluating the success of remediation efforts, characterizing and interpreting trends to improve our understanding of long-term ecosystem changes, defining cause-effect relationships needed to refine model frameworks, calibrating and validating models applied for planning and management, as well as identifying emerging problems within the basin.

Several of the papers presented at the workshop emphasized the importance of a comprehensive, coordinated monitoring program as a core component of an overall PCB management strategy for the study area. In addition, participants in the individual breakout sessions conducted on the second day of the workshop identified a number of key observations pertaining to the issue of monitoring. Following is a summary of those findings/observations within specific areas of emphasis.

1.1.1 Sources and Loadings

The Detroit River continues to be a significant source of PCBs to Lake Erie. The Trenton Channel is the most contaminated area within the River system.

- This finding was highlighted during the Management Breakout Session and was also emphasized by Marvin et al. [Appendix 8].

- Mass balance analysis of PCBs in surficial sediment of the Detroit River shows that the region located downstream of the Trenton Channel, which represents just under 17% of the total sediment surface area for the river, contains approximately 62% of the total PCB mass. [Drouillard and Haffner, Appendix 20]
- PCB-enriched sediments downstream of the Trenton Channel are susceptible to periodic resuspension events. Thus the area containing the highest mass and concentration of PCBs within the Detroit River poses a significant risk of contributing a pulse loading of contamination to Lake Erie during extreme storm events, i.e., those equivalent to or exceeding a 20-year storm event. [Reitsma, Appendix 21]

PCB loadings to the Detroit River have decreased substantially since their ban in 1977. However, sufficient data are not available to determine whether loadings have continued to decrease in recent years.

- This important observation was noted by members of the Monitoring Breakout Session and by several other speakers and workshop participants.

Current programs for monitoring PCB sources are inadequate for developing reliable estimates of annual loadings to the Detroit River and Western Lake Erie.

- A large gap exists in data needed to develop accurate estimates of upstream PCB loadings for the Detroit River-western Lake Erie basin, including contributions from individual tributaries. [Modeling and Research Breakout Session]
- Compliance monitoring (i.e., self-monitoring at end-of-pipe to meet NPDES permit requirements) does not provide suitable data for calculating reliable loading estimates for PCBs and other organochlorine compounds. [Monitoring Breakout Session]
- Information currently being collected for characterizing sources and loadings of PCBs to the Detroit River is incomplete and out of date. The existing system of using monthly operating data intended to assess permit compliance is ineffective for calculating reliable estimates of annual PCB loadings. [Dolan, Appendix 4].
- PCB concentrations measured in effluents and tributaries to Lake Erie between 1986 and 1999 are considered inadequate for computing PCB loadings. Concentrations consistently fall below the reporting limit for PCBs. [Painter, Appendix 3]

- Available data for estimating point source loadings of PCBs to the Detroit River is more limited and less useful now than in the past. Load calculation methods applied in 1986 were able to take advantage of lower detection limits for specific PCB congeners. As of the year 2000, the Detroit Water and Sewerage Department (DWSD) only reported total PCB concentrations in their wastewater effluent (as opposed to concentrations of specific congeners). The relatively high detection limit for total PCBs contributes to a very high percentage of "non-detect" observations in the available data base. While analytical detection limits have increased, the frequency of effluent sampling at DWSD has declined in recent years. This combination of circumstances now limits effective application of load estimation methods used in past years. As a result, point source loadings of PCBs to the Detroit River have not been estimated since 1997. [Dolan, Appendix 4]

There has been a general decline in atmospheric concentrations of PCBs near each of the Great Lakes over the past decade. It appears that PCB concentrations in the air may be approaching equilibrium.

- This finding was based on analysis of data collected at a number of atmospheric background stations and urban satellite stations located within the U.S. portion of the Great Lakes Basin. These stations are part of U.S. EPA's Integrated Atmospheric Deposition Network (IADN). [Nettesheim, Appendix 5]

1.1.2 Ecosystem Response

Long-term monitoring data indicate that significant declines in PCBs have occurred in water, sediment and biota of the western Basin of Lake Erie since the 1970s.

- This finding was highlighted during both the Monitoring Breakout Session and the Management Breakout Session. Several of the speakers provided supporting information.
- Lake-wide concentrations of PCBs in Lake Erie sediments have declined significantly since the 1970s, especially in the Western Basin. PCB concentrations in sediment

cores have dropped by as much as 80 percent at some locations. [Painter and Marvin, Appendix 7]

- Assessment of temporal trends in sediments of Lake Erie indicates that PCB loadings to the Lake have decreased significantly over the past fifteen years. [Painter, Appendix 3]
- PCB concentrations in walleye predominantly inhabiting the western basin of Lake Erie were much lower in 2001 as compared to the late 1970s. [Whittle, Appendix 15]
- Body burdens of PCBs in smelt collected from Western Lake Erie since 1977 exhibited a rapid and consistent increase from 1985/86 through 1990. They have since decreased from their peak level of approximately 0.76 ug/g in 1990. Over the past several years body burdens of PCBs in smelt have remained at levels averaging approximately 0.10 μg/g. [Whittle, Appendix 15]

The long-term monitoring of herring gull eggs has provided one of the most complete and consistent data bases for assessing PCB levels and ecosystem trends within the Detroit River-western Lake Erie basin. PCB concentrations in herring gull eggs collected from sites in the Detroit River and Western Lake Erie have exhibited a significant decline since the mid-1970s.

- This was a consensus finding of the Management Breakout Session members.
- Herring Gull eggs collected from up to fifteen sites throughout the Great Lakes basin between 1974 and 2001 were analyzed to evaluate temporal trends in PCB levels. Two of these sites were located in the Detroit River-western Lake Erie region: one at Fighting Island in the Detroit River and one at Middle Island in the western basin of Lake Erie. PCB concentrations in eggs from Fighting Island exhibited a significant declining trend from 1978 to 1996. No significant change occurred between 1996 and 2001. A similar trend was observed between 1974 and 2001 in eggs from Middle Island. [Weseloh, Appendix 18]
- Between 1978 and 2001, PCB concentrations in herring gull eggs from Fighting Island declined by 77 percent. Concentrations in eggs from Middle Island declined by 66 percent between 1980 and 2001. [Weseloh, Appendix 18]
- PCB levels in herring gull eggs from the Detroit River and Western Lake Erie were higher in 2001 than levels at all other locations from which eggs were collected with the exception of Channel-Shelter Island in Saginaw Bay. [Weseloh, Appendix 18]
- Ecosystem improvement within the study area has been evident from increased breeding populations of colonial waterbirds, notably cormorants and gulls. It is unclear whether this improvement is due to declining PCB levels or declines in concentrations of other chemical compounds. [Weseloh, Appendix 18]

Water concentrations of PCBs in the Detroit River have decreased since the 1970s. Concentrations in fish and herring gull eggs have also declined during this period. There is little evidence to suggest further improvements in PCB contamination levels within the Detroit River have occurred during recent years.

- Although PCB concentrations in Detroit River water have exhibited a decrease since the 1970s, the sediment of the River has not. In spite of clear evidence that conditions have improved, localized contamination problems remain. [Modeling and Research Breakout Session]
- Average PCB concentrations in Detroit River water have not changed during the past five years [Drouillard and Haffner, Appendix 20]
- Comparison of biomonitoring data at two Detroit River locations indicates that PCB concentrations in biota of the Detroit River have not changed over the past fifteen years [Drouillard and Haffner, Appendix 20]
- PCB concentrations in fish tissue from the Detroit River do not show an obvious trend or change from historical levels. [Ostaszewski, Appendix 11]
- Monitoring data collected within the Detroit Area of Concern (AOC) since 1993 by MDEQ indicate that PCB concentrations vary widely in water, sediments and fish.
- Benthic fish species from the Detroit River exhibit high levels of PCB congeners in their tissue. Specific PCB congeners have been measured in a growing number of species. These chemicals have been shown to elicit biological and toxicological effects in exposed organisms. [Letcher and Li, Appendix 17]
- Forty six percent of biota samples (including forage fish and benthic invertebrates) collected from the Detroit River and western Lake Erie near Middle Sister Island exceeded the IJC PCB tissue residue objective for the protection of fish-consuming birds and wildlife (0.100 mg/kg wet wt.). [Drouillard and Haffner, Appendix 20]
- Investigation of the impact of PCBs on snapping turtles in the lower Great Lakes showed that adult turtles live-trapped in three AOCs (St. Clair; the Detroit River; and Wheatley Harbour) exhibited poorer hatching success than those at two reference sites (Tiny Marsh and Algonquin Park, ON). Turtles captured within the Detroit River were the exception, exhibiting higher hatching success than those at all other sites. There were no differences among the AOCs in terms of hatchling survival. The rate of hatchling deformities at AOC sites was comparable to that at reference sites, with approximately 26% of snapping turtle hatchlings exhibiting some kind of deformity. [Fernie, Appendix 19]
- The reproductive success, development of young, and some physiological endpoints and morphology of adult male snapping turtles differs between AOC sites and reference sites. [Fernie, Appendix 19]
- Concentrations of PCBs were significantly higher in caddisflies collected from Detroit River sites than in reference sites along the Ausable and Gull rivers in Ontario in 1988. PCB concentrations in caddisflies from the Detroit River were also significantly greater than those from the St. Clair River (1987-90). A comparison of body burdens of PCBs in insects from the Detroit River revealed levels to be

significantly higher in organisms collected from the U.S. side of the river in1989. [Corkum , Appendix 14]

- Laboratory sediment dilution bioassays conducted in 1991 showed that the concentration of PCBs and other contaminants in Trenton Channel sediments was four times greater than that needed for Hexagenia mayfly survival to emergence. [Corkum, Appendix 14]
- Body burdens of PCBs in Hexagenia adults collected in 1994 exhibited a gradient of decreasing concentration from east (closest to the Detroit River) to west (farthest from the Detroit River). [Corkum, Appendix 14]

Many ecosystem indicators have exhibited a consistent pattern of decline in PCB contamination within the upstream portion of the Detroit River. Several of these same indicators suggest significantly less improvement has occurred in the lower River.

- This finding was identified during the breakout session on Modeling and Research.

1.1.3 Remediation Assessment

Comprehensive, coordinated monitoring is fundamental to the success of research, modeling and remediation efforts focused on PCB contamination within the region.

- This finding was highlighted during the Research and Modeling Breakout Session and is consistent with conclusions reached by several workshop presenters and participants.
- During 1997-1998 sediment remediation occurred in Evans Ditch and Newburgh Lake along the Rouge River. Over 313,000 m^3 of sediment was removed, representing an estimated 8,800 kg of PCBs. Follow-up analyses of PCBs in fish collected from Newburgh Lake during 2001 showed approximately an order of magnitude decline from levels documented prior to remediation. Such post-project monitoring is essential to document the efficacy of sediment remediation projects. [Murray and O'Meara, Appendix 12]

- The PCB cleanup effort at Fraleigh Creek on the Ottawa River demonstrated the importance of a comprehensive pre-project monitoring program to accurately characterize sediment deposition and composition, as well as the health of resident ecological communities. The information obtained from pre-project monitoring provides an important baseline from which the effectiveness of subsequent remedial actions can be judged. The information also helps identify pollution sources early in the process, thereby facilitating their elimination or control prior to implementation of sediment remediation activities. [Czeczele, Appendix 10]
- Model projections are used to support management decisions, yet there is little follow-up monitoring to effectively evaluate the impact of those decisions.[Research and Modeling Breakout Session]
- Sufficient data are lacking to conclude that any decrease in fish tissue concentrations of PCBs in walleye from western Lake Erie is directly attributable to remediation efforts on the Detroit River.[Hickey et al., Appendix 16]
- Studies of PCB concentrations in carp and largemouth bass from several locations along the Detroit River were undertaken to assess the effect of remediation projects completed in 1997/98. Although the drop in PCB levels in fish was less than expected following remediation projects, the full effect of these efforts has probably not yet been seen. [Hickey et al., Appendix 16]

1.1.4 Funding and Coordination

Current funding for coordination and support of monitoring programs to help understand ecosystem function, assess the effectiveness of remediation measures, track ecosystem changes, and support development of improved modeling frameworks, is inadequate.

- Generally there is inadequate commitment of resources to support monitoring programs needed to assess the effectiveness of PCB remediation programs. The percentage of overall project expenditures allocated for follow-up monitoring is small, making it difficult to reliably assess ecosystem response attributable to remediation efforts. [Monitoring Breakout Session]
- Current funding to support monitoring and modeling of PCB loadings and ecosystem impacts is inadequate. If even a small fraction of overall expenditures on remediation projects were routinely set aside for monitoring and modeling efforts, it would likely be enough to achieve significant improvement in the evaluation of management actions and the reliability of models which are used to help design those actions. [Research and Modeling Breakout Session]
- Responsibilities for designing and operating monitoring programs within the Detroit River-western Lake Erie basin are not clearly defined at present. There remains

uncertainty and confusion as to what organization(s) should assume a leadership role for coordination of monitoring activities and what type of monitoring is needed to meet specific management objectives. [Monitoring Breakout Session]

1.1.5 Other Observations

- Contaminant analysis of adult aquatic insects can complement monitoring of other ecosystem indicators (water, sediment fish, birds) to track the presence and distribution of toxic substances within the Great Lakes basin. [Corkum et al., Appendix 14]
- Monitoring protocols for PCBs are currently inadequate; standardization of sampling procedures is lacking. Limits of detection should be at least as sensitive as the lowest effect level guidelines for the protection of biota. [Monitoring Breakout Session]
- There is a lack of understanding as to who or what organizations are using monitoring information, as well as how that information feeds into the decision-making process and design of specific management actions. [Monitoring Breakout Session]

1.2 Modeling and Research

Mathematical models provide a crucially important tool for integrating data, improving our understanding of fundamental cause-effect relationships within complex ecosystems, evaluating management scenarios to assist in decision-making processes, communicating information to technical and non-technical audiences, and helping to identify critical areas for future research. Models have historically played a vital role in developing cost-effective strategies to manage the Great Lakes. Past successes in modeling the Lakes have helped to expand our knowledge of their expected response to a range of environmental stressors. However, more recent threats to the Great Lakes, including toxic contamination, introduction of non-indigenous species and loss of habitat, reveal a critical need for additional research to refine and expand existing model frameworks and further our understanding of key inter-relationships within the ecosystem. Effective programs to manage the future health of the Great Lakes must be based upon quantitative decision-making tools representing the best possible state-of-knowledge, and there is an obligation to advance that state-of-knowledge as new problems emerge within the local ecosystem.

In recognition of this important issue as it pertains to the Detroit River-western Lake Erie ecosystem, workshop participants identified a series of major findings to be highlighted in this report. These are presented below together with additional observations related to each.

Models are important and necessary tools for integrating research, monitoring and management information; evaluating expected outcomes of management decisions; and communicating our understanding of fundamental ecosystem relationships to all partners and stakeholders.

- This observation was emphasized by all participants in the Modeling and Research Breakout Session and was further acknowledged as a consensus finding of the workshop.

PCBs receive strong emphasis in developing models of ecosystem processes and relationships, yet these same model frameworks can be adapted for application to other compounds as well. This is especially important and helpful given that persistent chemicals are likely to pose a threat to the ecosystem long into the future.

- This finding was also highlighted during the Modeling and Research Breakout Session of the workshop.

Additional observations identified during the Modeling and Research Breakout Session of the workshop include the following:

- Application of existing models strongly indicates that PCB and other contaminant loadings to the Detroit River-western Lake Erie system are being significantly underestimated. For example, PCB concentrations in water samples from the Trenton Channel are three to four times greater than those in water samples from other parts of the Detroit River. These high concentrations are not consistent with expected loadings from contaminated sediments given the high flow rates within this channel and the very slow desorption kinetics of PCBs from contaminated particles. Assuming contaminated sediments were the only source of PCB loadings in this location, preliminary calculations indicate that the mass of PCBs needed to sustain measured water concentrations would result in sediment decontamination within a matter of months. Given the high PCB concentrations present in sediments from the lower Trenton Channel, it appears that other direct sources of PCBs must still be contributing to contamination of the area.

- Detroit River sediments are extremely transient as a result of storms and other stochastic events. Present efforts to quantify PCB loadings from sediment consider only the upper 20 cm of material. Surface sediments are continuously eroded and re-deposited, resulting in the continued re-contamination of Detroit River sediment.

Other findings of significance to improved ecosystem understanding and future research:

- Studies of Hexagenia nymphs collected in sediments from the Detroit River-western Lake Erie region indicate that zoobenthos are potentially a major source of contaminant transfer through the food web. Data are now available to develop spatially-explicit estimates of PCB transfers from zoobenthos to top predators. Because zoobenthos are immobile, these estimates will provide important spatial resolution and serve as a complement to more integrative measures, e.g., contaminant estimates for fish tissues and bird eggs. [Ciborowski et al., Appendix 9]

- The potential for mobilization of sediment-bound PCBs and subsequent contaminant transfer through the food web is significant. The mass of PCBs exported from the surface sediments of Lake Erie by emerging adult Hexagenia is equivalent to 20 to 50% of the annual aerial deposition. However, most of the PCB mobilization by adult insects occurs within a brief period during the summer. [Corkum et al., Appendix 14]

- There is evidence to suggest that invasion and proliferation of non-indigenous species in the U.S. and Canada has resulted in a redistribution of contaminants within the system and a consequential increase in PCB levels measured within local fish communities. As a result, the effectiveness of upstream remedial actions to reduce PCB loadings cannot be fairly judged. Changes in the form and function of local biological communities, triggered by invasion and proliferation of nuisance exotic species, contributed to a spike in PCB levels measured in various components of the western Lake Erie fish community. However, subsequent declines in PCB concentrations to the lowest levels ever measured in different trophic levels of the western Lake Erie fish community strongly suggests that a reduction in available PCBs has occurred over the most recent time period. [Whittle, Appendix 15]

1.3 Management

Historical efforts to identify and address environmental problems within the Great Lakes Basin provide a template for effective ecosystem management throughout the world. The boundaries of the Detroit River-Western Lake Erie basin contain four Areas of Concern (AOCs) where one or more beneficial uses of the local ecosystem have been impaired. Remedial Action Plans (RAPs) are under development which encourage participation of all local stakeholders, thereby helping to design and implement remediation programs which reflect broad input from affected parties. Lakewide Management Plans (LaMPs) are under design to complement local RAPs by identifying larger scale or whole-lake problems where effective remediation depends upon communication and collaboration among a range of jurisdictions, agencies, groups and individuals. Although much has been accomplished as a result of these efforts within the Great Lakes Basin, it is clear that successful management in the future will depend on our ability to learn from past successes and mistakes, to continually improve our understanding of a constantly changing ecosystem, to continue to work cooperatively toward cost-effective solutions, and to maintain a surveillance system capable of early detection of emerging problems.

Recent efforts to manage PCB contamination at several locations within the Detroit River-western Lake Erie basin were discussed at the workshop. Following are some of the key findings which were highlighted by speakers and by participants in the three breakout sessions.

1.3.1 Problem Areas and Case Studies

Disposal of PCB-contaminated sediment continues to be a major obstacle to the restoration of impaired beneficial uses in the Detroit River and at other locations within the basin.

- This finding was highlighted during the Management Breakout Session and was noted by several of the speakers and other workshop participants.
- Between 1993 and 2001, approximately $130 million was spent on sediment remediation projects within the Detroit River-western Lake Erie basin. The estimated volume of contaminated sediment removed as a result of these projects is just under 850,000 m^3. The mass of PCBs removed as a result of these same projects is estimated at just under 200,000 kg (200 tonnes). The mass of PCBs removed as a result of contaminated sediment remediation projects during this period is roughly two orders of magnitude greater than the mass of PCBs removed as a result of navigational dredging of shipping channels. [Hartig, Appendix 6].
- Deep burial of geographically-dispersed contaminated sediment may be the only option for managing this distributed source of PCBs. In localized areas where PCB

contamination of soil and sediment is high, the Lake Erie LaMP recommends more specific remediation programs be implemented. [Painter, Appendix 7].

- In 1998, approximately 27,000 cubic yards of contaminated sediment was removed from the River Raisin. Portions of the remediated area have now been re-contaminated. Approximately 0.5 million cubic yards of contaminated sediment remain in the River Raisin. [Ostaszewski, Appendix 11]
- Approximately 450,000 cubic yards of contaminated sediment were excavated from Willow Run Creek (a tributary to the Huron River) in 1977-78. The sediment removed was subsequently de-watered and buried on-site. Because the source of PCB contamination to these sediments has been removed, sediments have not experienced re-contamination to date. [Ostaszewski, Appendix 11]
- Approximately 3 million cubic yards of contaminated sediment remain in the Detroit River, Rouge River, and River Raisin combined. These sediments presently impact beneficial uses of the water. [Ostaszewski, Appendix 11]
- The Newburgh Lake Restoration Project, completed in 1998, was designed to remove PCBs in order to restore beneficial use of the lake. To achieve acceptable levels of risk, approximately 350,000 tons of contaminated sediment were removed and placed in a Type II landfill. In addition, 30,000 pounds of contaminated rough fish were eradicated and removed. These measures helped in eliminating existing fish populations exhibiting high levels of PCB contamination, while at the same time eliminating contaminated sediments posing a risk to newly-stocked game fish. Subsequent fish assessments for Newburgh Lake indicate that all fish species stocked in the lake have adapted well and are in good visual health. MDEQ collected fish for PCB analysis in the fall of 2001. Results show that fish tissue concentrations have dropped by nearly an order of magnitude from levels measured prior to the remediation project. Follow-up monitoring of sediments has shown non-detectable concentrations of PCBs. [Murray and O'Meara, Appendix 12]
- Investigation of recent PCB contamination problems within the canal and Ten-Mile Drain System in St. Clair Shores confirmed the presence of PCBs throughout. Inspection of storm and sanitary sewers using video cameras suggests that PCB-containing materials may have entered sanitary sewers via infiltration associated with seeps and/or leaky joints in local storm sewers. [El-Zein, Appendix 13]

1.3.2 Understanding and Communicating Success

Developing partnerships among diverse interest groups will be essential for planning and implementing successful cleanup programs in the future. Such partnerships tend to be more efficient and cost-effective than independent, uncoordinated efforts conducted by individual organizations. Partnerships ensure that the concerns of all parties are voiced and addressed under the same decision-making framework.

- This finding was emphasized in the discussion of PCB management efforts on Fraleigh Creek [Czeczele, Appendix 10] and was also noted by several other workshop participants.

2. Key Recommendations and Advice

Speakers at the PCB workshop were asked to formulate one or more recommendations which would help guide future efforts to understand and manage the Detroit River-western Lake Erie ecosystem. In addition, members of the three breakout sessions were asked to develop a set of major recommendations based on the knowledge, experience and insight of those present. Following are the core recommendations highlighted at the workshop.

2.1 Monitoring

2.1.1 Sources and Loadings

Current monitoring programs to evaluate PCB sources and loadings within the Detroit River-western Lake Erie basin need to be significantly expanded and improved in order to provide essential data for: calculating reliable loading estimates, evaluating impacts of historical remediation efforts, understanding short and long-term ecosystem trends, and refining modeling frameworks applied for management and decision-making.

- This recommendation was voiced by several of the workshop participants and was a consensus opinion within each breakout session.

- To support computation of reliable PCB loading estimates, methodologies endorsed by technical experts in the field should be applied. To insure that suitable data bases are available for application of these methodologies, monitoring programs must be designed to incorporate lower detection limits, quality assurance/quality control protocols for specific PCB congeners, and sampling frequencies which yield suitable data to meet reliability objectives. [Hartig, Appendix 6]
- Weekly rather than monthly sampling of PCBs in the wastewater effluent from DWSD should be maintained in the future. Chemical analyses should be conducted to identify and report concentrations of specific PCB congeners as opposed to total PCBs. Estimates of annual PCB loadings from DWSD and other point sources discharging to the Detroit River should then be calculated using methods applied in previous years, i.e., methods which sum contributions of different PCB congeners to arrive at an overall loading estimate for total PCBs. These estimates should then be compared with upstream /downstream sampling results to establish their consistency with observed PCB concentrations along the Detroit River. Adoption of this recommendation is crucial in order to provide sufficient data for calculating reliable estimates of annual PCB loadings to the Detroit River. [Dolan, Appendix 4]
- Based on findings from the Lake Michigan Mass Balance and Hudson River Remediation studies, a detection limit of 1 nanogram per liter (1 ηg/L) is recommended for measuring the concentration of total PCB. When PCB loading estimates are calculated based on a range of PCB congeners, the “method detection limit (MDL)” for each congener should be used. The MDL for individual congeners in ambient water should be approximately 0.005 ηg/L. The MDL for PCB congeners in tributaries to the Detroit River may be somewhat higher, e.g., 0.010 ηg/L. The MDL for point sources can be as high as 0.02 ηg/L. The final MDL value may be adjusted based on the volume of water collected. Some experimentation may be necessary to determine an appropriate MDL for specific congeners in different media. [Monitoring Breakout Session]

Expansion of the Integrated Atmospheric Deposition Network (IADN) to include an urban satellite station near Detroit should be considered.

- This recommendation was strongly supported during the breakout session on Monitoring. Session participants felt that an additional station strategically located within the study area would provide more locally-specific data, thereby resulting in more reliable atmospheric loading estimates.
- Existing satellite stations at St. Clair, MI and Pelee, ON currently provide important data for quantifying atmospheric loadings of PCBs in the general area [Nettesheim, Appendix 5]. However, the costs and benefits of at least one additional station located closer to Detroit and the Detroit River-western Lake Erie region should be examined.

2.1.2 Ecosystem Indicators

An integrated PCB monitoring program is needed to provide suitable data for calculating reliable loading estimates, evaluating short and long-term trends, supporting mass balance and ecosystem modeling efforts, as well as determining the effectiveness of specific remedial efforts from the standpoint of standards and de-listing criteria within the Detroit River-western Lake Erie basin. The monitoring program should include sampling of PCB levels in the atmosphere, sediment, water and biota at strategic locations, and should emphasize important loading sources and key indicators of ecosystem health, e.g., mayflies, fish, snapping turtles, and herring gulls.

- This was a consensus recommendation from participants in the monitoring breakout session.
- PCB concentrations in bottom-dwelling fish near industrialized areas like the Detroit River remain high in comparison to fish inhabiting the open waters of the Great Lakes. Monitoring of PCB levels (with emphasis on planar congeners) needs to be maintained in these problem areas to evaluate the full effect of recent remediation efforts. [Hickey et al., Appendix 16]
- The Lake Huron/Detroit River/western Lake Erie region provides an ideal setting for conducting future research on the impacts of PCBs and other contaminants. The herring gull monitoring program should continue as an effective means of tracking environmental impacts and trends attributable to these compounds. [Monitoring Breakout Session; Weseloh, Appendix 18]
- Estimates of PCB transfer from zoobenthos to top predators should be validated by appropriate monitoring. Collection of caddisflies and mayflies using light traps

provides an accurate and cost-effective approach for acquiring validation data essential for improving the precision of newly-developed models of sediment-based contaminant dynamics and bioaccumulation. [Ciborowski et al., Appendix 9]

Hotspots of PCB contamination in sediments and/or biota remain within the Detroit River-western Lake Erie basin. These hotspots should be identified so that monitoring programs can emphasize data collection that effectively characterizes temporal changes in contamination.

- This recommendation was formulated and supported by participants in the Monitoring Breakout Session.
- The design of monitoring programs should consider de-listing guidelines and criteria for Areas of Concern, thereby addressing data collection which is suitable for ascertaining restoration of impaired beneficial uses. [Monitoring Breakout Session]

2.1.3 Remediation Assessment

A strategic set of environmental parameters and ecological indicators should be identified and comprehensively monitored as a mandatory component of all sediment remediation projects.

- This recommendation reflects the content of workshop presentations [Hartig, Appendix 6] and feedback from the Monitoring Breakout Session.
- A strategic monitoring program for PCBs is needed to establish baseline loads and ecosystem conditions prior to implementation of remedial measures. Follow-up monitoring to assess the effectiveness of these measures should be coordinated with the baseline monitoring program to insure that the resulting data bases are compatible and sufficient for assessment purposes. [Monitoring Breakout Session]
- Post-project monitoring should place greater emphasis on ecological benefits and beneficial use restoration associated with sediment remediation projects. [Hartig, Appendix 6]

2.1.4 Coordination and Support

Significantly increased funding is needed to design, coordinate, and sustain an effective, integrated monitoring program focused on PCB loadings and ecosystem response within the Detroit River-western Lake Erie basin.

- Participants in the breakout session on Management expressed a concern over insufficient support for monitoring. The same concern was raised by several others attending the workshop.
- Monitoring within the study area should be coordinated with that conducted in other parts of the Great Lakes system. The Monitoring Upper Great Lakes Connecting Channels (MUGLCC) Committee should receive increased support for bi-national coordination of monitoring. [Management Breakout Session]
- An effort should be made to identify and fill critical gaps in monitoring of PCB loadings and associated ecosystem impacts. This effort should include consideration of new, innovative monitoring strategies which will further support and promote meaningful management of the local ecosystem. [Monitoring Breakout Session]
- Monitoring programs which have been in effect for several years should be maintained in the future to ensure a consistent set of data for evaluating historical trends in PCB contamination levels within the study area. Linkages to investigative monitoring (e.g., to identify PCB hotspots or to detect emerging chemicals of concern) and research to improve interpretation of contamination trends and effects should be strengthened. [Monitoring Breakout Session]
- Agencies involved in management of the Detroit River and Lake Erie should either increase the visibility of and support to the Monitoring Upper Great Lakes Connecting Channels Committee or establish a new task force or committee to oversee and coordinate surveillance and monitoring of the basin. Similar types of committees were established under the Great Lakes International Surveillance Plan. These committees were required to report every two or three years on monitoring activities throughout the Great Lakes region. During those years, monitoring of the basin received much greater emphasis as compared to today. The presence of a strong, active and effective monitoring committee would help gain increased support for future monitoring programs. The monitoring committee should be given a formal charge to design a detailed monitoring strategy for the study area, including justification for monitoring specific contaminant sources and appropriate ecosystem indicators. This strategy should incorporate an analysis of expected trade-offs between monitoring costs and expected benefits as it pertains to future management of PCBs within the basin. [Hartig, Appendix 6]
- Fundamental research, together with current understanding of existing frameworks for modeling PCBs, should be used to identify gaps in data provided by current monitoring programs. These data gaps should be communicated to managers and government officials in order to develop support for additional monitoring. [Monitoring Breakout Session]

- The Four Party Agreement needs to be strengthened to enhance coordination of monitoring and reporting of results. [Monitoring Breakout Session]

A protocol for funding PCB remediation projects is needed and should include a mandate that a fixed percentage of overall project expenditures be set aside for short and long-term post-project monitoring. This "tax" on project expenditures would exclusively support monitoring to assess project effectiveness and to provide data for evaluating ecosystem response, establishing trends, and enhancing modeling research.

- This recommendation was strongly endorsed by participants in the Monitoring Breakout Session.
- State/provincial/federal agencies responsible for sediment remediation projects should incorporate mandatory funding of post-project monitoring as part of all settlements and cooperative agreements. [Hartig, Appendix 6]

A mandate is needed to establish a strategic monitoring plan for the Detroit River-western Lake Erie basin. This plan should focus on PCB loadings and related impacts, as well as other contaminants and indicators which reflect the condition of the local ecosystem.

- This recommendation was developed by members of the Monitoring Breakout Session. The strategic monitoring plan should clearly specify:
  1. organizations responsible for support and coordination of monitoring;
  2. distinctions between monitoring efforts to meet different objectives, i.e., compliance monitoring, monitoring to support calculation of contaminant loadings, monitoring for assessment of remediation actions, monitoring to support model calibration and validation, and monitoring to evaluate ecosystem health and long-term trends;
  3. methods for maintaining and distributing data;
  4. protocols for trend analysis, interpretation, and communication.

2.2 Trends and Ecosystem Understanding

A comprehensive, integrated PCB project is needed to further develop our understanding of critical relationships among water, sediment, biota, storms and other factors that determine the fate and transport of PCBs and other contaminants within the local ecosystem. A significant financial commitment is needed to support and coordinate such an effort.

- This recommendation was strongly supported by members of the Modeling and Research Breakout Session. A good understanding of relationships between PCB loadings and ecosystem response is still lacking. A systematic modeling framework is needed to better define important ecosystem relationships. This framework should consider multiple stressors, not exclusively PCBs. [Modeling and Research Breakout Session]
- Rare events such as 100-year storms may have profound ecosystem effects, e.g., influencing PCB levels and distributions in the Detroit River-western Lake Erie basin. A framework is needed to anticipate and evaluate these effects under a range of possible scenarios, thereby assisting managers to better determine an appropriate response. More specifically, it is important to distinguish an ecosystem response that can be tracked to a manageable cause vs. a response resulting from a rare but natural cause. [Modeling and Research Breakout Session]

Additional recommendations set forth by members of the Research and Modeling Breakout Session include:

- It is inefficient to manage problems within the study area based on single issues. Future efforts should focus on design and implementation of management strategies at the ecosystem level.
- Historical trends in PCB levels within the Detroit River-western Lake Erie basin need to be rigorously analyzed to ensure their appropriate interpretation. Questions of reliability regarding the interpretation of trend information are linked directly to uncertainty in measurements and sample size. It is important to avoid "over interpretation" of data and trends by ignoring appropriate statistical protocols. A study is needed to help design a sampling strategy which reduces the uncertainty of trend information down to acceptable levels.

2.3 Modeling: Benefits and Needs

Further development and application of mass balance and ecological models is needed to assess relative PCB contributions from different sources and to predict ecological benefits resulting from specific remedial measures.

- This recommendation was developed by members of the Management Breakout Session and supported by a large majority of workshop participants.
- Data requirements for calibrating, verifying and applying such models need to be identified along with gaps in existing data bases. [Modeling and Research Breakout Session]
- Research should continue to pursue development of mathematical models that link PCB loadings and ecological response to introduction of non-indigenous species. Results from this research will help in the design of future management strategies and will support analyses of temporal trends in contaminant levels within different trophic levels of aquatic biota. [Whittle et al., Appendix 15]
- Models and the modeling process should be viewed as an essential component of monitoring, management and research activities. Models are a powerful tool for integrating information; understanding important ecosystem relationships, thereby helping to identify appropriate management strategies to meet specific goals and objectives; and defining data needs to achieve desired levels of reliability for interpreting ecosystem conditions and trends. [Modeling and Research Breakout Session]

Continued support should be provided to the Great Lakes Institute at the University of Windsor to sustain its monitoring and modeling programs focused on contaminants and ecosystem changes within the Detroit River-western Lake Erie basin.

- This recommendation was identified by members of the Management Breakout Session.

There is a need to develop and support creative new modeling approaches that take advantage of limited data bases and existing monitoring programs to provide "best available" estimates of ecosystem health. Results of concomitant uncertainty limits and sensitivity analyses could then be used as prescriptive tools to forecast where additional data would most contribute to our understanding of Detroit River conditions and dynamics.

- This recommendation was identified by members of the Modeling and Research Breakout Session.

2.4. Management

2.4.1 Remediation

Control of contaminants (PCBs and other persistent bioaccumulative toxic substances) at their source remains a primary imperative for action.

- This was a consensus recommendation from members of the Management Breakout Session and was also emphasized by several workshop participants.

Hotspots of contaminated sediment remain within the Detroit River-western Lake Erie basin and are contributing to beneficial use impairments. Although some success has been achieved through sediment remediation projects within the basin, higher priority must be placed on known contaminated sediment hot spots as part of a comprehensive remediation framework.

- This was a consensus recommendation from members of the Management Breakout Session and was endorsed by several of the workshop participants.
- At each of these locations, the following steps and/or questions should be addressed:
  1. Is the area an active source of PCBs?

2. What site-specific remedial actions should be considered (and avoided) based upon the unique characteristics of the area?
3. What is the existing level of risk and expected reduction in risk resulting from remediation of the area?
4. What is a realistic expectation in terms of the post-remediation condition of the area (e.g., something less than pristine)?
5. Design and adequately support a long-term, post-project monitoring program to assess the effectiveness of remediation actions.
6. Evaluate the relative contribution of each remedial action in terms of resolving the overall problem.

Responsible agencies in the U.S. and Canada must remain strongly committed to virtual elimination of persistent toxic substances. Identification of sources and concrete follow-up action to effectively manage contamination problems should remain a high priority for these agencies.

- This recommendation was identified and supported by the members of the Management Breakout Session.
- Contaminated sediments impacting beneficial use impairments should be removed and placed in Confined Disposal Facilities (CDFs) using established Best Management Practices (BMPs) employed for navigational dredging. Existing disposal capacity is plentiful and costs for resuspension control would not significantly increase the present cost of navigational dredging. [Ostaszewski, Appendix 11]
- Investigation of PCB contamination of the canal and Ten Mile Drain System in St. Clair Shores indicates that a removal action is needed to protect human health and the environment [Abstract 13, El-Zein]. The removal action should be designed to mitigate both existing as well as future contamination sites, and should include:
  1. power washing of the TMD system, collection and off-site management of sediment, and water treatment by means of a system to be provided by U.S. EPA;
  2. dredging those areas of the canal where PCB concentrations exceed the screening level; treatment of collected water and off-site management of sediment;
  3. treatment of water in Wahby Park Pond before discharge to the canal;
  4. reduction of the PCB concentration in sediments of the canal to 1 mg/kg; the water treatment goal is the reporting limit, and treated water is to be discharged to the canal;
  5. post-removal monitoring of air, sediment and water to confirm that source areas of PCBs have been controlled.

2.4.2 Coordination and Support

Organized efforts are needed to secure adequate funding for future sediment remediation projects within the Detroit River-western Lake Erie basin.

- This recommendation reflects feedback from members of the Management Workgroup and was strongly supported by several workshop participants.
- The Great Lakes Legacy Act will provide new funding for sediment remediation, but additional initiatives are needed, e.g., forming public-private partnerships for sediment remediation projects, developing new programs in Canada that will supplement support from the Great Lakes Sustainability Fund. [Management Breakout Session]
- Funding should be maintained to develop innovative, cost-effective PCB removal and treatment technologies. [Management Breakout Session]

A primary coordination entity is needed to oversee and react to existing and emerging issues within the Detroit River-western Lake Erie basin. This entity would assume long-term responsibility for stewarding the system.

- This recommendation was identified and supported by members of the Modeling and Research Breakout Session.

2.5 Sharing Information and Communicating Success

A program should be developed to identify important insights and lessons learned from past remediation experiences through a variety of initiatives, including critiquing projects and sharing results with all partners and stakeholders.

- This is a recommendation of the Management Workgroup. It was broadly supported by workshop participants.

- There is a need to report on ecosystem improvements/restoration as well as contamination hot spots and emerging problems. A balance should be maintained between communicating good news and bad news. There is a perception that problems are over-emphasized while non-problems are often ignored. When ecosystem improvements occur as evidenced from monitoring results, it is important that the information be communicated to all stakeholders. [Monitoring Breakout Session]

A central repository of data for the Detroit River-western Lake Erie basin should be established to facilitate broad, efficient access and retrieval for research, modeling and management of PCBs and other contaminants. This effort should also include creation of a comprehensive directory of monitoring contacts.

- This recommendation was highlighted by members of the Monitoring Breakout Session.

Additional recommendations in the area of information sharing and communicating success include:

- An education program should be developed to help agencies, environmental groups and the general public view sediment remediation as a routine, periodic activity similar to navigational dredging. The purpose of navigational dredging is well understood and broadly accepted. Similarly, sediment remediation should be viewed as a required, reoccurring activity to limit contaminants exposed to the ecosystem and to protect beneficial uses within the Detroit River-western Lake Erie basin. [Ostaszewski, Appendix 11]

- This workshop provided a unique opportunity for modelers, monitoring experts and management personnel to assemble and focus discussion on a common issue of concern. Future efforts of this type are needed to bring technical parties together in order to share information, discuss unique concerns, and work cooperatively toward an effective, coordinated strategy for managing the Detroit River-western Lake Erie system. [Modeling and Research Breakout Session]

Concluding Remarks

A diverse set of findings and recommendations have been identified through the presentations and deliberations of approximately fifty technical experts who attended the workshop detailed in this report. As noted previously in this report, there has been no attempt here to prioritize them. All are important. All reflect the expertise and insight of researchers, managers and other technical experts who are involved in different areas of environmental research and management pertaining to the Detroit River-western Lake Erie basin. However, there are a few themes that deserve special emphasis at the conclusion of this report.

It is clear from the results of the workshop that increased funding and coordination of monitoring within the Basin is critically important. Monitoring data are essential to our understanding and management of PCBs and other contaminant problems. These data support a number of different objectives, including 1) calculation of reliable loading estimates, 2) evaluating the effectiveness of remediation, 3) developing trend information to assess long-term ecosystem changes, 4) improving modeling frameworks and refining our understanding of cause-effect relationships, and 5) providing suitable data for model calibration and validation efforts. At present coordination and funding to support comprehensive monitoring is lacking. Self-monitoring data compiled for permit compliance assessment is inadequate for deriving reliable estimates of PCB loadings to the Detroit River. The lack of suitable data is currently a significant obstacle to maintaining an accurate overview of trends in both PCB loadings and ecosystem indicators affected by those loadings, thereby obscuring our understanding of remediation effectiveness and constraining our ability to improve available modeling frameworks. There needs to be an agency, organization, task force, or other entity established to identify reliable mechanisms for providing effective coordination and increased, sustained funding of future monitoring programs within the basin.

Monitoring programs must emphasize measurement of contaminant loadings as well as concentrations in water, sediment and biota. The health and diversity of resident biological communities strongly reflects the condition of the local ecosystem. Robust information on distributions of benthos, plankton, fish, birds, and turtles is crucial to our understanding of ecosystem impacts, trends and emerging problems.

Workshop results highlighted the need for appropriate analyses of monitoring data to provide practical and statistically-sound interpretation of trend information. A framework should be developed to conduct these analyses, to provide detailed interpretation designed to improve our understanding of ecosystem relationships, and to communicate these lessons to all partners and stakeholders.

Workshop attendees were emphatic in their support of a large, comprehensive study of PCBs which truly integrates elements of monitoring, modeling and management. If properly designed and adequately supported, such a study would facilitate improvements in coordination, communication, and collaboration among participants and provide a module for implementing and testing many of the recommendations developed during this workshop.

Finally, workshop attendees strongly supported future efforts to convene a diverse group of technical experts for the purpose of exchanging ideas, sharing information, and providing advice for better understanding and protecting the ecosystem of the Detroit River-western Lake Erie basin.

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APPENDIX 1. STEERING COMMITTEE MEMEBERS

Steering Committee Members

1. Jan Ciborowski – University of Windsor (GLIER)2
2. Demaree Collier – U.S. Environmental Protection Agency2
3. Ken Drouillard – University of Windsor (GLIER)2
4. John Gannon – U.S. Geological Survey2
5. Sandra George – Environment Canada 2
6. Doug Haffner – University of Windsor (GLIER)2
7. John Hartig – Greater Detroit American Heritage River Initiative2
8. Tom Heidtke – Wayne State University2
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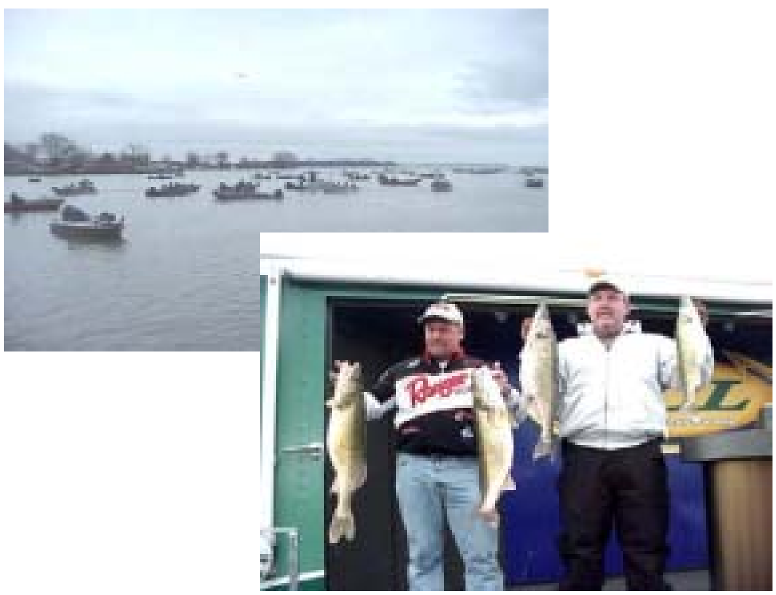
11. Julie Letterhos – Ohio Environmental Protection Agency2
12. Scott Painter – Environment Canada 2
13. Stan Reitsma – University of Windsor (GLIER)2
14. Chip Weseloh – Canadian Wildlife Service 2
15. Bonnie Yu – Wayne State University2
16. Mike Zarull – United Nations University2

APPENDIX 2. WORKSHOP AGENDA, PARTNERS/CO-SPONSORS, AND PARTICIPANTS

WORKSHOP ON

EVALUATING ECOSYSTEM RESULTS OF PCB CONTROL MEASURES WITHIN THE DETROIT RIVER-WESTERN LAKE ERIE BASIN



June 18-19, 2002

Held at the Great Lakes Institute for Environmental Research

University of Windsor
2990 Riverside Dr. W
Windsor, Ontario
Canada

Workshop Purpose

To assess recent trends in PCB loadings and associated ecosystem changes within the Detroit River – Western Lake Erie region, and to develop advice for future monitoring, modeling and management

Acknowledgements

This workshop is funded in part by a grant from U.S. Environmental Protection Agency's Great Lakes National Program Office to Wayne State University. Funding for the reception was provided by United Nations University. University of Windsor's Great Lakes Institute for Environmental Research helped plan the workshop and provided the facilities.

WORKSHOP AGENDA

Tuesday, June 18, 2002

8:30-8:40/ Welcome, introductions, and workshop purpose (Dr. Neil Gold, Vice-President, University of Windsor; Dr. Richard Lintvedt, Associate Vice-President for Research, Wayne State University; John Hartig, River Navigator, Greater Detroit American Heritage River Initiative)

Moderator: Russ Kreis, U.S. Environmental Protection Agency

8:40-9:00/ Lake Erie Lakewide Management Plan (LaMP) perspective on PCB sources and loadings (Scott Painter, Environment Canada)

9:00-9:20/ Trends in annual PCB loads to the Detroit River, 1986-1998 (Dave Dolan, University of Wisconsin-Green Bay)

9:20-9:40/ Atmospheric deposition of PCBs: an International Atmospheric Deposition Network (IADN) perspective (Todd Nettesheim, U.S. Environmental Protection Agency)

9:40-10:00/ Sediment remediation in the Detroit River–Western Lake Erie watershed (John Hartig, Greater Detroit American Heritage River Initiative)

10:00-10:20 Coffee Break

Moderator: Doug Haffner, University of Windsor – GLIER

10:20-10:40/ Spatial and temporal trends in Lake Erie sediment PCB concentrations (Scott Painter, Environment Canada)

10:40-11:00/ PCBs in suspended sediment from the Detroit River and western Lake Erie (Chris Marvin, Environment Canada)

11:00-11:20/ Sediment-zoobenthos interactions (Jan Ciborowski, University of Windsor – GLIER)

11:20-11:40/ A summary of Ottawa River PCB investigations, and the cleanup of Fraleigh Creek (Mike Czeczele, Ohio Environmental Protection Agency)

11:40-12:00/ PCBs in sediments – A remedial action plan perspective (Arthur Ostaszewski, Michigan Department of Environmental Quality)

12:00-12:20/ PCB trends in fish and sediment from the Rouge River following sediment remediation on Evans Ditch and Newburgh Lake (James Murray, Wayne County Department of Environment)

12:20-1:30 Lunch

Moderator: Rob Letcher, University of Windsor – GLIER

1:30-1:50 PCBs in adult aquatic insects (Lynda Corkum, University of Windsor – GLIER)

1:50-2:10/ Western Lake Erie fish community contaminant trends – 1977-2001 (Mike Whittle, Department of Fisheries and Oceans)

2:10-2:30/ PCBs in fish collected from St.Clair/Detroit River ecosystem (James Hickey, Sergei Chernyak, Linda Begnoche, and Richard T. Quintal, U.S. Geological Survey)

2:30-2:50/ PCB metabolism and phenolic contaminants in the plasma of Detroit River fish (Rob Letcher, and Hongxia Li, University of Windsor – GLIER)

2:50-3:10/ Spatial and temporal trends of PCBs in herring gull eggs from the western Lake Erie-Detroit River-southern Lake Huron corridor, 1974-2001 (Chip Weseloh, Canadian Wildlife Service)

3:10-3:30/ Contaminants and snapping turtles: Lake St. Clair, the Detroit River and western Lake Erie (Kim Fernie, Canadian Wildlife Service)

3:30-3:50 Coffee Break

Moderator: Russ Kreis, U.S. Environmental Protection Agency

3:50-4:10/ Biomonitors, surficial sediments, and foodweb datasets on the Detroit River (Ken Drouillard and Doug Haffner, University of Windsor – GLIER)

4:10-4:40/ Simulation of sediment dynamics in Detroit River caused by wind-generated water level changes in Lake Erie and implications to PCB contamination (Stan Reitsma, University of Windsor – GLIER)

4:40-5:00 Charge to Breakout Sessions (John Hartig)

Wednesday, June 19, 2002

8:30-10:40/ Three Concurrent Breakout Sessions (develop key findings, conclusions, recommendations on the topics assigned to each group)

RESEARCH AND MODELING BREAKOUT SESSION:

Facilitators: Jan Ciborowski and Mike Zarull

Questions:

- Based on what you have learned at the workshop, what key research/modeling findings and conclusions should be communicated to senior managers in government agencies and research/academic institutions?
- Based on workshop presentations and breakout session discussions, what key research/modeling recommendations should be made to senior managers of government agencies and research/academic institutions?

MANAGEMENT (point and nonpoint sources, sediment remediation) BREAKOUT SESSION:

Facilitators: John Hartig and Griff Sherbin

Questions:

- Based on what you have learned at the workshop, what key management findings and conclusions should be communicated to senior mangers in government agencies and research/academic institutions?
- Based on workshop presentations and breakout session discussions, what key management recommendations should be made to senior managers of government agencies and research/academic institutions?

MONITORING (both near field and far field) BREAKOUT SESSION:

Facilitators: John Gannon and Russ Kreis

Questions:

- Based on what you have learned at the workshop, what key monitoring findings and conclusions should be communicated to senior managers in government agencies and research/academic institutions?
- Based on workshop presentations and breakout session discussions, what key monitoring recommendations should be made to senior managers of government agencies and research/academic institutions?

10:40-11:00	Coffee Break
11:00-Noon/	Reports from the three breakout sessions and open discussion and integration of results/findings/recommendations (Facilitators: Jan Ciborowski, University of Windsor – GLIER; John Hartig)
Noon	Adjourn

WORKSHOP PARTNERS AND CO-SPONSORS

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Wayne State University2

University of Windsor (GLIER)2

Environment Canada2

Wayne County GIS Management2

International Association for Great Lakes Research2

United Nations University2

Detroit River Remedial Action Plan2

U.S. Environmental Protection Agency2

Lake Erie Lakewide Management Plan2

Canadian Wildlife Service2

U.S. Army Corps of Engineers2

Lake Erie Millennium Network2

Detroit River Canadian Cleanup2

U.S. Fish & Wildlife Service2

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3. Jose Belen – Detroit Water and Sewerage Department2
4. Florence Bissell – U.S. Army Corps of Engineers Detroit District 2
5. Duncan Boyd – Great Lakes Investigations (Environment and Energy)2
6. Sergei Chernyak – U.S. Geological Survey2
7. Jan Ciborowski – University of Windsor (GLIER)2
8. Demaree Collier – U.S. Environmental Protection Agency2
9. Lynda Corkum – University of Windsor (GLIER)2
10. David Crates – Ontario College Family Physicians2
11. Frank Crowley – Michigan Marine Doring, LLC2
12. Mike Czeczele – Ohio Environmental Protection Agency2
13. Joe DePinto – Limno-Tech2
14. Dave Dolan – University of Wisconsin-Green Bay2
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16. Jim Drummond – Detroit River Canadian Cleanup Committee 2
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18. Kim Fernie – Canadian Wildlife Service 2
19. John Gannon – U.S. Geological Survey2
20. Sandra George – Environment Canada 2
21. Doug Haffner – University of Windsor (GLIER)2
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27. John Hummer – Great Lakes Commission 2
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36. Chris Marvin – Environment Canada 2
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42. Scott Painter – Environment Canada 2
43. Joe Rathbun – Michigan DEQ-SWQD2
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46. Bruce Roberts – BASF CORP2
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48. Roger Santiago – Environment Canada 2
49. James P. Selegean – U.S. Army Corps of Engineers Detroit District 2
50. Rajesh Seth – University of Windsor2
51. Ian (Griff) Sherbin – Consultant 2
52. Marc Tuchman – U.S. Environmental Protection Agency2
53. Lisa Tulen – University of Windsor (GLIER)2
54. Jennifer Vincent – Environment Canada 2
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56. Mike Whittle – Department of Fisheries and Oceans2
57. Lisa L. Williams – U.S. Fish and Wildlife Service 2
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APPENDIX 3. LAKE ERIE LAKEWIDE MANAGEMENT PLAN PERSEPECTIVE ON PCB SOURCES AND LOADINGS

Scott Painter
Environment Canada

Many pollutants arising from past and present agricultural, industrial, and municipal sources are impairing or could impair the beneficial uses of Lake Erie. Of the fourteen beneficial uses identified in the Great Lakes Water Quality Agreement (Annex 2), fish consumption advisories exist lakewide in Lake Erie due to PCB contamination. As a result, PCBs have been designated as a lakewide critical pollutant in the Lake Erie Lakewide Management Plan (LaMP).

The LaMP Sources and Loadings Committee has integrated and characterized monitoring data available from 1986 to 1999. Fourteen major environmental databases, representing contributions from 10 national, 10 state and provincial, four binational, and two nongovernmental monitoring programs were examined. Databases evaluated for the United States were Storage and Retrieval System-EPA (STORET), Permit Compliance System (PCS), Toxics Release Inventory (TRI), Ohio Sediment Inventory (OSI), Fully Integrated environmental Locational Decision Support System (FIELDS), National Sediment Inventory (NSI), and United States Geological Survey (USGS). Databases evaluated for Canada were Storage and Retrieval System-Environment Canada (STAR), Connecting channel database (ENVIRODAT), Provincial Water Quality Monitoring Network (PWQMN), Sample Results Data Store (SRDS), and National Pollutant Release Inventory (NPRI). Binational networks evaluated were Integrated Atmospheric Deposition Network (IADN) and Mercury Deposition Network (MDN).

The results of the analysis of these data (Painter et al. 2000) indicate that available concentration data for PCBs in effluents and tributaries are not suitable to compute loads (Table 1, 2, 3, and 4).

PCB concentrations were monitored and reported at 15 facilities in the United States, but only 5 percent of the nearly 1,000 observations were reported above the reporting limit. Likewise, data for PCBs reported by monitoring programs for tributaries in the United States and Ontario did not meet the minimum criteria to characterize loads to Lake Erie. Only the atmospheric data from the Integrated Atmospheric Deposition Network were sufficient to estimate loads for trace organics, including PCBs.

Although environmental data from point sources and tributaries for most trace organic substances were not suitable for computing loads, the same data can be used to indicate sources. For example, of the 15 facilities in the U.S. Permit Compliance System data for 1998-99, PCB concentrations or loads were reported in effluents from 5. Meanwhile, receiving environment information such as streambed or lakebed sediment PCB concentrations can indicate a local source. Integration of the available information can facilitate a weight of evidence analysis of PCB sources and an analysis of existing monitoring and remediation programs. Maps of discharge locations will be compared to tributary, connecting channel, and lake concentrations, tissue concentrations, and aquatic sediment concentrations to identify source areas and contaminated areas in the basin. Existing implementation and remediation efforts will be cross-referenced with the source and environmental information. The analysis can point out where further attention may be needed, whether it be monitoring or remediation.

The LaMP is committed to virtual elimination in the environment through virtual elimination of discharges of PCBs and mercury. The LaMP collaborates with the Binational Toxics Strategy to accomplish source phaseout, in other words, the elimination of industrial and commercial processes and products that unnecessarily use these pollutants. Of course, we also have to deal with our past practices which have unfortunately resulted in both widespread elevated levels of both pollutants as well as locally contaminated sites. The widespread occurrences of fish consumption advisories, for example, are the legacy of the geographically dispersed sediment contamination in the Great Lakes basin. Unfortunately, we must accept that deep burial of contaminated sediments in depostional environments such as the Great Lakes is our only management option. However, there are localized contaminated sites, both soils and sediments, that behave like sources in that offsite migration of pollutants can be observed. The LaMP encourages the remediation of these active sites thereby eliminating additional local "legacy" sources and therefore moving us one step closer to virtual elimination in the environment.

References

Painter, S., D.N. Myers, and J. Letterhos. 2000. Characterization of Data and Data Collection Programs for the Lake Erie LaMP.

Table 1. Pollutant class, pollutant, number of reporting facilities, number of observations, and percent of samples reported above the detection limit, Lake Erie basin in the United States; 1986-1997.

Pollutant class	Pollutant	Number of Facilities	Number of Observations	Percent Above Reporting Limit
Organochlorine Compounds	DDT	3	127	2
	Mirex	0	0	0
	Dioxin	1	94	0
	Chlordane	0	0	0
	PCBs	15	926	5
Polynuclear Aromatic Hydrocarbons	Anthracene	0	0	0
	Benz(a)anthracene	2	18	0
	Benzo(a)pyrene	5	59	7
	Benzo(b)fluoranthene	0	0	0
	Benzo(k)fluoranthene	0	0	0
	Benzo(g,h,i)perylene	0	0	0
	Chrysene	2	18	0
	Indeno(123-cd)pyrene	0	0	0
	Flouranthene	3	260	0
Trace Metals	Mercury	170	7,664	23
	Lead	214	11,522	40
Other Pollutants	Total phosphorus	591	47,609	74
	Nitrate-nitrogen	153	9,883	92
	Fecal coliform bacteria	388	17,234	72
	Escherichia coli	93	1,994	75
	Total nonfilterable residue	945	98,523	70

Table 2. Pollutant class, pollutant, number of reporting facilities, number of observations, and percent of samples reported above the detection limit, Lake Erie basin in Ontario, 1995.

Pollutant Class	Pollutant	Number of Facilities	Number of Observations	Percent Above Reporting Limit
Organochlorine Compounds	DDT	0	0	0
	Mirex	0	0	0
	Dioxin	17	62	1.6
	Chlordane	0	0	0
	PCBs	15	37	0
Polynuclear Aromatic Hydrocarbons	Anthracene	19	43	0
	Benz(a)anthracene	13	35	0
	Benzo(a)pyrene	19	69	0
	Benzo(b)fluoranthene	13	35	0
	Benzo(k)fluoranthene	13	35	0
	Benzo(g,h,i)perylene	19	43	0
	Chrysene	19	43	0
	Indeno(123-cd)pyrene	19	43	0
	Flouranthene	19	43	0
Trace Metals	Mercury and its compounds	21	143	12.6
	Lead and its compounds	17	1,514	73.2
Other Pollutants	Total phosphorus	31	1,530	83
	Nitrate-nitrogen (in solution, pH >6.0)	13	41	73
	Fecal coliform bacteria	1	8	25
	Escherichia coli	1	30	47
	Total nonfilterable residue	40	7,372	83.9

Table 3. Pollutant class, pollutant, percentage of samples with detected concentrations, number of samples, number of sites, and number of sites within indicated range of samples per site, Lake Erie basin tributaries in the United States: 1986-1996.

Pollutant Class	Pollutant (STORET pcode)	Percent Greater Than Detection Limit	No. of Samples[a]	No. of Sites	Number of Sites Within Indicated Range of Samples per Site: 1-9	10-49	50-99	100-500	>500
Organochlorine Compounds	DDT (39300, 39310, 39320, 39360, 39365, 39370)	11.2	596	93	88	4	0	1	0
	Mirex (39500)	0.0	141	77	73	4	0	0	0
	Chlordane (39350)	0.0	117	9	4	4	1	0	0
	Dieldrin (39380)	23.6	199	93	88	4	1	0	0
	PCBs (39488-39516, 34671, 81648, 81649)	0.1	1,112	89	79	5	1	4	0
PAHs	Benzo(a)pyrene (34247)	0.0	196	120	116	4	0	0	0
Trace metals	Mercury (71900)	17.4	3,197	312	228	74	2	8	0
	Lead (01051)	46.2	10,433	1,141	972	120	30	19	0
Other pollutants	Atrazine (39632, 39033)	85.6	938	11	4	2	0	5	0
	Nitrate-N (00630, 00631)	94.6	32,607	1,417	1,181	153	32	38	13
	Total phosphorus (00665)	95.5	35,078	1,435	1,175	162	44	41	13
	Escherichia coli (31633, 31648)	99.8	1,503	35	9	16	7	3	0
	Suspended sediment or total nonfilterable residue (00530, 70300, 80154)	89.8	29,477	1,418	970	336	46	59	7

Note: STORET, Storage and Retrieval system for environmental data in the United States; pcode, parameter code, a numeric2 label that identifies a specific chemical compound, physical property, characteristic, or biological property and indicates how it 2 was analyzed; >, greater than; no., number.2

[a]Includes all observations reported as less than detected or with remark codes indicating the same.2

Data are from the STORET database.2

Table 4. Pollutant class, pollutants, percentage of samples with detected concentrations, number of samples, number of sites, and number of sites within indicated range of samples per site, Lake Erie Basin tributaries in Ontario: 1986-1996.

Pollutant Class	Pollutant	Percent Greater Than Detection Limit	No. samples	No. sites	Number of Sites Within Indicated Range of Samples per				
						10-49	5-99	100-500	>500
Organochloine Compounds	DDT	0.07	2,673	5	0	1	1	2	1
	Mirex	0.0	850	5	1	1	1	1	1
	Chlordane	0.0	976	5	0	2	0	2	1
	Dieldrin	0.0	850	5	1	1	1	1	1
	PCBs	0.2	899	5	0	2	1	1	1
PAHs	Benzo(a)pyrene	0.0	0	0	0	0	0	0	0
Trace metals	Mercury	15.2	1,253	4	0	0	1	3	0
	Lead	14.6	2,334	19	2	2	9	6	0
Other pollutants	Atrazine	70.3	791	3	0	1	0	1	1
	Nitrate-N	97.6	3,534	29	2	3	11	12	1
	Total phosphorus	99.8	3,408	29	2	3	11	13	0
	Escherichia coli	76.9	338	27	5	22	0	0	0
	Suspended sediment or total nonfilterable residue	98.0	3,383	29	1	4	12	12	0

Note: No., number; numbers of samples shown are for those sites located at downstream terminus of stream basin; >, greater2 than.2

[a]Includes all observations reported as less than detected or with remark codes indicating the same.2

Data are from Ontario's Provincial Water-Quality Monitoring Network (PWQMN).2

APPENDIX 4. TRENDS IN ANNUAL POINT SOURCE PCB LOADS TO THE DETROIT RIVER, 1986-1998

Dave Dolan 2
Natural and Applied Sciences 2
University of Wisconsin — Green Bay2

Introduction

The Detroit River Area of Concern (AOC) has a long history of pollution problems dating back to the turn of the 19th century. As governments became aware of the adverse impacts of water pollution, the concepts of loading and assimilative capacity were used with some success to design treatment facilities to reduce gross pollution entering the river. Mathematical modeling of algal production in Lake Erie allowed the establishment of a target load for total phosphorus that, in turn, provided a goal for treatment of sewage entering the lake and the Detroit River. In the mid-1980s, attention turned to reducing persistent toxic substances that were the cause of fish advisories, bird and animal deformities, and other impairments of beneficial uses. The Upper Great Lakes Connecting Channels Study (UGLCCS, 1988) included efforts to balance the mass of PCBs and other contaminants using synoptic upstream/downstream and input sampling. The Detroit River corridor was determined to be a source for several persistent toxic substances including PCBs. The Remedial Action Plan (RAP) for the Detroit River (1991) identified six chemicals of concern: cadmium, copper, lead, mercury, PCBs and zinc. Remedial activities were to focus on reducing the loadings of these chemicals. Success in the implementation of the RAP could then be judged by evidence of substantial reductions in loadings.

Background

Sampling of PCBs in ambient Detroit River water during UGLCCS was complicated by the problem of censored (below detection limit) data. The combination of large flow rates and low concentrations leads to arbitrary load estimation procedures, depending on how the censored data are handled. This problem was recognized for the Niagara River and a statistical procedure was implemented to address it (Niagara River Data Interpretation Group, 1986). If reductions in point source loadings occur over time, the issue of censored data can become important for effluent sampling also. PCB sampling of point sources to the Fox River in Green Bay, Wisconsin yielded some censored data. The methods developed for the Niagara River were extended to allow estimation of total PCB loads from effluents (Dolan et al., 1993).

In 1995, the Detroit River Point Source/Nonpoint Source Technical Work Group estimated point source loads of contaminants, including PCBs, for an update of the Detroit River Remedial Action Plan. Because the concentration data for many of the sources were known to be censored, methods were developed to estimate loads of PCBs and other chemicals of concern (Dolan et al., 1995).

In 2000, the Four Parties (U.S. EPA, Environment Canada, Michigan Department of Environmental Quality, and Ontario Ministry of the Environment) wished to further update the information on loadings of the six chemicals of concern. Available point source data were collected from U.S. and Canadian municipal and industrial dischargers and used to estimate these loadings in the same manner as previous studies (El-Shaarawi and Dolan 1989; Dolan and El-Shaarawi 1989).

Study Objectives and Research Methods

The objectives of the original (1995) study were to update the point source loadings for PCBs and other chemicals of concern and compare total loads to the UGLCCS report. The objectives of the 2000 study were to further update the loads with available data and assess the current state of knowledge of effluent loadings in the Detroit River AOC.

Total PCB loads were estimated using a modification of the method for the Fox River point sources data. In that study, congener specific data were available, but some of it was censored. The procedure of El-Shaarawi and Esterby (1992) was used to estimate replacement values of censored congener concentrations. This allowed summation of congeners to total PCBs. For Detroit River point sources, data on Aroclors were available. Replacement values were estimated for censored data for Aroclors 1242, 1254 and 1260 and total PCBs estimated by assuming equal weights among Aroclors.

Discussion of Results

As Figure 1 shows, there is no evidence for declining point source loadings of PCBs. Loads have either remained constant or increased.

During the data collection exercise, it was observed that the data being reported was becoming less and less useful for load estimation. Only Detroit Water and Sewerage Department (DWSD) was still reporting total PCBs and did so with lower frequency and higher analytical detection limits. Although the load estimation methods used allowed for some censored data (non-detects), data from later years (e.g., 1998) were such that no estimate was possible.

Conclusions and Recommendations

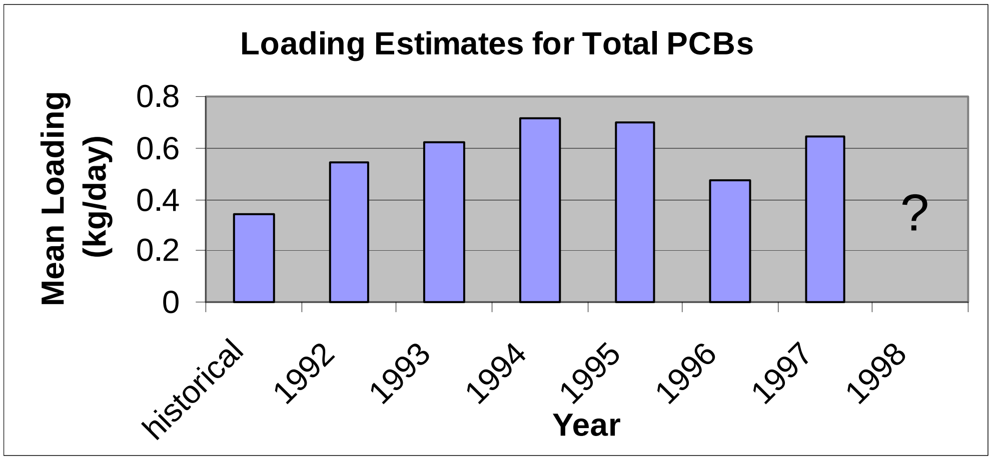
One of the conclusions of the UGLCCS study was that point sources of PCBs were significant contributions to the observed increase of downstream concentrations of PCBs vs. upstream in the Detroit River. Available data from the mid-1990s (1992-1997) do not indicate any reductions. Since 1998, there has been no point sources data reported for PCBs, except for DWSD, which reports a censored concentration of 15 mg/kg total PCBs on a monthly basis.

There has not been congener specific PCB analysis of Detroit River point sources since 1986. Packed column PCB analysis results in total PCB concentrations that are not directly comparable to congener specific analysis and have higher detection limits.

Information on sources and loadings of PCBs to the Detroit River is incomplete and out of date. The situation is rapidly becoming worse. The current system of collecting point source data that is intended to monitor compliance and using it to estimate loadings of persistent toxic substances is not working.

Weekly sampling of PCBs in the DWSD effluent should continue, but with chemical analysis by congener specific methods. Loadings should be estimated and compared to new upstream/downstream sampling results. Other point sources in the Detroit River AOC should be sampled occasionally by the same congener specific methods to verify levels of PCB load contributions.

Figure 1. Detroit River Total PCB Loads (kg/day), 1992-1997.



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APPENDIX 5. ATMOSPHERIC DEPOSTION OF PCBS: AN INTEGRATED ATMOSPHERIC DEPOSITON NETWORK (IADN) PERSPECTIVE

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Introduction and Background

It became evident that the atmosphere could be a source of toxic pollutants to the Great Lakes when, after the uses of many of these substances were banned and direct discharges to the Lakes were reduced, concentration levels in biota decreased drastically and then seemed to level off in the mid-1980s (Buehler et al. 2001). Over the last few decades, scientific research has confirmed these theories. It is currently estimated that the atmosphere contributes between 82-95% of total PCB loadings to Lake Superior and approximately 80% of PCB loadings to Lake Michigan (Hoff et al. 1996, Miller 1999, Green and Hornbuckle 2000).

Network Objectives and Methods

The Integrated Atmospheric Deposition Network (IADN) was established in 1990 to carry out surveillance and monitoring of toxic contaminants in the Great Lakes region as required under Annex 15 of the Great Lakes Water Quality Agreement and the Clean Air Act Amendments of 1990. The IADN is a binational atmospheric monitoring network operated by Environment Canada and the United States Environmental Protection Agency's Great Lakes National Program Office. The primary objective of the IADN is to determine the magnitude and trends of atmospheric loadings of toxic contaminants to the Great Lakes.

The IADN operates a network of 15 atmospheric monitoring stations (Figure 1). There are 5 master stations, one on each of the Great Lakes, located in rural areas to represent regional background conditions. There are also 10 satellite stations that provide additional detail about levels of pollutants in the air around the Great Lakes. The IADN collects gas, particle, and precipitation phase samples at each of the master stations. Vapor and particle phase samples are collected every 12 days for 24 hours at a time. At the 3 U.S. master stations, approximately 815 m^3 of air are collected using a XAD-2 resin to trap the gaseous contaminants. At the 2 Canadian master stations, the average volume of air collected is 350 m^3 using polyurethane foam (PUF) to trap the gaseous contaminants. The Canadian master stations use glass fiber filters for particle phase collection, while the U.S. master stations use quartz fiber filters. Precipitation-phase samples are collected as 28-day composites at the 3 U.S. master stations and Point Petre. Precipitation samples are collected as 14-day composites at Burnt Island (Buehler et al. 2001). Meteorological data, including wind speed and precipitation measurements necessary for the loadings calculations, are also collected on-site at each master station.

The IADN currently measures and reports on 13 polycyclic aromatic hydrocarbons (PAHs), 18 organochlorine pesticides, and 56 polychlorinated biphenyl (PCB) congeners or congener groups (Buehler et al 2001 and Buehler and Hites 2002). Chemical analyses for the IADN is performed by gas chromatographic mass spectrometry, gas chromatography with electron capture detection, and liquid chromatography with fluorescent detection. Total PCB concentrations and loadings reported in this abstract correspond to the suite of 56 PCB congeners and congener groups, which accounts for approximately 90% of the total PCB mass at each site and includes the most toxicologically important congeners.

Discussion of Results

One of the goals of the IADN is to determine the temporal trends of toxic contaminants in air and precipitation collected near the Great Lakes. Figure 2 shows the annual average atmospheric gas-phase total PCB concentrations (in pg/m3) for each IADN master station, as well as the two U.S. satellite stations, beginning in 1991. Although it is not immediately apparent from Figure 2, there has been a decline in total PCB concentrations in the air near each of the Great Lakes in the past 10 years (Buehler and Hites 2002). Hillery et al. (1997) first found declining trends in total PCB concentrations over time near Lakes Michigan and Erie. A review of pre-1990 PCB data collected near Lakes Superior and Michigan from the literature further supports the notion that total PCB concentrations are declining and approaching equilibrium around the Great Lakes (Buehler and Hites, unpublished).

Another goal of the IADN is to determine the spatial trends of toxic contaminants in air and precipitation collected near the Great Lakes. Figure 2 also clearly illustrates the spatial variations of gas-phase total PCB concentrations in air near the Great Lakes. Note the logarithmic scale for concentrations in Figure 2, which shows that total PCB concentrations at the Chicago satellite station have been about an order of magnitude higher than at all the other sites (Buehler and Hites 2002). It is expected that PCB concentrations should be elevated in the Chicago urban area because of the widespread use of PCBs in industrial application in the middle of the 20th century. However, the IADN also measures an “urban effect” on the PCB concentrations at the Sturgeon Point master station, which is approximately 20 kilometers southwest of the Buffalo urban area. Furthermore, recent research is revealing that the influence of the Chicago urban area may reach as far away as Lake Superior (Hafner and Hites, unpublished).

The recent IADN loadings report (Buehler et al 2001) explored the impact of the Chicago urban area on total PCB loadings to Lake Michigan. The results indicate that the “urban effect” has a strong effect on lake-wide loadings of total PCBs. For example, in 1998, the inclusion of Chicago data decreases total PCB volatilization from the lake by approximately 53% and conversely increases total PCB deposition to the entire lake by over 500% (Buehler et al. 2001).

The recent IADN loadings report (Buehler et al 2001) also estimated loadings to the Great Lakes basin from 1992 to 1998, using data only from the 5 master stations. Figure 3 shows the total regional loadings for Į -HCH, Û-HCH (lindane), and total PCBs. On a region-wide scale, the waters of the Great Lakes have been volatilizing PCBs into the atmosphere for at least 7 years and that the rate of volatilization has generally decreased over time. This analysis further supports the notion that the air-water partitioning of PCBs in the Great Lakes region is approaching equilibrium.

Conclusions and Recommendations

Total PCB concentrations and loadings are decreasing in rural areas of the Great Lakes region. On a regional scale, total PCBs are volatilizing out of the Great Lakes and approaching equilibrium. PCBs also exhibit a strong “urban effect”, with gas-phase concentrations an order of a magnitude higher in urban areas. These elevated urban concentrations have a significant effect on lake-wide loadings of total PCBs.

The IADN will continue to measure concentrations of PCBs in the air and precipitation of the Great Lakes region. The IADN would also like to establish additional urban satellite stations to determine if elevated concentrations of PCBs are found in other urban areas around the Great Lakes. The IADN also plans to continue as an active participant in current research identifying and quantifying sources of PCBs to the atmosphere in the Chicago urban area.

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Figure 1: The Integrated Atmospheric Deposition Network.

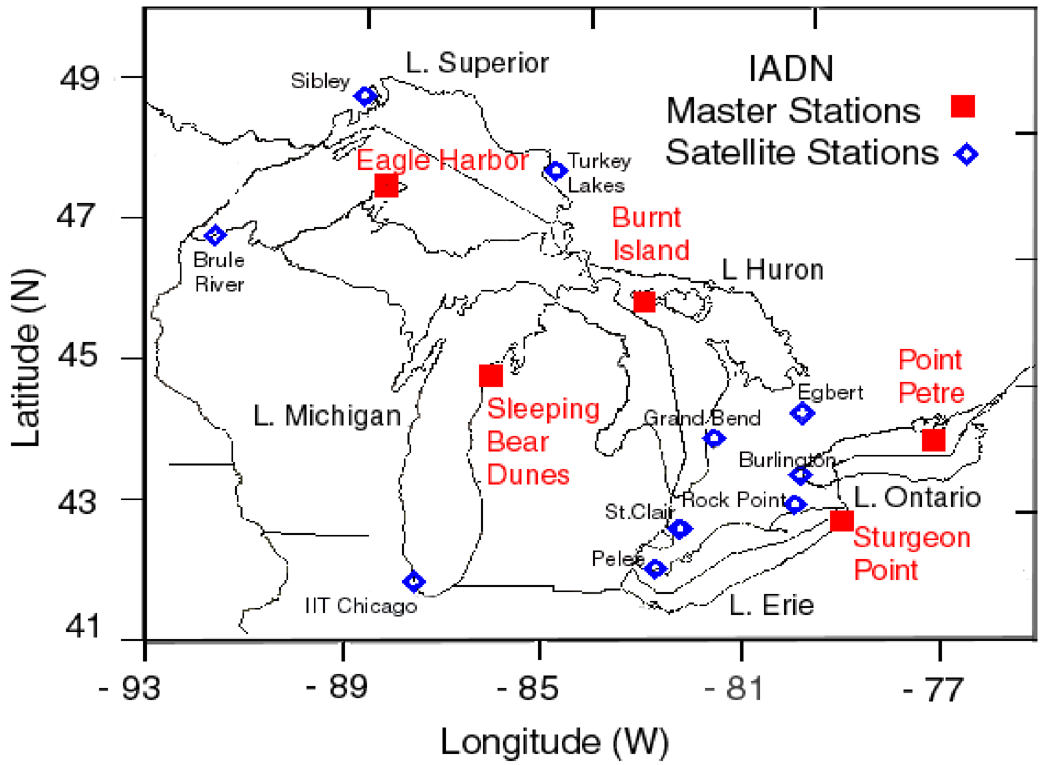


Figure 2: Average Annual Atmospheric gas-phase total PCB concentrations.

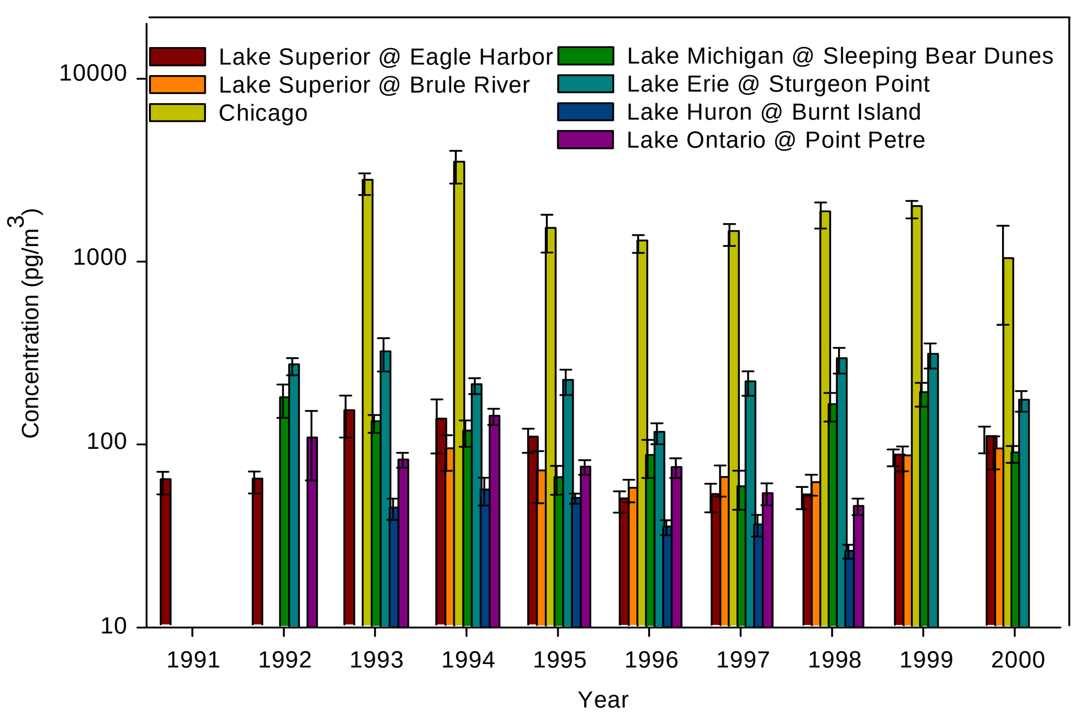
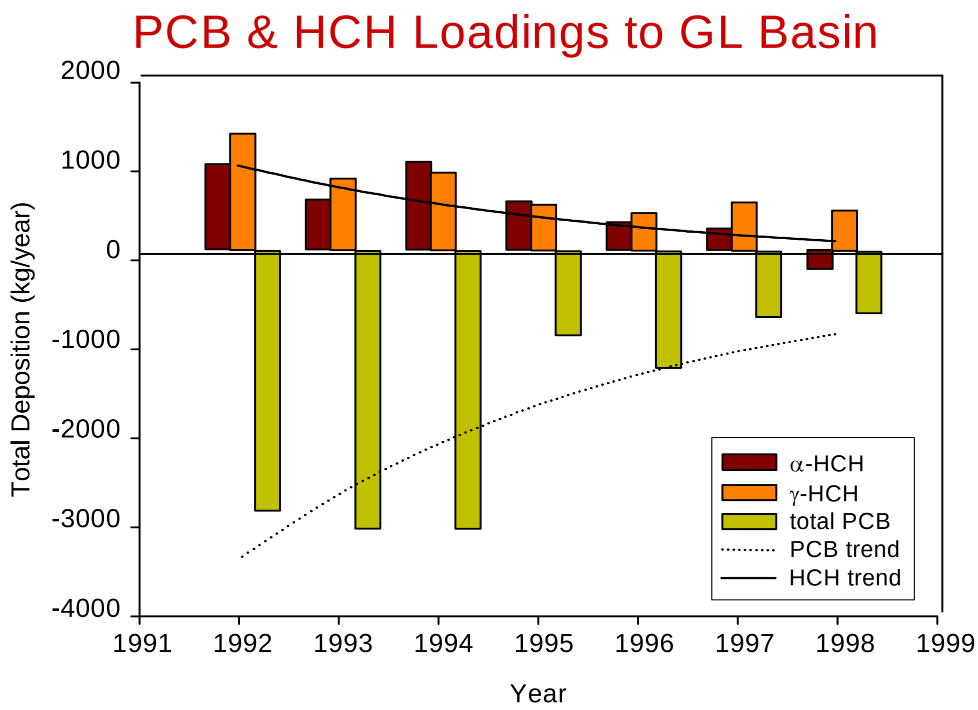


Figure 3: Annual loadings for Į -HCH, Û-HCH (lindane), and total PCBs into or out of the five Great Lakes collectively.



Source: Buehler and Hites, ES&T in press

APPENDIX 6. SEDIMENT REMEDIATION IN THE DETROIT RIVER – WESTERN LAKE ERIE WATERSHED

John H. Hartig2
Greater Detroit American Heritage River Initiative2

Loadings of PCBs to the Detroit River and Lake Erie have substantially decreased since the 1970s (Zarull et at. 2001). However, the atmosphere and certain other sources continue to contribute loadings. In addition, all Areas of Concern around Lake Erie have contaminated sediment. Contaminated sediment is viewed as a universal obstacle in restoring uses in Areas of Concern and Lake Erie (Sediment Priority Action Committee 1999). In general, PCB levels in Lake Erie biota declined during the 1970s and 1980s in direct response to reduced loadings. However, PCB levels in Lake Erie biota remained fairly stable or the rate of decrease has slowed substantially during the early 1990s.

During the 1980s and 1990s considerable emphasis was placed on minimizing inputs of PCBs from active sources. In addition, between 1993 and 2001 there was approximately $130 million spent for sediment remediation within the western Lake Erie/Detroit River basin (Table 1 and Figure 1). This includes 10 sediment remediation projects and at least two containment projects in the Detroit River/Western Lake Erie basin (BASF Riverview Site, Riverview, Michigan; Dura Landfill, Toledo, Ohio). Total estimated volume removed in the 10 sediment remediation projects was 843,500 m^3 (1,103,290 yd^3). Total estimated mass of PCBs removed in the 10 projects was 197,623 kg or 198 tonnes.

It is also important to recognize that dredging for navigational purposes is another means of contaminant removal and containment that has ecosystem consequences. For example, navigational dredging of the Rouge River between 1963 and 2001 resulted in 3,278,519 m^3 (4,288,303 yd^3) of material removed and disposed (Figure 1). Navigational dredging of the Detroit River between 1963 and 2001 resulted in 11,215,409 m^3 (14,669,755 yd^3) of material removed and dredged (Figure 2). It is difficult to accurately estimate the mass of PCBs removed as a result of navigational dredging, however, the U.S. Army Corps of Engineers-Detroit District has been able to provide some rough estimates. Again, an estimated 198 tonnes of PCBs were removed between 1993 and 2001 as a result of sediment remediation projects. For comparative purposes, we have used the same time frame of 1993-2001. In comparison, based on preliminary estimates, approximately one tonne of PCBs was removed as a result of navigational dredging (608 kg removed by dredging 150,358 m^3 (196,668 yd^3) of material during 1993-2001 from the Rouge River and 317 kg removed by dredging 507,225 m^3 (663,450 yd^3) of material during 1993-2001 from the Detroit River). This number would obviously be higher if one looked at longer term dredging (where larger volumes were removed that had undoubtedly higher levels of PCB contamination). Therefore, based on a preliminary assessment and evaluation, it is concluded that between 1993 and 2001 a substantially higher mass of PCBs (over two orders of magnitude higher) was removed as a result of contaminated sediment remediation as compared to navigational dredging of shipping channels.

Conclusions and Recommendations

Control of contaminants at source remains the primary imperative for action. Monitoring of loading reductions and effectiveness of remedial actions is essential. The old adage of "If you can't measure it, you can't manage it" really holds true. A higher priority must be given to measuring and monitoring loadings and system responses. Annual source loadings of PCBs must be estimated with appropriate methodologies, sufficient data for loading computation, and adequate detection limits and quality assurance/quality control protocols.

It should be mandatory to monitor ecological/environmental response following sediment remediation. One way of achieving this would be for the state/provincial/federal agencies responsible for sediment remediation to incorporate into settlements and cooperative agreements some specific commitments and resources required for post-project monitoring of effectiveness of sediment remediation (Sediment Priority Action Committee 1999). Some good examples include the Welland River project (Ontario), the settlement under the Natural Resource Damage Assessment for Saginaw River and Bay (Michigan), and the Thunder Bay cleanup project (Ontario). In addition, a higher priority should be placed on monitoring ecological benefits and beneficial use restoration (Sediment Priority Action Committee 1999).

Agencies involved in the management of the Detroit River and Lake Erie should also consider having a task force or committee established for surveillance and monitoring similar to what was present under the Great Lakes International Surveillance Plan. When such surveillance and monitoring committees were functioning and were required to report out every two or more years, there was a higher priority given to monitoring.

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Table 1. Sediment remediation projects in the Detroit River/Western Lake Erie watershed.

RIVER	SEDIMENT REMEDIATION PROJECT	DATE	COST (MILLIONS)	ESTIMATED VOLUME OF SEDIMENT REMOVED	ESTIMATED MASS OF PCBs REMOVED
Rouge River (Michigan)	Evans Products Ditch Site	1997	$ 0.75	7,300 m^3	8,000 kg
Rouge River (Michigan)	Newburgh Lake	1997-1998	$11	306,000 m^3	800 kg
Detroit River (Michigan)	Carter Industrial Site	1986-87 - residential; 1995-1996 - soil excavation	$7	35,100 m^3	6,268 kg
Detroit River (Michigan)	BASF Riverview Property (formerly the Federal Marine Terminal Site)	2003	$8	Water tight barrier walls will encircle this 30-acre site and prevent contaminated groundwater from entering the Detroit River via maintaining a inward hydraulic gradient	No accurate estimates of the mass of PCBs exist. However, Michigan Department of Environmental Quality has reported that the average concentration of PCBs was 2.5 ug/L in well samples taken from along the Detroit River. Modelling of the rate of flux of PCBs into the Detroit River, prior to implementation of remedial measures, has estimated a loading of 0.03 kg/yr. Again, the remedial measures will maintain an inward hydraulic gradient at the site and stop any loading to the Detroit River.
Detroit River	Wayne County's Elizabeth Park Marina	1993	$1.3	3,100 m^3	Limited data are available, however, a rough estimate would be approximately 5 kg

Detroit River	Monguagon Creek	1997	\$3	19,300 m^3	PCBs were not a major contaminant at this site. Only three samples out of 22 collected by Michigan Department of Environmental Quality had measurable concentrations (3.2, 3.0, and 1.6 mg/kg). In all other samples, PCBs were less than the detection limit. Therefore, no accurate estimate of mass of PCBs removed is available. However, it would be very low.
Detroit River	Conners Creek	2002-2003	\$4	87,200 m^3	302 kg
Detroit River	Black Lagoon	Planned for 2003	\$9	23,000 m^3	38 kg
Huron River	Willow Run Creek	1998	\$70	336,400 m^3	136,400 kg
River Raisin	Ford Motor Company Site	1996-1997	\$6	20,000 m^3	20,500 kg
Ottawa River	Fraleigh Creek	1998	\$5	6,100 m^3	25,300 kg

Figure 1. Locations of sediment remediation in the Detroit River and Western Lake Erie, 1993-2001.

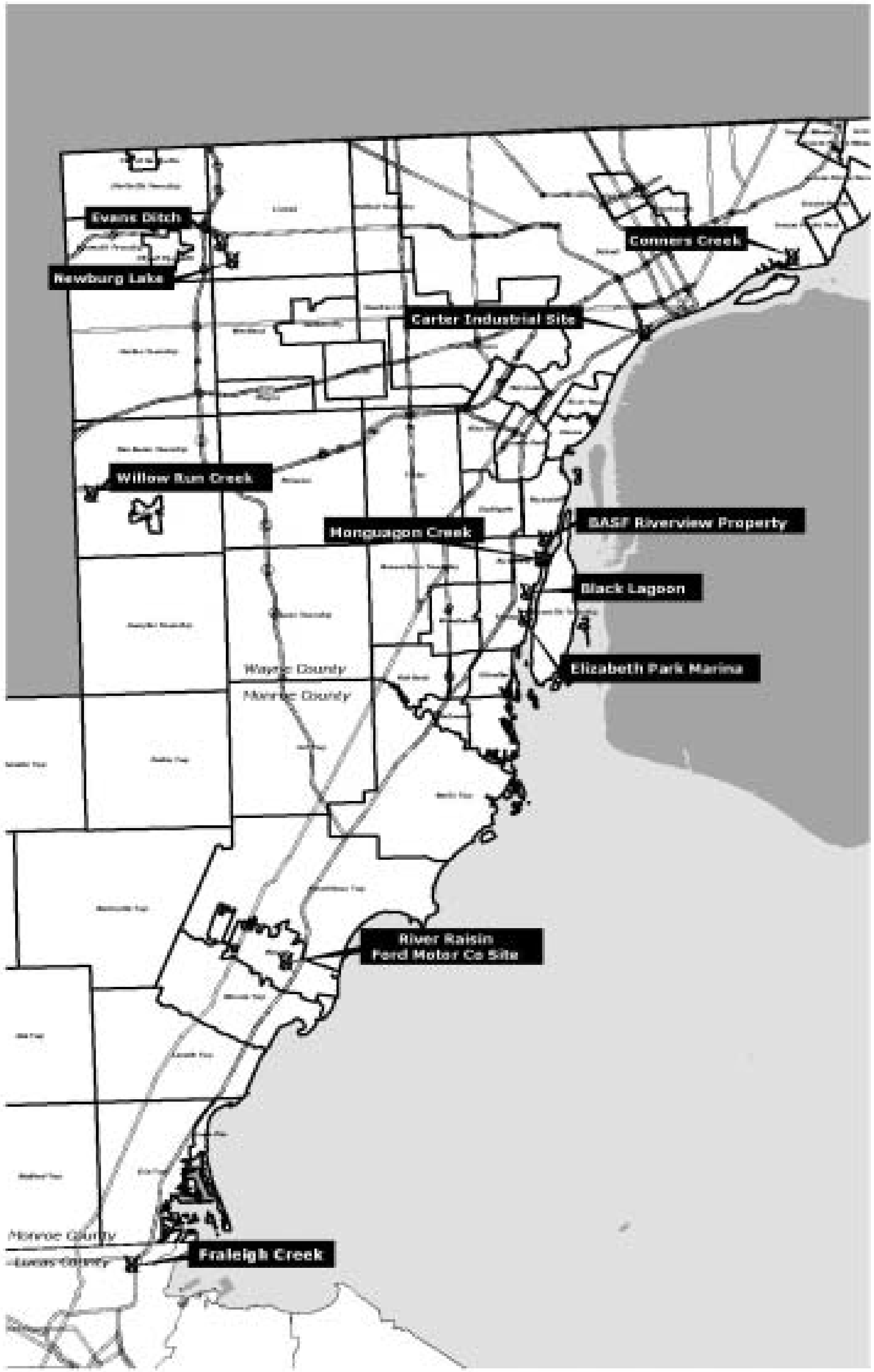


Figure 2. Navigational dredging in the Rouge River, 1963-2001 (total volume removed: 3,278,519 m^3).

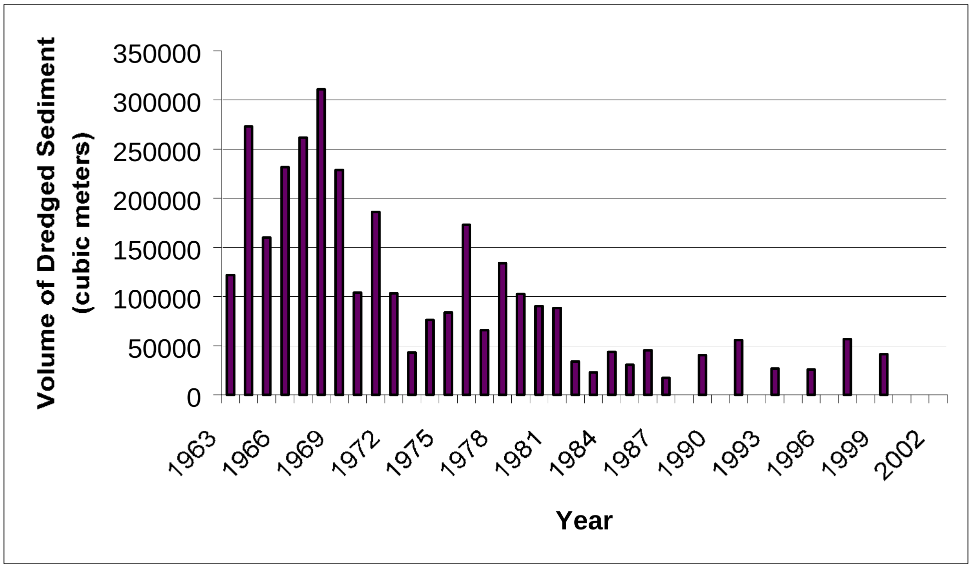
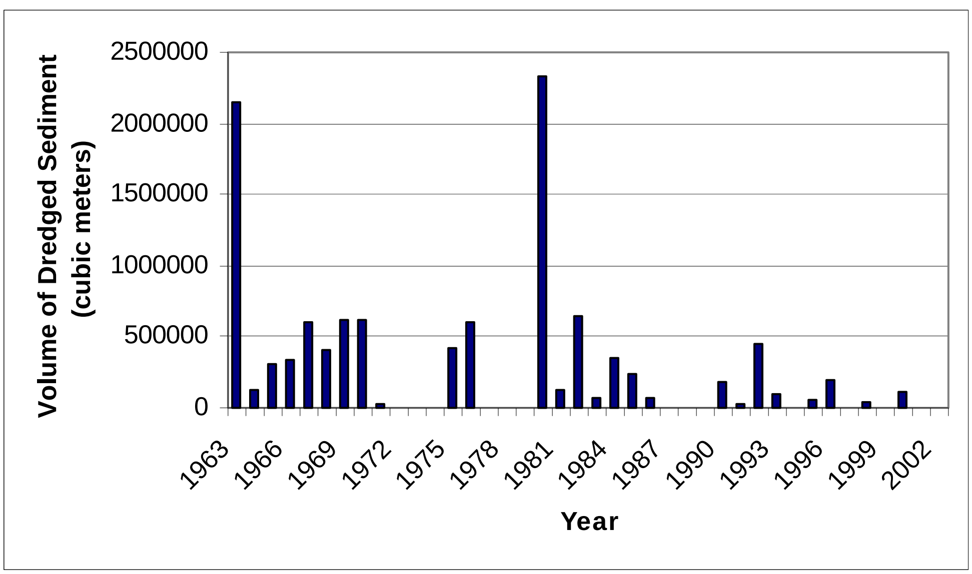


Figure 3. Navigational dredging in the Detroit River, 1963-2001 (total volume removed: 11,215,409 m^3).



APPENDIX 7. SPATIAL AND TEMPORAL TRENDS IN LAKE ERIE SEDIMENT PCB CONCENTRATIONS

Scott Painter & Chris Marvin
Environment Canada

In the early 1970s, Rich Thomas and others at Environment Canada conducted a spatially-intensive survey of sediment contamination in the Great Lakes and the data was archived in Environment Canada's Envirodat database by Norm Rukavina. Even more fortuitously, Rich and Norm had ensured that archived samples were still available from those earlier surveys and Mike Fox seized on the opportunity to analyze them using today's analytical methods. As well, Mike conducted a survey of 50 of the original sites in 1995 to compare spatial and temporal trends over the intervening period. In 1997, Chris Marvin expanded the information base to include a total of 70 sites and an expanded list of analytes (Painter et al. 2001). Chris has also extended the information to include the other Great Lakes thereby providing a retrospective opportunity with the earlier Environment Canada surveys.

Figure 1. Spatial and temporal PCB sediment concentrations in 1971, 1995 and 1997 illustrating the relative magnitude reduction in the absolute concentration.

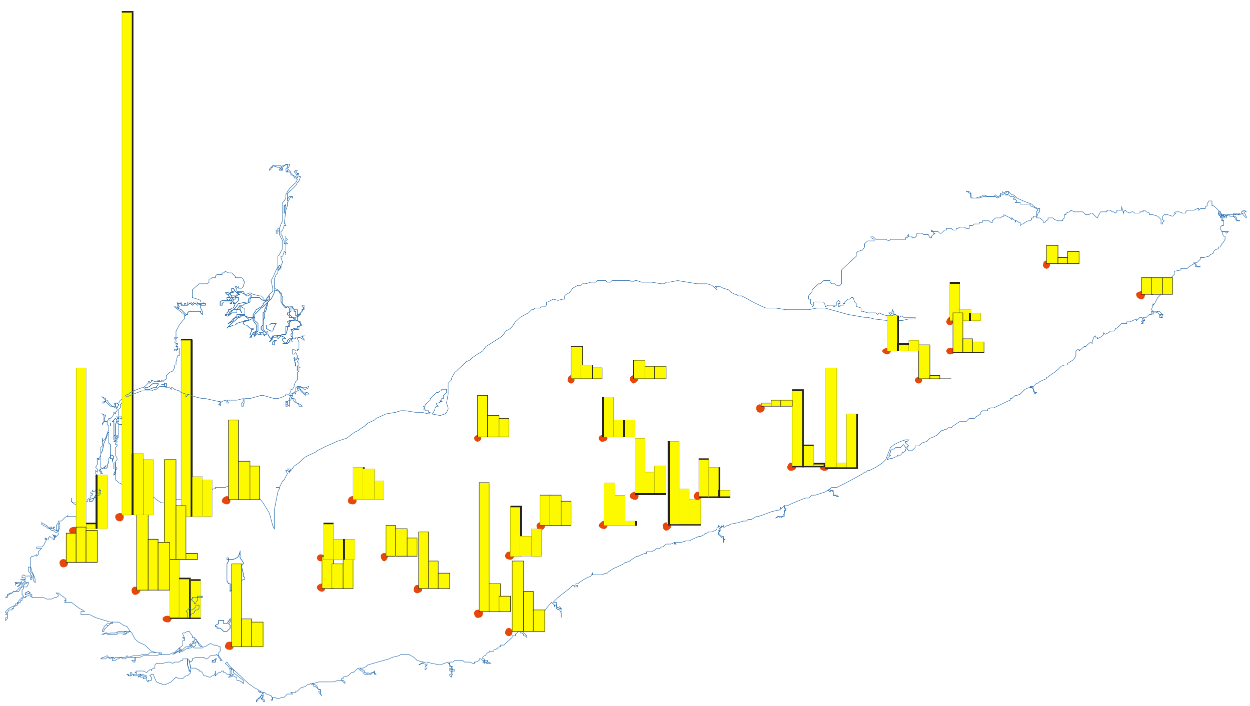
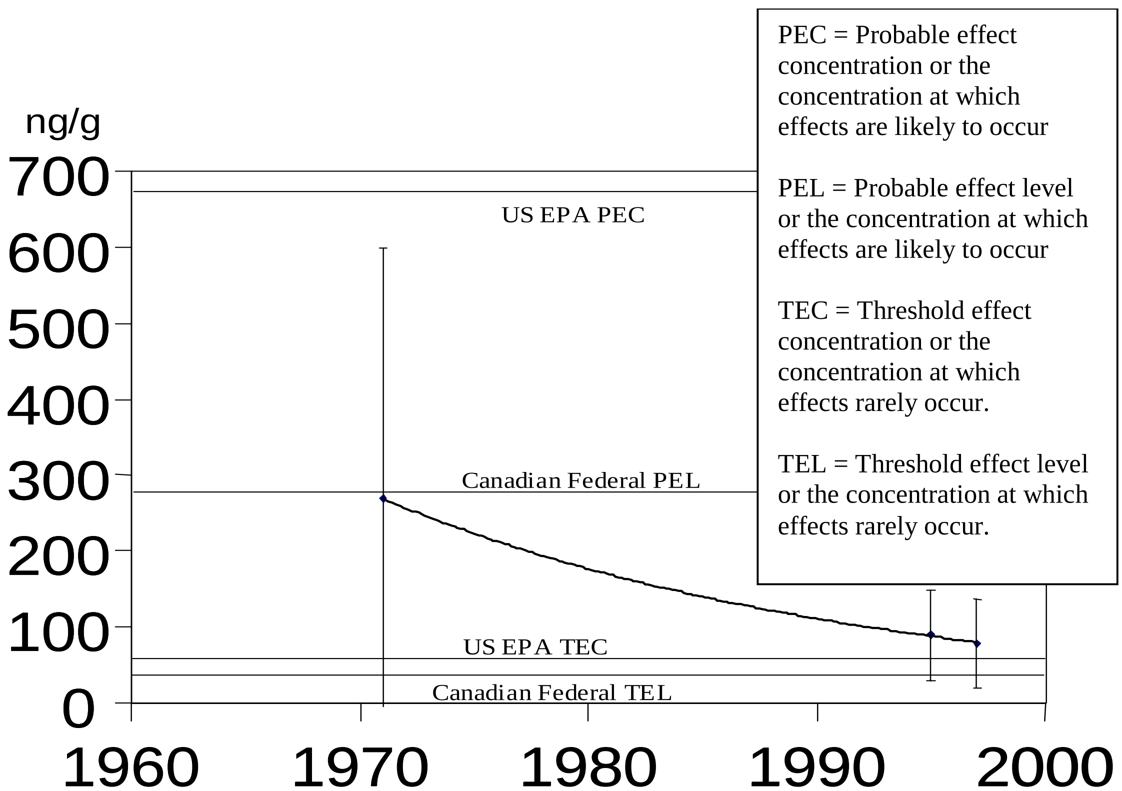


Figure 1 illustrates the spatial and temporal patterns in sediment PCB concentrations at 38 sites with data available from all three time periods. Based on these data, lakewide concentrations have declined by 80%. Declines are particularly dramatic in the western basin. Sediment cores from the western and central basin also confirm decreasing concentrations over time, although the decrease was approximately 40 – 50% at those specific locations.

The decline in the lakewide concentration is converging on several desirable US and Canadian sediment quality guidelines (Figure 2). Future surveys will continue to track the response in lakewide concentrations.

Figure 2. Lakewide sediment PCB average concentrations over time compared to guidelines.



Spatial patterns in the present day concentrations illustrate a west to east and south to north decrease in concentrations (Figure 3). These patterns are partly a result of sediment type patterns as well as proximity to historical sources. All of the eastern basin and at least half of the central basin are below the Ontario provincial lowest effect level of 70 ng/g and the US EPA threshold effect concentration.

Figure 3. Sediment PCB concentrations in 1997 illustrating spatial patterns.

In summary, PCB sediment concentrations have declined dramatically over the last 30 years, especially in the western basin. Present day lakewide concentrations are approaching provincial, U.S. and Canadian federal lowest effect or threshold effect concentrations.

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APPENDIX 8. POLYCHLORINATED BIPHENYLS (PCBS) AND OTHER PERSISTENT ORGANIC POLLUTANTS ASSOCIATED WITH DETROIT RIVER SUSPENDED SEDIMENTS

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Introduction

Environment Canada routinely monitors suspended sediment quality in the western Lake Erie - Detroit River corridor to assess the occurrence and spatial distribution of contaminants in order to understand the role anthropogenic activities play in discharging these compounds, and to provide information to devise effective strategies to mitigate potentially deleterious health impacts. Some Detroit River suspended sediments can originate in areas of severe chemical contamination, and thereby represent significant sources to downstream areas including the western basin of Lake Erie. Suspended sediment quality can also be used as a benchmark for future assessment of the efficacy of remediation of sites of contaminated sediment. Suspended sediments from the Detroit River have been collected since 1999 using sediment traps at sites ranging from western Lake Erie to southern Lake St. Clair and analyzed to determine the spatial distributions of contaminants including polychlorinated biphenyls (PCBs) polychlorinated dibenzo-*p*-dioxins and dibenzofurans (PCDDs/PCDFs) including dioxin-like PCBs (DLPCBs) and polychlorinated naphthalenes (PCNs).

Methods

Single-point sediment trap moorings were deployed from April to November at eight stations in 1999, and nine stations in 2000, in the Detroit River ranging from the mouth at the outflow to western Lake Erie to the head in southern Lake St. Clair. Each sediment trap mooring consisted of six individual 1-metre length sections of core tubing (7 cm internal diameter) affixed to a steel rack. The key parameter in the design of the traps is the aspect ratio, defined as the ratio of the internal diameter of the trap tube to the length. This aspect ratio determines if material collected passively in the tubes can be resuspended and flushed from the collection cups by *in situ* currents. The assembly was anchored using a railway wheel in order to maintain the stability of the mooring in strong current regimes. This design has proven to be a simple and robust method for field applications, and provides stability and ease of retrieval in riverine environments that may be subject to high current velocities and debris. A removable cup of high-density polypropylene was fitted to the bottom of each tube to provide a receptacle for sediment accumulation. The moorings were refurbished monthly and accumulated material deposited in the traps was removed, refrigerated at 4°C and transported to the laboratory.

Results and Discussion

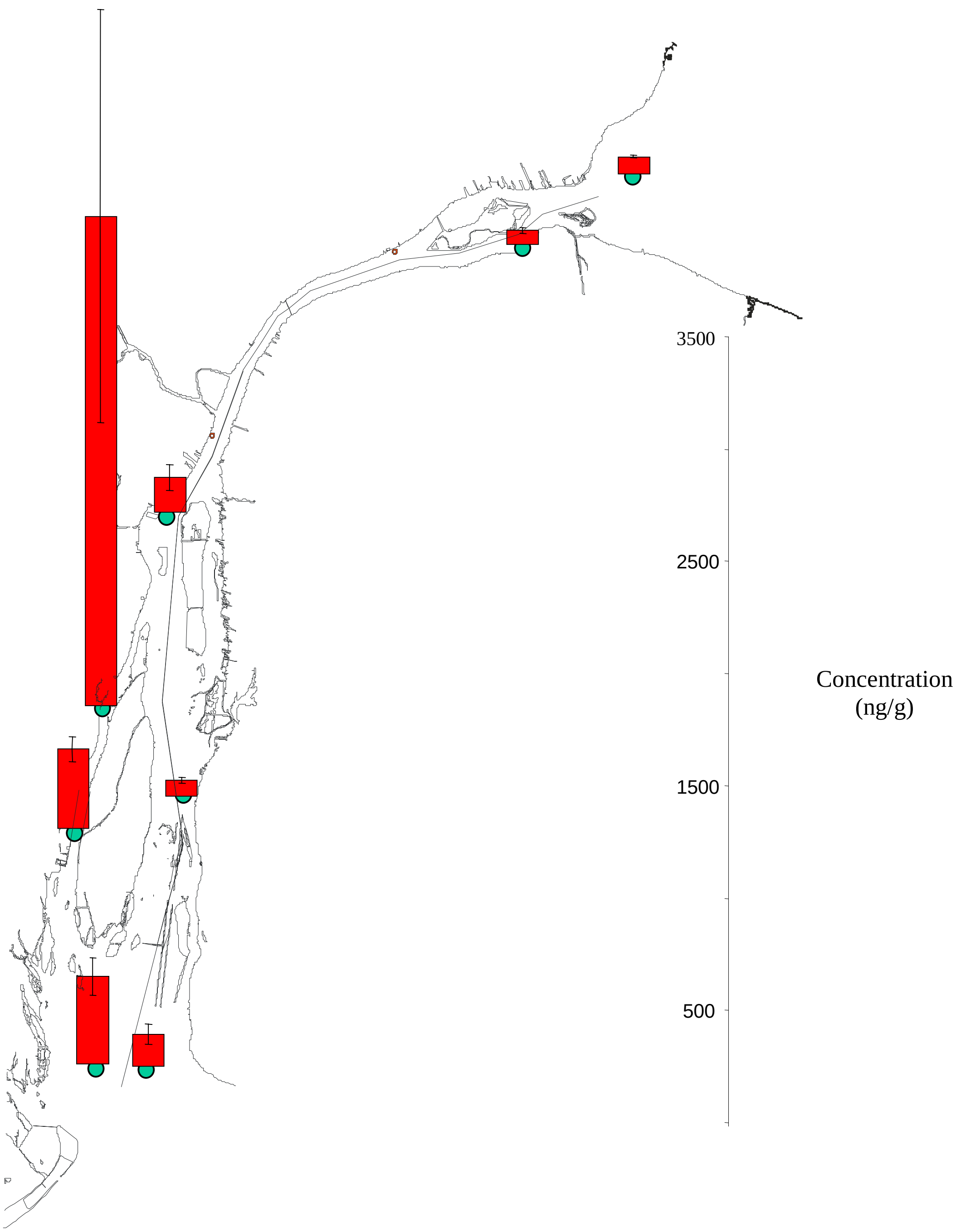
The spatial distributions of all contaminant classes were similar to that of PCBs (Figure 1), and concentrations were elevated at sites in the lower reaches of the river in the Trenton Channel. This area was historically characterized by intensive industrial activities including steel and chemical manufacturing, and coal-generated power generation. The Trenton Channel has been identified by the Michigan Department of Environmental Quality as containing the majority of contaminated sediment within the Detroit River. Concentrations of total PCBs in suspended sediments in 1999, expressed as the annual mean from six monthly samples from May to October, ranged from 62 mg/kg (dry wt.) in lower Lake St. Clair to 2,200 mg at a site near Monguagon Creek, immediately downstream of the Grosse Ile toll bridge (Figure 1). Two stations co-located in latitude but on opposite sides of the River, showed a roughly three-fold higher level of contamination at the outflow of the Trenton Channel, compared to the station influenced primarily by the Livingstone Channel. Sites upstream of the Trenton Channel exhibited a more homogenous spatial distribution with contaminant levels indicative of ambient background or moderate contamination.

The potential influence of the Trenton Channel as a source of contamination to western Lake Erie was further evidenced by PCDD/PCDF homologue profiles, which indicated a contribution from chemical manufacturing in addition to the normal background combustion profile. Toxic equivalents (TEQs) for PCDDs/PCDFs generally exceeded those for DLPCBs; combined total TEQs in July 2000 for these two compound classes ranged from 2.30 pg/g in southern Lake St. Clair to 306 pg/g at a station just downstream of Monguagon Creek in the Trenton Channel. The spatial distribution of PCN contamination was similar to that of PCDDs/PCDFs and DLPCBs, with the highest level of total PCNs (8,200 mg/kg) detected at a site in the Trenton Channel near Elizabeth Park; TEQs for PCNs in the Trenton Channel ranged from 73 pg/g to 3,300 pg/g. These data indicate that PCNs represent a significant contribution to dioxin-like biological activity in Detroit River suspended sediments. The relatively low PCN concentrations at the upstream stations also indicated that there are few major sources of PCNs upriver of the Trenton Channel.

Conclusions and Recommendations

There is a definitive gradient toward increasing suspended sediment contamination moving downstream from the upper reaches of the Detroit River through the Trenton Channel in the lower river. These results indicate that the river continues to be a source of loadings of a variety of contaminants to the western basin of Lake Erie but the significance of these loadings, compared to material originating in the upper lakes and connecting channels, is difficult to determine. The Detroit River continues to be the primary vector for contamination; however, an assessment of temporal trends in sediments in western Lake Erie has determined that loadings of PCBs have decreased significantly in the last 25 years.

Figure 1. Annual average spatial distribution of polychlorinated biphenyls (PCBs) in suspended sediments in the Detroit River in 1999.



APPENDIX 9. SEDIMENT-ZOOBENTHOS INTERACTIONS

Jan J.H. Ciborowski and Lynda D. Corkum 2
Department of Biological Sciences and Great Lakes Institute2
University of Windsor2

Introduction and Background

Benthic invertebrates may form an integral link in food webs of aquatic and terrestrial ecosystems. Highly toxic sediments produce profound but sometimes nonspecific reductions in benthic abundance and richness. Less toxic sediments may elicit sub lethal stresses within populations that are undetectable at the community level. Relative effects of acutely toxic sediments can be evaluated through laboratory sediment bioassays using dilution series. Where sub lethal effects are suspected, immatures can be examined for bioaccumulation potential, impairment of growth, morphological deformities or other biomarkers. Because benthic invertebrates accumulate PCBs and other compounds from the sediments in which they dwell, their body burdens can serve as valuable indicators of contaminant transfer to upper trophic levels. Thus, even when sediments are not acutely toxic, such persistent compounds can be biomagnified through the zoobenthos to the extent that zoobenthivores and their predators accumulate body burdens that are toxic.

In the Detroit River as in other flowing water systems, zoobenthic distribution is regulated by the prevailing flow conditions and the characteristics of the river bottom. Slow-flow, soft sediment areas with moderate to good water and sediment quality support *Hexagenia* mayflies, gammarid amphipods, molluscs, and chironomids. Hydropsychid (net-spinning) caddisflies, molluscs, gammarids and chironomids are most characteristic of the hard substrates of erosional zones when water quality is good. Degraded areas become dominated by oligochaetes.

Similar patterns pertain to western Lake Erie. Soft, muddy sediments of deeper waters are dominated by *Hexagenia* mayflies and *Oecetis* caddisflies when water and sediment quality are good, but support primarily tubificid worms in degraded conditions (Wright and Tidd 1933, Carr and Hiltunen 1965). Rocky, wave-washed shoreline areas support hydropsychid caddisflies and other taxa characteristic of flowing-water habitats (Barton and Hynes 1978).

Study Objectives and Research Results

Bioaccumulation of PCBs from sediments by Detroit River benthos: Laboratory bioassay studies conducted with *Hexagenia* mayfly larvae grown in Detroit River (Trenton Channel) sediments indicate that most PCB congeners reach steady state within 30 days (Drouillard et al. 1996). Other bioassays showed that although half-grown *Hexagenia* larvae are not killed by 21-d exposure to Detroit River (Trenton Channel) sediments, newly-hatched mayflies could grow to emergence only in sediments diluted to 25% with reference sediment (Corkum et al. 1995). Regression analysis of total PCB concentration in sediments vs. concentrations in *Hexagenia* nymphs surviving to the end of that 244-day experiment showed a strongly linear relationship (R^2= 0.92). Total PCB concentrations in nymphs (mg/kg lipid) were 10.8 times the sediment concentrations (mg/kg organic carbon; Ciborowski et al. 1993). Adults that emerged from bioassay jars just prior to the end of the experiment had the same PCB concentrations as nymphs recovered at the end of the study. Kovats and Ciborowski (1993) observed minimal differences between PCB concentrations in *Cheumatopsyche* (Hydropsychidae) caddisfly larvae from the Detroit River and concentrations in adults captured from the same location in light traps. Therefore, concentrations of PCBs in both larval and adult mayflies and caddisflies are precise indicators of the concentrations in the sediments in which they grow. Corkum et al. (this volume) report on the spatial and temporal patterns of PCB concentrations in adult insects collected from the Detroit River and western Lake Erie.

Bioturbation: The burrowing activities of *Hexagenia* larvae cause significant bioturbation (Ciborowski et al. 1999, Bachteram and Ciborowski 2002). Sediment reworking by *Hexagenia* in the Detroit River and western Lake Erie may keep sediment-associated PCBs in the biogenic zone and resuspend particles together with their bound contaminants.

Composition and distribution of Detroit River zoobenthos: Historical studies of zoobenthic community composition dating as early as the 1920s reported that depositional zones of the Lower Detroit River have been moderately or severely degraded up until the mid 1960s (Table 2). Zoobenthic community composition in the early 80s indicated some improvement in the lower Detroit River reaches. In particular, *Hexagenia* mayfly larvae were found at approximately 70% of locations sampled (Thornley and Hamdy 1984). There has been little change in benthic community composition since that time. In particular, the Trenton Channel remains depauperate of zoobenthos (Wood 2002). However, the presence of *Hexagenia* mayflies and hydropsychid caddisflies provides an opportunity to monitor the spatial distribution and temporal changes in bioavailable concentrations of PCBs and other persistent organic compounds (Corkum et al. 1995, Corkum et al. this volume).

Composition and distribution of Lake Erie zoobenthos: The *Hexagenia* population has historically been an important component of the western Lake Erie food web. Reynoldson et al. (1989) summarized basin-wide densities of *Hexagenia* up to the mid-1980s and discussed extirpation of the population in the 1950s. The westernmost portion of western Lake Erie has been degraded by Detroit River flows since at least the 1930s. *Hexagenia* mayflies had disappeared from the Detroit rivermouth long before their extirpation in the rest of western Lake Erie. Organic pollution entering the Detroit River had resulted in degraded sediments in the western-most portions of western Lake Erie by 1929 (Wright and Tidd 1933). Although basin-wide *Hexagenia* density was still high in 1951, nymphs were rare or absent from the western half of the basin (Wood 1970). Tubificid oligochaetes and one or two genera of chironomids made up most of the benthic community in these areas (Carr and Hiltunen 1965, Schloesser et al. 1995).

Chironomids collected in 1982 from areas extending from the mouths of the Detroit and Maumee Rivers exhibited elevated incidences of mouthpart deformities. Teratogenicity had decreased by 1993 (Doherty et al. 1998). The most likely causes of such deformities are sediment-associated trace metals, chlorinated pesticides and possibly PAHs.

Krieger et al. (1996) and Schloesser et al. (2001) documented *Hexagenia's* reappearance in the early 1990s. Basin-wide densities have increased by 2-4X annually. By 1998, values were comparable to those reported prior to the 1950s. Although basin-wide densities of *Hexagenia* have returned to their former levels, the present distribution of larvae and their PCB body burdens are markedly different from historical patterns. *Hexagenia* nymphs first reappeared in western Lake Erie in Maumee Bay and east of the Detroit rivermouth around 1990, and their distribution has since expanded eastward. In 1998, nymphs were abundant throughout the western basin except in the Pigeon Bay region north of Pelee Island and in a broad band corresponding to the flow path of the Detroit River through western Lake Erie (Ciborowski et al.

unpubl.). In 1929 and 1951, only 8-11 percent of the western basin's *Hexagenia* s24 biomass (totals of 1.63×10^4 and 9.3×10^3 tonnes dry mass, respectively) was located in the western-most third of western Lake Erie. In 1999, the western-most third of the basin supported 65 percent of the estimated basin-wide biomass of 1.89×10^4 tonnes (Ciborowski et al. unpubl.). The current distribution corresponds more closely to areas of industrial contaminant deposition in sediments than did the distribution of nymphs prior to their disappearance in the 1950s. This implies that *Hexagenia* are likely a more important agent of biomagnification through the food web and contaminant remobilization (through bioturbation) now than previously.

Research, modeling, monitoring and management recommendations relative to sediment-biota interactions

Zoobenthos are clearly a major source of contaminant transfer through the food web. They are also likely major agents of contaminant remobilization through bioturbation. We have newly-acquired knowledge of current and historical sediment-associated PCB distributions (Painter et al., Marvin et al., this volume), zoobenthic distributions, and sediment-biota bioaccumulation and bioturbation transfer coefficients. The data are now available to permit us to develop spatially explicit estimates of PCB transfers through zoobenthos to top predators. Because zoobenthos are immobile, these estimates would have much higher spatial resolution than more integrative measures such as contaminant estimates of fish tissues or bird eggs.

Such estimates must be validated by appropriate monitoring. Collection of adult caddisflies and mayflies using light traps (Corkum et al., this volume) provides an accurate and highly cost-effective means of doing this. These data will be integral in improving the precision and predictions of our new models of Detroit River sediment-associated contaminant dynamics (Reitsma et al., this volume) and bioaccumulation (Drouillard et al., this volume).

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APPENDIX 10. A SUMMARY OF OTTAWA RIVER PCB INVESTIGATIONS, AND THE CLEANUP OF FRALEIGH CREEK

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Introduction

In 1985, the Lower Maumee River and Maumee Bay were listed as Areas of Concern by the International Joint Commission, mainly because of PCB contamination. A major source of the PCB contamination in the Bay was thought to be originating from the Ottawa River. The main reason for this was the presence of "wall to wall landfills", and several operating and abandoned industrial sites bordering the river. The water was severely impacted visually and chemically by oil sheens. Biologically, the river was not able to support healthy or diverse aquatic communities.

Data were collected in the late 1980s and early 1990s that supported the idea that PCBs were prevalent in the Ottawa River. It also became apparent that a major source of PCBs into the river was coming from an unnamed tributary, (later named Fraleigh Creek), located 5.9 river miles upstream of the confluence of the Ottawa River with the Maumee Bay. In 1991, the Ohio Department of Health issued a fish consumption and contact advisory for the Ottawa River from the mouth upstream to river mile 8.8.

Study Objectives and Research Methods

Ottawa River

Several investigations have been performed on the Ottawa River to better quantify the distributions of PCBs (as well as other contaminants), and determine the impacts on the biological communities. In 1994 a screening of surface sediments was conducted using immunoassay field kits. This was followed in 1998 by a comprehensive sampling effort which included the coring of sediment at every tenth of a mile along the creek up to river mile 8.8. At each tenth of mile, three cores were collected, one from each side of the river, and one from the middle of the river (in the channel). The cores were collected mechanically using a "vibra-core" unit with a plastic coring tube approximately ten feet in length. During this study 180 cores were collected, and from those, 365 samples were extracted and analyzed by a laboratory. Additionally in 2000, sediment and water quality samples were collected to fill data gaps necessary to conduct an ecological and human health risk assessment on the Ottawa River.

Fraleigh Creek

In 1988, Ohio EPA identified that the highest level of PCBs in the sediment along the Ottawa River was 2,500 mg/kg at a location adjacent to Fraleigh Creek. A more intensive investigation revealed that fish tissue of carp collected from the Fraleigh creek contained PCB concentrations up to 500 mg/kg. Sediment in the creek contained PCB concentrations up to 74,000 mg/kg. This investigation resulted in a cleanup of the severely contaminated area.

A partnership was formed which included governmental and private entities. The project involved hydraulically separating the drainage in the area from the Ottawa River, cleaning and rerouting drainage tiles from upland areas, removal of PCB sediments, backfilling after the removal, and site-grading to conform to desired flow conditions.

Discussion of Results

The major sources of PCB's that were flowing into the Ottawa River have been addressed and controlled. These source controls included such things as barrier separation through sheet-piling walls, leachate collection and treatment, capping, and removal activities. The Fraleigh Creek area has undergone significant removal, thus eliminating another significant source of PCBs into the river.

In 2000, sediment data, along with fish tissue, water quality, food web, and other pertinent data collected from the Ottawa River, were used to conduct a human health and ecological risk assessment. This assessment concluded that fish ingestion should continue to be avoided, and that the ecological communities are still unable to exist to the levels that would be needed to achieve the designated use of the river. To date, areas have been identified that have the highest levels of contaminants, and currently the feasibility of cleanup alternatives is being investigated.

Conclusion and Recommendations

Throughout the history of working toward the reduction of PCB loadings into the Western Lake Erie Basin, developing partnerships among diverse groups of people with differing interests seems to be the most effective means for planning investigations and cleanups. This reduces the amount of effort, time, and dollars that would be required if all parties were to conduct their work independently of each other, and ensures that all interests are brought up together and evaluated together.

Because the advisory zone of the Ottawa River is a stretch of almost nine miles, a thorough characterization of river sediment deposition and composition, and the health of the ecological communities was helpful to a) identify potential sources needing investigated and/or controlled, b) perform required risk calculations to determine the level of remedial effort necessary and c) provide a basis for later comparison to determine the effectiveness of remedial actions.

It is also important to thoroughly identify the pollutant sources early in the planning process so that they can either be eliminated or controlled prior to performing sediment remediation.

APPENDIX 11. PCBS IN SEDIMENTS – A REMEDIAL ACTION PLAN PERSPECTIVE

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What do we know about PCBs in sediment?

Sediments carry the highest concentrations, the greatest mass at any point in time, and are the largest source of contaminants that effect Beneficial Use Impairments (BUIs) as outlined in the Great Lakes Water Quality Agreement (GLWQA). This holds true especially for Polychlorinated Biphenyl compounds (PCBs) in Areas of Concern (AOCs) such as the Detroit River, River Rouge, and River Raisin.

Historic discharges were the primary source of existing PCB contamination to the sediments. Sediment depositional zones have been delineated and thoroughly assessed in the Detroit River-Western Lake Erie Basin. Numerous system-wide assessments have been conducted since the late 1970s. Since 1993, the MDEQ-SWQD in partnership with USEPA-Great Lakes National Program Office, and USEPA-Large Lakes Research Station, has concentrated on delineating the extent of sediment contamination in AOCs in preparation for remedial actions.

Has there been change over time in PCB levels in fish, water, and sediments based on MDEQ monitoring data?

Concentrations of PCBs, along with other contaminants, vary tremendously within environmental matrices. There is no meaningful "average" Detroit River PCB value for fish, water, or sediment samples. However, general trends in PCBs over time can be inferred. They point to a large decrease in PCB loadings to the Detroit River and Western Basin of Lake Erie in the past 30 years. Sampling has also showed that concentrations in both the water and sediments continue to be significantly greater along the nearshore areas of the Michigan mainland, than in other areas of the AOC.

Fish

Changes in fish tissue concentrations for the Detroit River (no remediation) and River Raisin (by mechanical dredging) do not show a significant trend or response. Levels of PCBs in Belleville Lake walleye did decrease following PCB excavation in Willow Run Creek, a major tributary. National results collected by EPA Region V show that PCB sediment remediation significantly decreases PCB levels in fish tissue (4x – 9x) over time.

Water

Based on historical and more recent studies in the Detroit River, loadings of PCBs have decreased 20 fold since their ban in 1977, and further decreased an additional 50% between 1985 and 1995. Current PCB concentrations in the water column of the Detroit River range between <5 and 35 ng/l. Point sources, specifically in the Trenton Channel, are not a significant source of PCBs to Lake Erie, and current point sources are also not a significant source of PCBs to sediments in the Detroit River. National trends show that PCB concentrations in surfaces waters decrease up to 17x following sediment remediation.

Sediments

There have not been significant changes over time in sediment PCB concentrations in the Detroit River AOC or Rouge River AOC, since there have been few areas remediated. Based on assessments to date, there remains approximately 764,526 m^3 (1,000,000 yd^3) of contaminated sediments in the Detroit River, and another 764,526 m^3 (1,000,000 yd^3) of contaminated sediments in the Rouge River (turning basin to Detroit River).

In the River Raisin, bulk removal of the contaminated hotspot in 1998 removed 20,642 m^3 (27,000 yd^3) from the system. Portions of the area remediated have been re-contaminated. In the River Raisin AOC, approximately 382,263 m^3 (500,000 yd^3) of sediments remain contaminated with PCBs.

Willow Run Creek, a tributary to the Huron River, was diverted and excavated in 1997-1998, with 344,037 m^3 (450,000 yd^3) of sediments dewatered and buried on-site. Since the source of the contamination was historic, sediments have not been recontaminated.

Recommendations

There remains approximately 2,293,578 m^3 (3,000,000 yd^3) of sediments that impact BUIs in the Detroit River, Rouge River, and River Raisin combined. The USACE (Corp) has taken navigational channel dredged material from these AOCs to Confined Disposal Facilities (CDFs) at a cost of under $5.00 per cubic yard. The contaminant level in navigation channel sediments are not significantly different than those immediately outside the channel.

The Point Mouillee CDF was commissioned in 1974 at a capacity of 10,703,364 m^3 (14,000,000 yd^3) and a life span of 10 years. The CDF today has 6,880,734 m^3 (9,000,000 yd^3) of capacity remaining, and accepts approximately 136,086 m^3 (178,000 yd^3/year) in Corp and public navigational dredge spoils. If all of the contaminated sediments from the Detroit River, the River Rouge, and the River Raisin AOCs, 2,293,578 m^3 (3,000,000 yd^3), could be removed from and placed in the Point Mouillee CDF, over 50 years of navigational dredging capacity would remain. Contaminated sediments placed in some CDFs have been shown to impact local biota and groundwater, though the benefits of removing and confining the contaminants far outweigh the consequences of leaving them in place. Monitoring of PCBs and other contaminants in the Detroit River and Western Lake Erie Basin should move from a focus of “detection” to a focus of “protection”. There are areas of the Detroit River AOC that are pristine, and could be considered for ”sub-watershed” delisting. Areas such as Peche Island, Belle Isle, Humbug Marsh, and areas in the International Wildlife Refuge (Calf, Humbug, Celeron, Stoney, Sugar Islands) would likely qualify.

Conclusion

From a Remedial Action Plan perspective, in the short term, contaminated sediments that effect BUIs should be removed and placed in CDFs, using best management practices, in a similar mandated fashion as navigational sediments are currently removed. Disposal capacity is not an issue, and costs for resuspension controls would not significantly add to the costs as compared to navigational dredging.

Sediment remediation is still in development, and each area presents unique challenges. Agencies, environmental groups and the general public may need to view sediment remediation in the same vein as navigational dredging, not as a one time exercise, but as a periodic necessity to limit contaminants exposed to the eco-system and maintain levels that do not effect beneficial uses. In the long term, treatment technologies need to be developed and utilized if we are to achieve our vision of virtual contaminant elimination in AOCs.

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APPENDIX 12. PCB TRENDS IN FISH AND SEDIMENT FROM THE ROUGE RIVER FOLLOWING SEDIMENT REMEDIATION ON EVANS DITCH AND NEWBURGH LAKE

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Newburgh Lake is a 105-acre impoundment located on the Rouge River in Wayne County, Michigan, a branch of the Detroit River basin. Newburgh Lake had the potential of being one of the valuable recreational areas in the urban metropolitan Detroit area and therefore a local asset to the Lake Erie Basin.

The history of the lake encompasses over 65 years of sediment accumulation, some contaminated with PCBs, which over time, degraded the lake water quality. Shallow water depths resulting from the sediment accumulation and nutrient-rich water led to excessive growth of aquatic plants and the presence of organic contaminants such as PCBs that tend to bioaccumulate, as they pass up through the food chain, resulted in a potential human health hazard. Construction on a project was initiated in the spring of 1997, after initial studies and design had been completed, to remediate and restore Newburgh Lake and there by return this valuable resource to the citizens of the region.

Removal of the sediment and restoration of the lake was completed through a variety of construction practices. Sediment was removed from the lake by use of cutter-head dredges, draglines, and conventional earth moving equipment. The removal operation was complicated by the varying nature of the sediments in the lake bottom, the urban setting, storm events, the highly used park area, and a major sanitary sewer that ran under the lake. The contaminated material and some of the non-contaminated material was hauled to a solid waste landfill in the area. Additional clean sediment was used to help create shallow water shoals and increase surface area of an island for habitat.

The Newburgh Lake Restoration Project set out as its overall objective to reduce to acceptable levels of risk at the lake associated with the sediment by removing and disposing of the sediment and restoring the lake to beneficial use. This main objective was accomplished. The project: 1) Repaired level controls in the dam structure, 2) Removed approximately 558,000 tons of sediment for the lake, approximately 350,000 tons of sediment removed contained PCBs based on the project's classification, 3) Disposed of all 558,000 tons in a Type II landfill, 4) Deepened the lake to a minimum of 8 feet, except were shoal were constructed, 5) Established 10 acres of aquatic vegetation on the shoals, 6) Eradicated, removed, and disposed of approximately 30,000 pounds of contaminated and rough fish, 7) Created structural and spawning bed fish habitat, 8) Restocked the lake with game fish, 9) Resurfaced 2 miles of roads through the park/lake area, 10) Provided a new boat ramp and docks, and 11) Cleared areas of park for more recreational use.

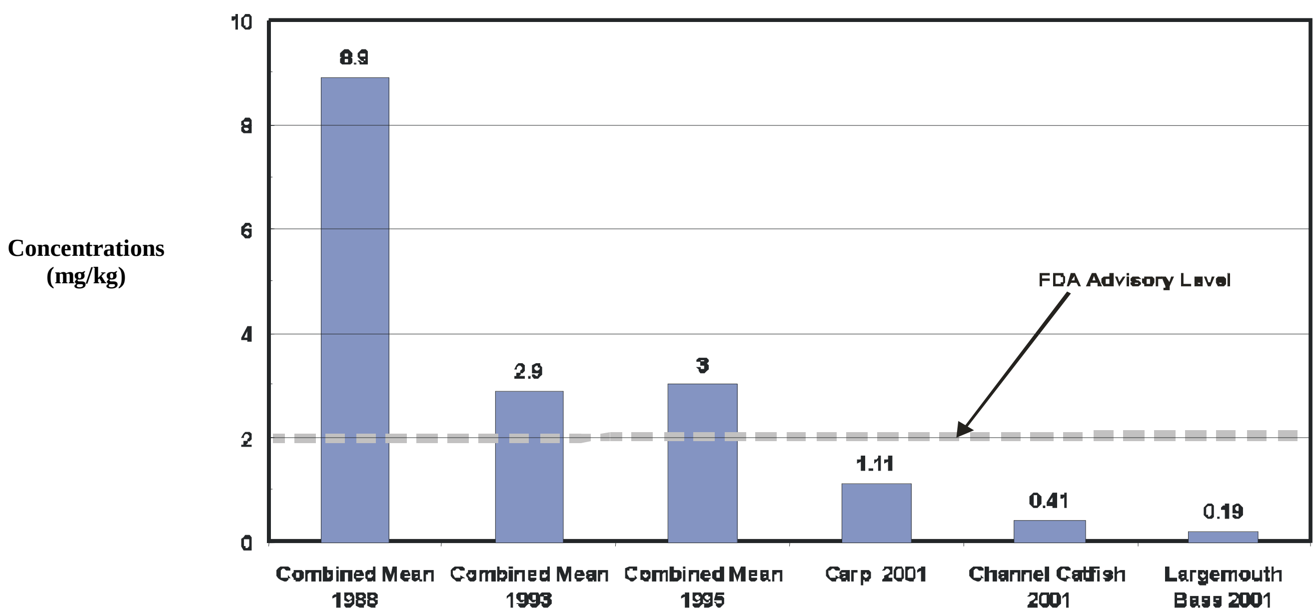
As stated previously over 30,000 pounds of contaminated and rough fish were removed from the lake and river upstream. This was done specifically to aid in the elimination of the fish advisory for PCBs and therefore reduce human health risks. The two fish eradications conducted in June 1997 and August 1998 removed the PCB contaminated fish from the river and lake.

Since PCBs bioaccumulate in the food chain, the removal of the PCB contaminated sediments will prevent future fish contamination from PCBs. Additionally, new game fish were restocked in September 1998 with additional restocking in each of the next two years. As a follow up to the restocking program, fish assessments have been performed at Newburgh Lake over the past few years in order to determine the relative health and growth of fish populations. The results of these assessments is that all fish species that were stocked in Newburgh Lake have adapted well and are in good visual health. MDEQ in the fall of 2001 collected fish for PCB analysis for review of the fish advisory in place at the lake. The results were released in the fall of 2002 and the data looked very good (Figure 1). The mean concentrations of the fish collected for advisory analysis were as follows:

- Largemouth Bass = 0.19 +/- 0.09 mg/kg (standard deviation)
- Carp = 1.11 +/- 0.61 mg/kg (standard deviation)
- Channel catfish = 0.41 +/- 0.26 mg/kg (standard deviation)

The FDA limit for PCBs in fish is 2.0 mg/kg.

Figure 1. Newburgh Lake fish mean PCB concentrations.



The MDEQ will present the data to the Michigan Department of Community Health this fall, with the recommendation that the fish consumption advisory for Newburgh Lake be loosened from “Do not eat these fish” to some lesser advisory that is typical for this river system.

Follow-up sediment sampling since the projects completion in 1998 has continued to show non-detectable concentration of PCBs. As a result the lake has once again become a valuable resource to the community.

APPENDIX 13. TEN-MILE DRAIN POLYCHLORINATED BI-PHENYL INVESTIGATION AND REMOVAL ACTION SITE

ST. CLAIR SHORES, MACOMB COUNTY, MICHIGAN2

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Introduction and Background

The Ten-Mile Drain (TMD) PCB Investigation Site lies on the northern side of Detroit, on the western shore of Lake St. Clair. The site is located in a residential and commercial area of St. Clair Shores, Macomb County, Michigan (Figure 1). In March 2002, U.S. Environmental Protection Agency (EPA) assistance was sought in conducting a site assessment and in evaluating the nature and extent of potential threats to human health and the environment at the site.

Figure 1. St. Clair Shores, Michigan located on the western shore of Lake St. Clair.

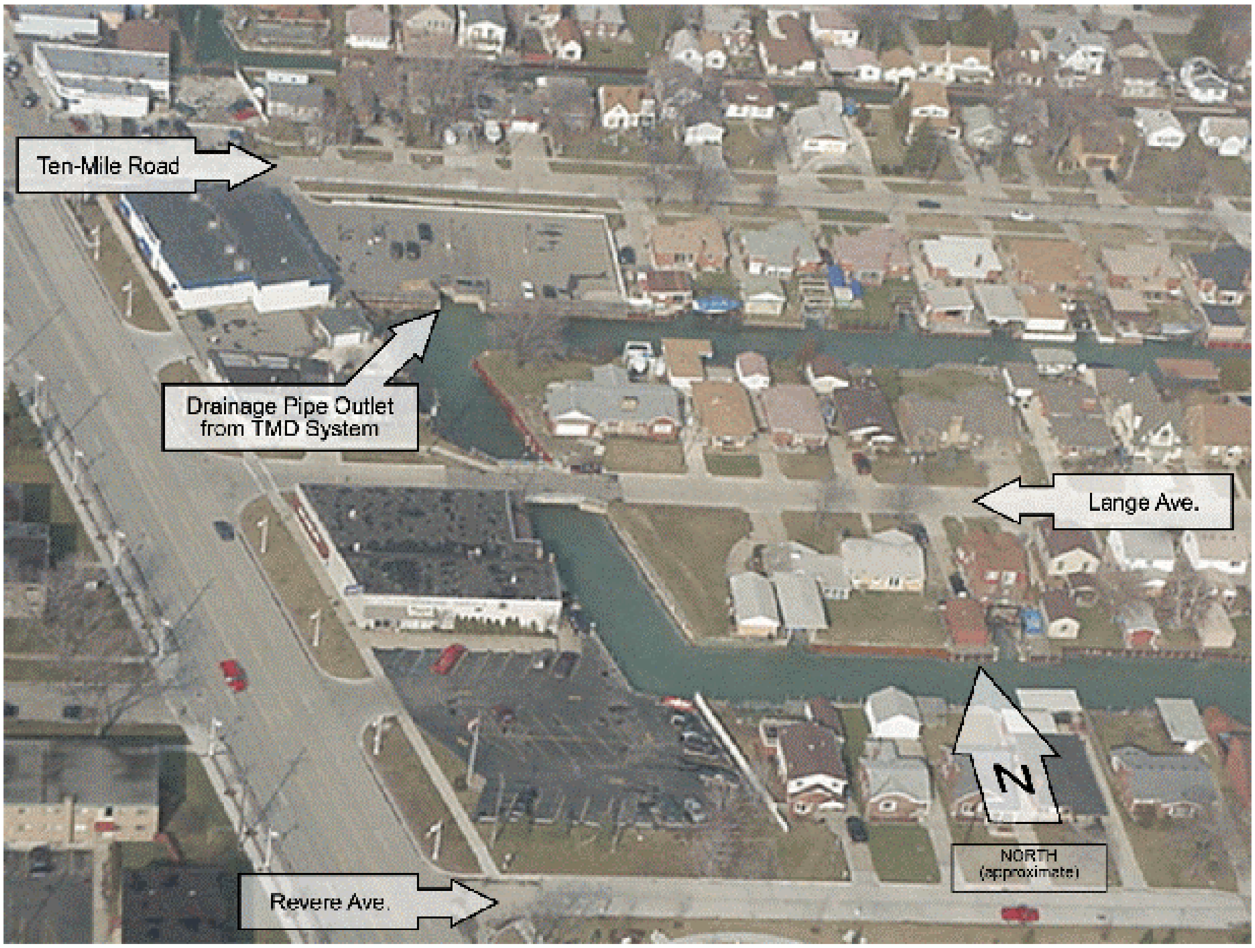
The TMD PCB Investigation Site includes the following components: (1) the TMD System, (2) sanitary sewers along Bon Brae Avenue, and (3) the Ten-Mile/Lange/Revere Canal (the canal) (Figure 2). Preliminary data indicated that sediment in the TMD System and canal had been impacted by PCBs and that the highest PCB concentrations were found in sediment located within the TMD System near the intersection of Harper and Bon Brae Avenues. It also appeared that contaminated materials from the TMD System had impacted the canal near a drainage pipe outlet from the TMD System in the northwest corner of the canal. The canal is connected to Lake St. Clair, which is connected to Lake Erie.

Study Objectives and Research Methods

The objectives of this study were to obtain usable data quickly to evaluate the nature and extent of contamination for a large area (including over 260 acres of storm sewer lines, sanitary sewer lines, and canal area) and to identify potential sources of the contamination. As documented in the site assessment plan, water, sediment, and wipe samples were collected from the TMD System and selected sanitary sewers. Water and sediment samples were also collected from the canal (Tetra Tech 2002a). In addition, the U.S. EPA FIELDS team provided support in measuring depth in the canal and modeling contaminant concentrations in the canal. The site assessment report should be available to the public in August 2002. Ambient air samples also were collected and a water sample was collected from a pond at a local park, which had received water from the canal. Sediment, water, wipe, and air samples were analyzed for PCBs using U.S.

Figure 2. Western end of the Canal in St. Clair Shores, Michigan.

EPA-approved methods (U.S. EPA 1996 and 1999a).



To address the need to obtain data quickly, two analytical laboratories were used and data validation was conducted on an ongoing basis. Preliminary, unvalidated data was used to assist in guiding later rounds of sampling. Approximately 300 samples were collected and analyzed between March and June 2002. Data validation was conducted and documented for all samples (U.S. EPA 1994, U.S. EPA 1999b, and Tetra Tech 2002b). Challenges associated with this site assessment include the time frame of the sample collection and incorporating uncertainty associated with analytical results of PCBs. This uncertainty factor and the means used to address this uncertainty will be described in the site assessment report.

U.S. EPA standard practices and approaches for the site assessment were used to complete the site assessment. Activities included: (1) use of appropriate decontamination protocols, (2) identifying appropriate screening levels, (3) validating all data, (4) using Geographic Information System (GIS) tools, (5) evaluating other available data such as historical records and data obtained by other agencies, (6) generating site maps, and (7) preparing a site assessment report.

Discussion of Results

Analytical data confirm that PCBs are present throughout the TMD System. The source area appears to be concentrated at the western end of the storm sewer line near the intersection of Bon Brae and Harper Avenues; concentrations of PCBs in sediment along Bon Brae were as high as 121,00 milligrams per kilogram (mg/kg) and many samples were above the screening level of 10 milligrams per kilogram (mg/kg). The highest concentration of PCBs in a water sample was above the established screening level of 0.5 micrograms per liter (0.5 μg/L) and was obtained from the storm sewer. The sanitary sewer lines provided fewer locations where sediment samples could be obtained. Only one sediment sample was obtained from the sanitary sewer sampling locations. The PCB concentration in the sample was below the screening level of 10 mg/kg. The highest concentration of PCBs detected in a sanitary sewer water sample (4.1 μg/L), which was significantly lower than those concentrations detected in storm sewer water (510 μg/L). Based on video camera inspection of the storm and sanitary sewers and a review of structural maps, it appears that PCB-containing materials could have entered the sanitary sewers through potential infiltration from the storm sewer through seeps or leaky joints in the system. Materials in the sanitary sewer discharge to the city of Detroit publicly-owned treatment works (POTW).

Eighty-two sediment samples were collected from 33 locations in the canal, at various depths. The highest concentrations of PCBs in sediment generally occurred in the western end of the canal (particularly around the drainage pipe outlet from the TMD System). PCBs were detected in six of the seven water samples. Samples contained PCBs at concentrations above the screening level for water (0.5 μg/L). The highest PCB concentration (5.8 μg/L) was detected in the sample collected nearest to the TMD System drainage pipe outlet. The water sample collected from Wahby Park Pond contained PCBs at a concentration of 52 μg/L.

Conclusions and Recommendations

Hazardous substances have been identified at the TMD PCB Investigation Site and have been demonstrated through laboratory analysis of samples collected on site. PCBs are the contaminant of primary concern and were documented to be present on site. The concentration of PCBs in the TMD System storm sewer are as high as 121,000 mg/kg in sediment, with a number of samples containing PCBs above the screening level of 10 mg/kg in the source area. The levels of PCBs in the sediment in the canal are as high as 4,900 mg/kg and 62 of 66 samples from the western end of the canal contained PCBs in sediment above the screening level.

Materials in the TMD System migrate to the canal by design (the TMD System is a drainage system) and sediment contamination by PCBs and metals at the outlet of the drainage pipe to the canal document that migration has occurred. Also, backflow from the canal to the TMD System and throughout the TMD System occurs periodically; this could further spread the contamination throughout the TMD System. Finally, contaminants in the canal can migrate to the adjacent Lake St. Clair and could be transferred to adjacent residential properties. Transfer from the canal to the adjacent properties could occur through drawing of water from the canal to provide water for lawn maintenance; pets which access the canal and then enter adjacent residential properties, or through recreational activities by humans such as boating in the canal which could transfer pollutants or migration to the lake. Also, migration has occurred from water in the canal to the pond in Wahby Park; this pond is no longer receiving water from the canal but documented migration has occurred in the past.

Contaminants pose a threat to surface water and sediment. Potential exposures arise from the presence of contaminants in surface water and sediment, the migration of materials in the canal, the proximity of the site to Lake St. Clair and Lake Erie, and the proximity of the site to nearby residential areas. Based on the above results, a removal action is warranted to protect human health and the environment. The removal action will be required to mitigate existing and potential future threats posed by site-related contaminants and will include:

- Power washing of the TMD System, collection and off-site management of sediment, and treatment of water using a wastewater treatment system to be provided by U.S. EPA
- Dredging of areas of the canal that are above the screening level. Treatment of collected water in the wastewater treatment system and off-site management of the sediment
- Treatment of water in Wahby Park Pond before discharge to the canal
- The cleanup goal for sediment in the canal is 1 mg/kg of PCBs. The water treatment goal is the reporting limit; treated water will be discharged to the canal.
- Conducting post-removal action sampling of air, sediment, and water to confirm that the PCB source areas have been removed.

U.S. EPA will continue to coordinate with City of St. Clair Shores, Macomb County, Michigan Department of Environmental Quality and other officials throughout this effort. U.S. EPA also will continue to support community involvement efforts for the site. Sediment cleanup began in 2002 and will cost approximately $4 million.

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APPENDIX 14. PCBS IN ADULT AQUATIC INSECTS

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Introduction

Benthic invertebrates have been shown to accumulate organochlorine (OC) compounds from contaminated sediments (Larsson 1984, Schuytema et al. 1988) and to serve as agents of contaminant transfer between sediments and higher trophic levels in aquatic systems (Menzie 1980, Reynoldson 1987). Researchers have reported high concentrations of OCs in tissues of mussels (Kauss and Hamdy 1985), oligochaetes (Fox et al. 1983), and aquatic insect larvae (Thornley and Hamdy 1984). However, there are numerous problems associated with collection of aquatic invertebrates from the sediment:

- The patchy distribution of organisms;2
- Difficulty in collecting a large enough sample of a single taxon2 for contaminant analysis (3 g are typically desirable);
- Time and cost of sorting live specimens from debris;
- Cost of sampling includes boats, motors; and,
- Hazards of sampling in strong currents and commercial shipping traffic.

Recognizing the difficulties of collecting benthic invertebrates, adult aquatic insects have been used successfully as indicators of sediment contamination (Mauck and Olson 1977, Clements and Kawatski 1984, Ciborowski and Corkum 1988). The winged, night-active adult forms of bottom-dwelling larvae are collected easily using ultraviolet lights for 2 h at sunset. Adults are short-lived, do not feed or defecate, and with the exception of a small proportion of contaminants shed with larval or pupal exuvia (Larrson 1984), body burdens are retained following emergence to the adult stage. There are several advantages if using adult aerial insects for contaminant analysis:

- Organisms are available in large numbers at least one time during the year;
- Sampling equipment is simple and inexpensive and requires less effort for aerial insects than benthic invertebrates or fish; and,
- Abundant biomass of adult insects from light traps can be obtained and processed more quickly than an equivalent amount of benthic invertebrates or fish.

Spatial patterns of contaminants in aerial insects (Ephemeroptera, Trichoptera) correspond to those in sediments in the Great Lakes Connecting Channels (Ciborowski and Corkum 1988, Kovats and Ciborowski 1989, 1993). Although dispersal and weather conditions may complicate precise identification of the sample source, the approach is an especially good one for synoptic and long-term monitoring programs.

Organic Contaminants in Adult Aquatic Insects in the Detroit River

Night flying insects, mainly Trichoptera (caddisflies) and Ephemeroptera (mayflies), were collected along the Canadian shoreline of the Detroit and St. Clair rivers and analyzed for contaminants and compared with reference sites, the Ausable and Gull rivers in Ontario. Concentrations of selected contaminants (PCB 66, PCB 180, HCB, and dieldrin) were significantly higher in caddisflies collected from Detroit River sites than from reference sites (Kovats and Ciborowski 1989). When samples were analyzed from insects collected along the Canadian shoreline of the Huron-Erie corridor, concentrations of highly chlorinated PCBs (hex-, hepta- and octachlobiphenyls) were significantly greater in caddisflies emerging from Detroit River sites than in samples from St. Clair River sites (Ciborowski and Corkum 1988). Levels of non-PCB organochlorine compounds (QCB, HCB, OCS) were higher in caddisflies collected from the St. Clair River than from the Detroit River (Ciborowski and Corkum 1988). The detection of elevated OCS concentrations at St. Clair River sites and high PCB levels at Detroit River sites is consistent with assessments of local contamination. When samples from upstream and downstream Detroit River sites were compared, concentrations of PCB were highest in July compared with June and August (Kovats and Ciborowski 1993). Levels of other contaminants remained relatively constant with time. No spatial trends were observed along the Detroit River on the Canadian shoreline. When contaminant concentrations in insect body burdens were compared at sites on the US and Canadian sides of the Detroit River near Belle Isle, concentrations of PCB congeners were significantly higher in the US than in Canada (1-way ANOVA, $p<0.025$; Kovats and Ciborowski 1993).

Sediments from the Trenton Channel, between the US mainland and Gross Isle, in the downstream portion of the Detroit River, are notoriously contaminated. Adult mayflies have not been collected from the area because sediments are too toxic. We studied survivorship of the burrowing mayfly, *Hexagenia*, in dilutions of the contaminated sediment with formulated (reference sediment) in the laboratory (Corkum et al. 1995). Dilutions were prepared by combining known proportions (dry mass) of Trenton Channel sediment with the standard reference sediment to produce six mixtures, designated 1X, 0.5X. 0.25X, 0.125X, 0.063X and OX, where 1X represents 100% Trenton Channel sediment and 0X represents 0% Trenton Channel sediment (=100% reference sediment). A suite of contaminants (PCB congeners, pesticides, industrial OC) were analyzed in sediment, larvae and adults. We showed that the concentration of contaminants in Trenton Channel sediment was four times too toxic for adult *Hexagenia* emergence (Corkum et al. 1995).

The Effects of Detroit River Contaminant Loads on the Western Basin of Lake Erie

Because the Detroit River provides the largest contaminant load, particularly of PCBs, entering the western basin of Lake Erie (Kelly et al. 1991), we hypothesized that body burdens of *Hexagenia* adults would reflect a gradient of decreasing concentrations from west to east across the basin. Because the Detroit River water oscillates irregularly north and south of Middle Sister and East Sister islands, differences in body burdens of mayflies may exist between shoreline and open areas. Sufficient mass of *Hexagenia* adults was collected at three sites along the Detroit River and nine sites in Lake Erie Adult *Hexagenia* were analyzed for 59 organochlorines including 42 congeners of PCBs. Highest PCB concentrations were in mayflies collected from Monroe, MI and were attributed to industrial discharge. High concentrations of contaminants in adult mayflies at Middle Sister and East Sister islands and lower concentrations of contaminants from mayflies collected from the northern and southern shorelines of the basin supported our hypothesis (Corkum et al. 1997).

Remobilization of Contaminants by Aquatic Insects

Development of transfer efficiency models of contaminants in the ecosystem should consider a number of pathways to both aquatic and terrestrial food chains. Aquatic insects represent an integral link in both food chains. One can use feeding and assimilation rates to determine the potential bioaccummulation factor from contaminants in the sediment to the biota through the food chain (Gobas et al. 1989).

To estimate the total body burden of PCBs of *Hexagenia* from Lake St. Clair (area: 1115 km^2), let the average adult dry mass of one *Hexagenia* be about 15 mg (15 mg x 1 g/10^3 mg x ca 250 adults emerging per m^2 = 3.75 g/m^2), with a known body burden of 0.015 ug PCB (0.015 ug x 1 g/10^6 ug x 250 adults/m^2 = 3.8 x 10^{-6} g/m^2). Based on these values, the total PCB mobilization in *Hexagenia* adults is 4.237 kg/y (3.8 x 10^{-6} g/m^2 x 1 kg/10^3g x 1.115 x 109 m^2) from the surface of Lake St. Clair (Corkum et al. 1995). Similar calculations apply to Lake Erie. PCBs exported by adults represents 20 to 50% of aerial deposition (Government of Canada 1991). Most of the mobilization of contaminants by adult insects occurs within a brief period in summer. The total contaminant load is partitioned among aerial deposition on land (shoreline areas), food items for aquatic and terrestrial predators and redeposition on water. Thus, the potential for contaminant transfer of adults alone through food webs is significant.

A Monitoring Program using Volunteers

The ease with which adult aquatic insects can be trapped and stored makes it unnecessary for highly trained personnel to be on-site for collections. Thus, simultaneous broad scale sampling becomes a relatively straightforward task of logistics rather than one of training. Volunteers involved with Areas of Concern and Lake Management Plans could participate in the collection of specimens. Corkum and Ciborowski (1995) prepared an educational video for volunteers outlining procedures used in collecting flying insects. A monitoring approach using volunteers has proven effective in providing a wide range of samples over a relatively short collection intervals (Fremling 1960, Dukerschein et al. 1992).

The role of the principal investigator is one of coordinating, procuring and distributing equipment, timing collections and recovery and analysis of samples. This approach permits essentially simultaneous collection of material across the sampling region, while insuring that methodology is standardized. All data from subsequent contaminant analyses can be made available to sampling teams using a computer-accessed bulletin board. This provides an immediate mechanism to share information and build support among participants.

In conclusion, contaminant analysis of adult aquatic insects provides a reliable and cost-effect means of monitoring persistent toxic substances in the Great Lakes Basin as well as in other large geographical areas.

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APPENDIX 15. WESTERN LAKE ERIE FISH COMMUNITY CONTAMINANT TRENDS (1977-2001)

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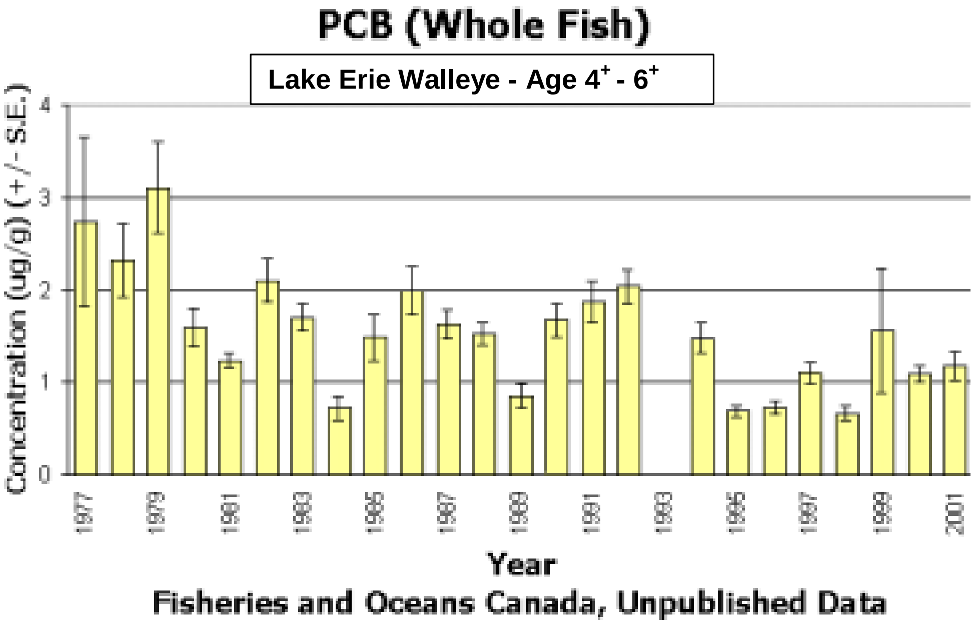
Since 1977, the Department of Fisheries & Oceans has been conducting annual monitoring studies to assess the temporal trends of contaminant burdens in representative top predator and forage fish species from Lake Erie. The Lake Erie survey was part of a binational Great Lakes Fish Contaminants Surveillance Program which was initiated in response to the specific requirements of Annex 11 (Surveillance & Monitoring) of the Great Lakes Water Quality Agreement. The intent of this program was to: "*To survey collectively, the concentration of contaminants in selected species of Great Lakes fish and other biota with the specific purpose of determining environmental trends in contaminant levels and relating these, where possible, to sources of such pollution, the effectiveness of remedial actions, and the potential implications to Great Lakes fish stocks*". Therefore, the results of the Lake Erie fish contaminants monitoring activities are potentially applicable to the objectives of this workshop to evaluate ecosystem results of PCB control measures within the Detroit River-Western Lake Erie basin.

Remedial activities, related to contaminant control, routinely address sources. The reduction of point source discharges is often followed by a decrease in the amount of contaminant in the ambient environment and therefore, available for accumulation by the biological community. The use of fish as indicators of the level of bioavailable contaminants has long been seen as a valuable tool for environmental monitoring and a measure of the success of remedial actions related to the elimination or reduction of contaminant sources. Assessment of temporal trend contaminant burden data for fish has often focused on the fact that changes in concentrations are uniquely related to changes in point source discharges. Several other factors must be incorporated in the analyses of these trend data to determine the magnitude of effect changes in point source loadings have on ambient or downstream fish community contaminant burdens.

Figure 1. Total PCB Trends in Lake Erie Western Basin Walleye (1977-2001).



In 2001, total PCB levels in walleye predominately inhabiting the western basin of Lake Erie were significantly less than concentrations measured in the late 1970s. Over a 25 year period, concentrations fluctuated considerably. Figure 1 presents the temporal trend total PCB data for a limited age class of samples from the entire Lake Erie walleye population.

There have been periodic increases (1984-86, 1989-92) in PCB body burdens followed by decreases through to the mid 1990s (Whittle. D.M. 1998). Most recently, levels of total PCB, as measured in whole individual walleye in the age range of 4 to 6 years, have remained at a concentration of approximately 1.0 mg/kg which is significantly lower than the mean concentration of between 2.0 and 3.0 mg/kg measured in a similar age class of fish in the late 1970s.

Smelt, representing a major prey species in the Lake Erie western basin fish community, have also been collected annually since 1977 and analyzed for body burdens of total PCB (Whittle, 1998). PCB levels measured in smelt demonstrated a rapid and continuous significant increase from the period 1985/86 through to 1990 when they reached a maximum level of 0.76 mg/kg which has never again been measured by this study during the 25 year period from 1977 to 2001. After 1990, total PCB levels measured in smelt declined and remained at levels averaging about 0.10 mg/kg through to 2001.

Lake Erie was one of the first Great Lakes systems to respond to the invasion and proliferation of Dreissenids in the late 1980s. The response of the biological community was a change in both energy flows within the system and a significant change in the composition and function of both the invertebrate and fish communities (Kiriluk et al. 1998). These changes led to a change in the pathways and fate of contaminants within the system. There has been evidence presented that this change in community composition, energy flow and contaminant pathways resulted in a redistribution of contaminants within the system and a consequential increase in levels measured in portions of the fish community (Morrison et al. 1998, 2000). Therefore, the effectiveness of remedial actions upstream to reduce PCB inputs was temporarily compromised by the changes in the form and function of the biological community triggered by the invasion and proliferation of nuisance exotic species. This change led to a spike in PCB levels measured in various components of the Lake Erie fish community. Subsequent declines in PCB concentrations to minimum levels ever measured in different trophic levels of the Lake Erie western basin fish community have provided evidence that a reduction in available PCBs has occurred over the most recent time period.

Contaminants contained in the sediments of the shallow western basin of Lake Erie are often resuspended during storm events and become available in the water column in the freely dissolved form. Based on models developed by Morrison et al. (1997, 2002), the continued reduction in PCB inputs to the system and a decontamination of the bottom sediments would reduce the availability of PCBs to aquatic biota. A continuation of this modeling activity to incorporate both changes in upstream loadings of PCBs and the ongoing response of the biological community to introductions of additional exotic invading species would be useful in focusing future remedial activities. These modeling activities would support the analyses of temporal trend contaminant data as measured in aquatic biota representing different trophic levels.

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APPENDIX 16. PCBS IN FISH COLLECTED FROM ST. CLAIR/DETROIT RIVER ECOSYSTEM

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Introduction and Background

Since the 1970s the U.S. Geological Survey/Great Lakes Science Center (GLSC) has had a continuous program of monitoring contaminant trends in Great Lakes fish. As a part of this program, walleye (*Stizostedion vitreum vitreum)* of a prescribed length range were collected in Lake St. Clair and both eastern and western Lake Erie. These fish were then analyzed for PCBs, chlorinated pesticides, and selected halogenated hydrocarbons (chlorostyrenes, brominated flame retardants, etc.) Walleye collected from the monitoring site at Anchor Bay in Lake St. Clair have a contaminant body burden that reflects PCB residues from the Anchor Bay area and all of Lake St Clair, as well as southern St. Clair River and possibly the northern Detroit Rivers, and so are of some relevance to the current workshop. The GLSC also made a detailed study of contaminant distribution in carp (*Cyprinus carpio*) and smallmouth bass (*Micropterus dolomieui)* collected from a number of different locations in the Detroit River in 1999 in conjunction with the US Department of Agriculture. The data thus available from our Center serve as a "snapshot" of PCB levels for one year (1999) near several remediation sites in two species of bottom-dwelling fish, and give a temporal view of residue activity in predator fish near and possibly influenced by the area of interest. Our studies have not been focused on the fate of PCBs in the relevant area, so this report is a description of our existing data.

Research Methods

All collected fish were immediately placed singly, whole, and without incisions in plastic bags, frozen, and maintained at –30 ^{0}C until processing and analyses. PCBs (and other analytes) were solvent-extracted from fish tissue, the lipids were removed from the extract by gel permeation chromatography, and the analytes then separated by column chromatography. Analyses were conducted using a Hewlett-Packard Model 5973 GC/MS in selected-ion mode (SIM). PCBs were determined using electron capture negative chemical ionization (NCI) detection methods.

Discussion of Results

In contrast with other monitoring sites in the Great Lakes, where PCBs reached their maximum levels in fish in the late 1970s to middle 1980s and then dramatically declined, the distribution of PCBs in the Lake St. Clair ecosystem appears to be more complex. Concentration of total PCBs in walleye was about 2500 mg/kg in 1977 and steadily increased each year until 1984 when total PCBs reached a level of 4500 mg/kg. By 1991, total PCBs decreased to 950 mg/kg, which might have been influenced by the removal of sediments from industrial sites. Other contaminants seemed unaffected by this sediment removal. For instance, DDT-family pesticides decreased slightly, and brominated flame-retardants increased in the same samples. Concentration of total PCBs in walleye from Lake St. Clair began to increase and nearly reached a level of 4000 mg/kg by 1995, but then decreased to 3500 mg/kg in 1997 and reached a level of 1000 mg/kg in 1999. It is important to note that in the same samples, polybrominated diphenyl ethers (PBDE) concentrations increased by one order of magnitude while other chlorinated hydrocarbons decreased only by single digit percentages. It is also important to mention that in our last observation concentrations of planar PCBs reached their lowest observed levels to date. For instance, PCB #126 was measured at 1.7 mg/kg compared to a level of 8.0 mg/kg in 1995. PCB #77 was last observed at 1.4 mg/kg and at 5.8 mg/kg in 1995. PCB # 91 and PCB # 95 were last observed below detection limits compared with 3.2 mg/kg each in 1995.

Some positive results of the remediation processes could be demonstrated from analyses of fish tissue from Lake Erie. PCB residues in walleye collected during the middle 1990s (1994, 1996) from western Lake Erie's Middle Bass Island showed total PCB concentrations were 1.5-2 times lower than PCBs found in walleye collected at the same time from the Lake St. Clair. Total PCB concentrations peaked in fish tissue in 1992 at 2200 mg/kg, with some fish containing 3000 mg/kg. By 1994 PCB residues had dropped to 900 mg/kg, but then elevated to 2000 mg/kg in 1996. This trend is nearly identical to that observed at Anchor Bay in Lake St. Clair for the corresponding years. And, no evidence of a decrease is observed at Middle Bass Island that can be directly attributed to remediation efforts on the Detroit River. The planar PCBs found in walleye from Middle Bass Island were 3-5 times less than those found in Lake St. Clair walleye from the same period. Further east at Dunkirk, NY, total PCB concentrations in walleye were 1.5 –2 times lower still compared to Middle Bass Island, and the more toxic planar congeners were at trace levels in 1995.

Major remediation efforts in the Detroit River were largely completed in 1997 – 1998. Studies of PCB distribution in carp and largemouth bass collected in 1999 from several sites in the Detroit River 1-2 years after completion of several major sediment remediation projects in the area showed a shift of PCB patterns in comparison with walleye caught for the same year as well as fish collected earlier. Carp showed a range for total PCBs of 3.5 – 5.0 mg/kg, and 0.6 – 0.9 mg/kg for smallmouth bass. There was a proportional increase of tri- and tetra- chlorinated congeners relative to the higher chlorinated congeners, a proportional decrease of PCB #153 and PCB #163, and a significant decrease of planar PCBs (especially PCB #126). The observed residue levels were lower than were expected, but we do not feel that we are seeing the full effect of the remediation efforts as these fish had accumulated some PCBs prior to and during the remediation projects.

Conclusions and Recommendations

Our observations would suggest that remediation processes are proving to be successful but to a degree that we cannot quantify. PCB concentrations in bottom-dwelling fish remain high in comparison with other less industrialized areas and the open waters of the Great Lakes. These areas need to be monitored further for PCBs (with the emphasis on planar congeners) to observe the full effect of recent remediation efforts.

APPENDIX 17. PCB METABOLISM AND PHENOLIC METABOLITES IN THE PLASMA OF DETROIT RIVER FISH

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Introduction

The Detroit River is a channel connecting Lake Huron to Lake Erie via Lake St. Clair. The sediments and aquatic biota (zooplankton, benthic invertebrates and fish) of the Detroit River contain high concentrations of persistent polyhalogenated contaminants such as polychlorinated biphenyls (PCBs) and organochlorine (OC) pesticides (e.g., DDTs, chlorobenzenes and chlordanes, and octachlorostyrene (OCS)) (Metcalfe et al. 1997, Metcalfe et al. 2000, Russell et al. 1999, Haffner et al. 1994, Pugsley et al. 1985). Benthic and pelagic fish species are exposed to these xenobiotics via dietary uptake and/or chemical accumulation by partitioning from water. For contaminants, including PCBs, with high K_{ow} values (log $K_{ow} > 6.3$) accumulation in Detroit River benthic fish (e.g., freshwater drum (*Aplodinotus grunniens*), shorthead redhorse (*Moxostoma macrolepidotum*), stonecat (*Noturus flavus*) and rock bass (*Ambloplites rupestris*)), was shown to be mainly a function of trophic interactions (Russell et al. 1999). Furthermore, benthic feeding fish are more contaminated than pelagic feeding fish, even though some of the pelagic fish examined were piscivores, suggesting sediment ingestion act as an important exposure pathway to Detroit River biota.

Benthic fish from the Detroit River such as brown bullhead (*Ameiurus nebulosus*) have been shown to rapidly metabolize polycyclic aromatic hydrocarbons (PAHs). However, the rate of PCB metabolism in fish is considerably lower than for PAHs and is more congener selective. Immunochemical and catalytic assays have demonstrated that cytochrome P450 monooxygenase (CYP) activity is inducible in fish, whereas CYP2B-type enzyme activity is generally low and non-inducible (Stegeman et al. 1989). Benthic fish species from the Detroit River possess significant levels of *meta-para*, chlorine-unsubstituted PCB congeners [3], which are ideal substrates for CYP2B-type enzymes, and precursors for persistent aryl methyl sulfone PCB ($MeSO_2$-PCB) metabolites (Letcher et al. 2000). Persistent $MeSO_2$-PCB and retained hydroxylated PCB (OH-PCB) have been reported in a growing number of species, and have been shown to elicit biological and toxicological effects in exposed organisms, and *in vitro* cell systems, including estrogenic and thyroidogenic endocrine effects (Letcher et al. 2000). More than 120 phenol-type organohalogen substances, including OH-PCBs, OH-polybrominated diphenyl ethers (OH-PBDEs) and pentachlorophenol (PCP), were recently detected in the blood, muscle and eggs of Baltic salmon (*Salmo salar*), although a majority of these compounds were not identified (Asplund et al. 1999). In general, very little is known regarding PHAH metabolism and/or accumulation of polyhalogenated phenolic metabolites in fish. In the present study, PCBs, OCs (DDTs, chlordanes, HCH and OCS), phenolic PCB metabolites, and other polyhalogenated phenolic compounds were determined and compared in the plasma from 2 pelagic and 3 benthic fish species that were collected from areas in the upper Detroit River, i.e., largemouth bass (*Micropterus salmoides), n*orthern pike (*Esox lucius),* brown bullhead (*Ameiurus nebulosus),* common carp (*Cyprinus carpio*) and white sucker (*Catostomus commersoni*).

Materials and Methods

Fish were collected and blood taken from individuals captured during August and September of 2001. The plasma was isolated by centrifugation and stored frozen at -20°C until chemical analysis. The plasma from 3 or 4 individual fish from each species or collection site (Table 1) required pooling to permit adequate detection and quantification of PHAHs, especially phenolic PHAHs. Approximately 3.0 to 4.0 grams of the plasma pools were extracted and four contaminant fractions were separated, i.e., PCBs, OCs, and OH-PCBs. The procedures of Sandau et al. (2000), Hovander et al. (2000), and Letcher et al. (2000), were used with modifications. All four fractions were analyzed using gas chromatography/electron capture detection (GC/ECD). GC/electron impact mass spectrometry (GC/MS(EI)) and/or GC/MS with electron capture negative ionization (GC/MS(ECNI)) were used to identify the structure or isomer of the OH-PCBs in plasma. An external standard quantification approach was used for PCBs (40 congeners including coelutions) and OCs (*p,p'*-DDT, *p,p'*-DDE, *p,p'*-DDD, α-HCH, β-HCH, γ-HCH, oxychlordane, *trans*-chlordane, *cis*-chlordane, *cis*-nonachlor, heptachlor epoxide and OCS). CB-83 and CB-122 were used as PCB and OC internal standards. GC/ECD quantification for the OH-PCBs was based on an OH-PCB internal standard (4-OH-CB72) method. ECD responses and retention times were compared to 14 authentic OH-PCB standards. Extraction efficiencies for PCBs and OCs were >90% while the OH-PCB internal standard was >85%.

Results and Discussion

Table 1 lists PCB and OC concentrations and the concentrations of identified congeners or isomers of phenolic PCB metabolites in plasma of Detroit River fish. Despite variations in species and sampling location, the Σ-PCB (38 to 210 mg/kg, wet weight), Σ-chlordane (1 to 8 mg/kg, wet weight) and Σ-DDT (4 to 26 mg/kg, wet weight) concentrations were comparable. All fish species examined were capable of forming a number of OH-PCBs. Variable numbers of OH-PCB congeners (Σ-OH-PCBs, 0.5 to 3 mg/kg, wet weight) were identified and quantified. Plasma OH-PCBs are dependent on the relative activity of Phase I CYP enzyme, Phase II conjugation enzymes and thyroid hormone transport protein in the blood (Letcher et al. 2000). The presence of OH-PCBs indicates that PCB metabolism, and OH-PCB retention are active processes in these fish species. The Σ-OH-PCB / Σ-PCB ratio ranged from 0.007 to 0.027, which was similar to the approximate six-fold difference in the Σ-PCB levels (Table 1). This ratio suggests that the OH-PCB forming capacity of these benthic fish is low and/or the OH-PCB conjugation activity is high. Ì -OH-PCB / Ì -PCB ratios were similar to the ratio of 0.002 in plasma from Canadian Arctic ringed seal (Letcher et al. 2000).

Variable amounts of penta- to hepta-chlorinated OH-PCBs were observed in the fish plasma (Table 1), while octa- and nona-OH-PCB isomers were detected only in white sucker and carp plasma (comprising 30% to 60% of the Σ-OH-PCB). The presence of penta- to nona-chlorinated OH-PCBs are consistent with the range of chlorinated metabolites reported in human, polar bear, seal and bird plasma samples (Letcher et al. 2000). Judging by the greater number of detectable OH-PCBs in white sucker and carp, it appeared that these more highly exposed individuals had a higher capacity to form OH-PCB metabolites. This may reflect a higher CYP enzyme activity, and thus metabolic capacity to form OH-PCBs, or the uptake patterns of PCB congeners. In the plasma of sucker, OH-Cl_9-CB and 4-OH-CB112 were dominant compared to the lower levels of 3'-OH-CB138 and 4'-OH-CB130. In the rat, 4-OH-2, 3, 5, 3', 4'-pentaCB dominates, whereas the higher chlorinated OH-PCBs are only minor components. In human plasma, the hepta- and hexa-chlorinated OH-PCBs are much more abundant compared to the rat (Bergman et al. 1994).

To our knowledge, this study is the first report on phenolic PCB metabolites in fish from the Detroit River. It is likely to assume that these phenolic metabolites do not accumulate via the diet, since these phenolic metabolites are not known to be accumulative and are unlikely formed via PCB metabolism in lower, dietary trophic levels (e.g., zooplankton, benthic invertebrates). OH-PCBs are known to possess estrogenic and/or thyroidogenic modulation potential (Letcher et al. 2000, Sandau et al. 2000). We are currently carrying out parallel metabolite studies in an additional 4 pelagic and 4 benthic fish species. Knowledge of OH-PCBs is important to understand the influence and importance of metabolism in the fate and toxicokinetics of PCBs. Furthermore, OH-PCBs are capable of endocrine disrupting activity, and their presence are therefore of concern to the reproductive and developmental health of Detroit River fish.

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Table 1. **Concentrations of PCBs, OCs and OH-PCB metabolites in the plasma of three benthic and two pelagic fish species from the Detroit River. Concentrations are in mg/kg (wet weight basis).**

Sample Capture Site	White Sucker Celeron Island	Common Carp #1 Grosse Isle	Common Carp #2 Grosse Isle	Brown Bullhead #1 Hennipen Marsh	Brown Bullhead #2 Peche Isle	Large Mouth Bass #1 Grosse Isle	Large Mouth Bass #2 Celeron Island	Northern Pike Grosse Isle
4'-OH-CB101	-	-	0.050	0.064	0.228	-	-	-
4'-OH-CB121	0.092	0.126	0.362	0.086	0.073	0.149	0.111	0.075
4-OH-CB112	0.728	0.150	0.492	0.165	-	0.144	0.073	0.554
4-OH-CB107 [a]	0.112	0.131	0.132	0.129	0.236	0.226	0.193	0.145
4-OH-CB165	0.027	0.028	-	-	0.036	0.052	0.037	-
3'-OH-CB138	0.010	1.111	-	-	-	0.071	-	-
4'-OH-CB130	0.009	0.031	-	-	-	0.054	-	-
4-OH-CB187 [a]	0.117	0.047	0.013	-	0.048	0.339	0.338	0.197
4'-OH-CB159	0.019	0.010	-	-	0.049	0.073	0.089	0.755
3'-OH-CB180 [a]	0.014	0.084	0.008	-	-	0.033	-	0.052
4-OH-CB193	0.038	0.053	0.021	0.019	-	0.042	0.028	0.053
OH-Cl_8-CB [a, b]	0.172	0.505	0.084	-	-	-	-	-
OH-Cl_9-CB [a, b]	1.456	0.653	0.379	-	-	-	-	-
Ì PCB	103.869	193.588	60.460	38.392	80.526	161.85	210.65	137.37
Ì chlordane	2.828	3.952	1.374	0.887	1.170	3.01	7.238	3.665
Ì DDTs	10.442	26.204	3.95	2.311	8.658	10.524	14.829	11.949
OCS	0.012	0.013	0.045	0.008	0.036	0.046	0.069	0.051
Ì OH-PCB	2.794	2.911	1.541	0.463	0.442	1.995	1.396	1.997
Ì OH-PCB/**Ì** PCB	0.027	0.015	0.026	0.012	0.005	0.012	0.007	0.014

[a] confirmed by GC/MS(ECNI) in white Sucker plasma.
[b] confirmed by GC/MS(ECNI) in common carp plasma.

APPENDIX 18. SPATIAL AND TEMPORAL TRENDS OF PCBS IN 2 HERRING GULL EGGS FROM THE WESTERN LAKE ERIE-DETROIT2 RIVER-SOUTHERN LAKE HURON CORRIDOR,2 1974-20012

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The Herring Gull, *Larus argentatus*, has been used by the Canadian Wildlife Service to track annual contaminant levels in the Great Lakes for more than 25 years (Hebert et al. 1999). It has many advantages over other species: as an adult, it is a year-round resident on the Great Lakes, feeds primarily on fish, has a relatively high lipid content in its eggs, is a top of the food web predator and is distributed in all 5 Great Lakes (Mineau et al. 1986). Several lake-specific presentations of the monitoring data have appeared elsewhere (e.g., Weseloh et al. 1990, 1994) and Great Lakes-wide data have appeared in three atlases, Pekarik et al. (1998) being the most recent. The purpose of this extended abstract is to present PCB data from Herring Gull eggs from the western Lake Erie-Detroit River-southern Lake Huron corridor for the years 1974 to 2001.

Up to 13 fresh Herring Gull eggs were collected from up to 15 sites (Figure 1) from throughout the Great Lakes and connecting channels during early incubation, late April- early May, each year 1974-2001. Eggs were analyzed individually from 1974 to 1986 but have been analyzed as site pools since 1987. Methods follow those of Peakall et al. (1986). The annual PCB trend data are presented on the basis of a 1:1 ratio of Arochlor 1254 and 1260. In this report, I focus on data from 4 sites: Channel-Shelter Island (Saginaw Bay, SW Lake Huron), Chantry Island (southern Lake Huron), Fighting Island (Detroit River) and Middle Island (western Lake Erie)(Figure 1).

PCB levels in Herring Gull eggs from Saginaw Bay, the Detroit River and western Lake Erie were the greatest of 15 sites sampled from throughout the Great Lakes in 2001; those from Chantry Island were among the lowest (Figure 2).

Temporal trends in PCB levels in Herring Gull eggs from Fighting Island showed a significant declining trend from 1978 to 1996 but a non-significant trend, i.e. no change, from 1996 to 2001 (Figure 3). At Chantry and Middle Islands, PCB levels showed the same significant rate of decline from 1974-2001 but with change points (Pekarik and Weseloh 1998) in 1990 and 1996, respectively (Figures 4 and 5).

Overall PCB levels have declined from 30-95% at Fighting and Middle Islands and the two “upstream” sites in Lake Huron (Figure 6).

The concentrations of the 9 most prevalent PCB congeners in Herring Gull eggs from Fighting, Middle and Chantry Islands are shown in Figure 7; they are PCBs # 99, 118, 146, 153, 170, 180, 182, 183 and 201.

Over the years, ecosystem improvement has been evident from increased breeding populations of colonial waterbirds, notably cormorants and gulls (Weseloh et al. 1995, Blokpoel and Tessier 1996). Whether this is due to declining levels of PCBs or a combination of several compounds which also have declined, e.g. DDE, HCB, is unresolved.

The upstream-downstream situation of Lake Huron-the Detroit River-Western Lake Erie provides an almost laboratory setting for conducting future research on the impacts of PCBs and other contaminants, for which the Detroit River is a major source. Needless to say, the Herring

Gull monitoring program should continue as a means of tracking environmental trends of these compounds.

Figure 1. 15 Herring Gull Annual Monitor Colonies, 1974-2002.

1. Strachan I.
2. Snake I.
3. Toronto Hrbr.
4. Hamilton Hrbr.
5. Niagara R.
6. Port Colborne
7. Middle I.
8. Fighting I.
9. Channel Shelter I.
10. Chantry I.
11. Double I.
12. Gull I.
13. Big Sister I.
14. Agawa Rks.
15. Granite I.

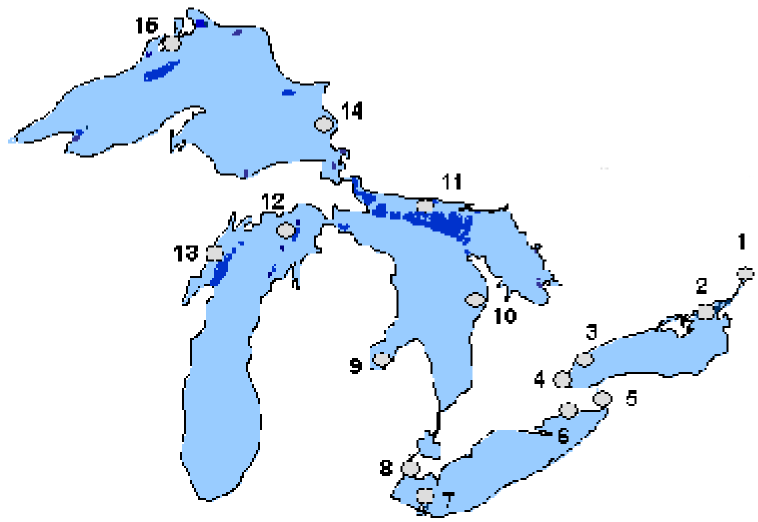


Figure 2. PCB 1:1 in Herring Gull eggs from Annual Monitor Colonies, 2001.

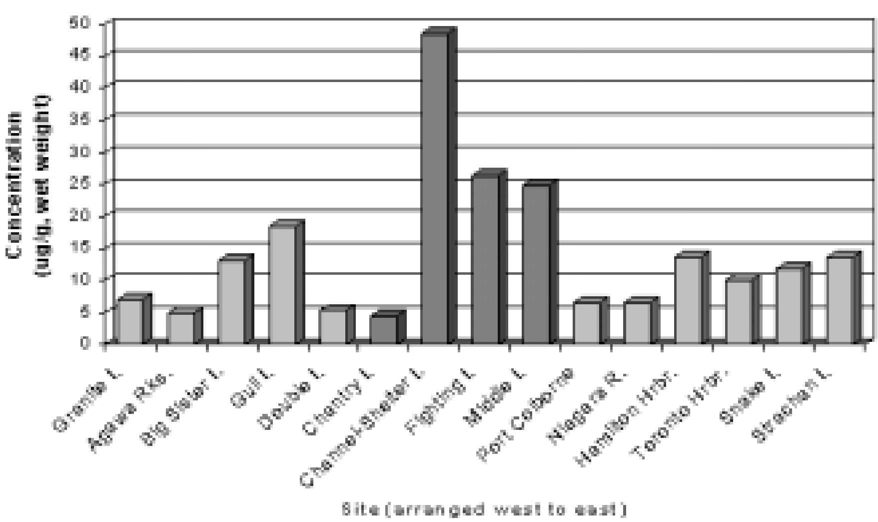
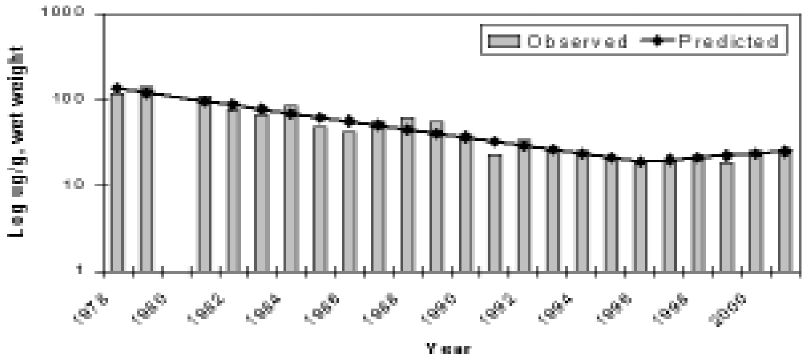
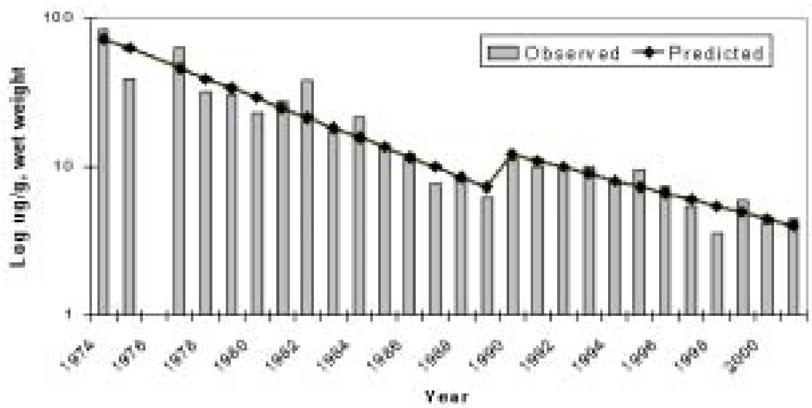


Figure 3. PCB 1:1 in Herring Gull eggs – Fighting I., 1978-2001.



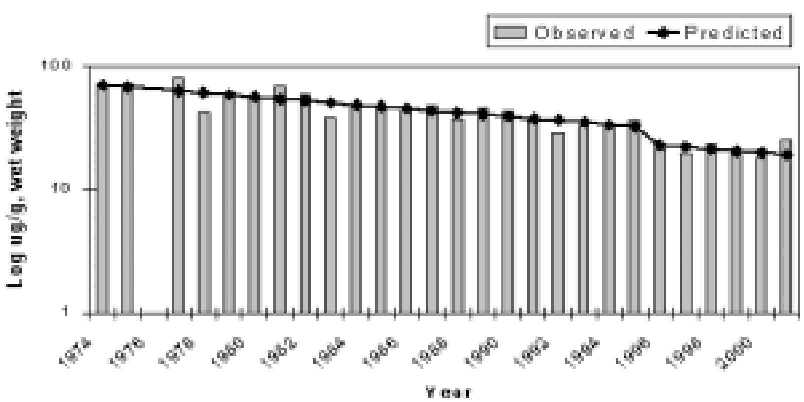
Model shows a significant decline before the change point and a non-significant trend after the change point in 1996.

Figure 4. PCB 1:1 in Herring Gull eggs – Chantry I., 1974-2001.



Model shows a slower rate of decline after the change point in 1990.

Figure 5. PCB 1:1 in Herring Gull eggs – Middle I., 1974-2001.



Model shows the same significant rate of decline before and after the change point in 1996.

Figure 6. PCB 1:1 (ug/g, wet weight) and percent declines from the first year of analysis, 1974 (Fighting = 1978; Channel-Shelter = 1980) and 2001.

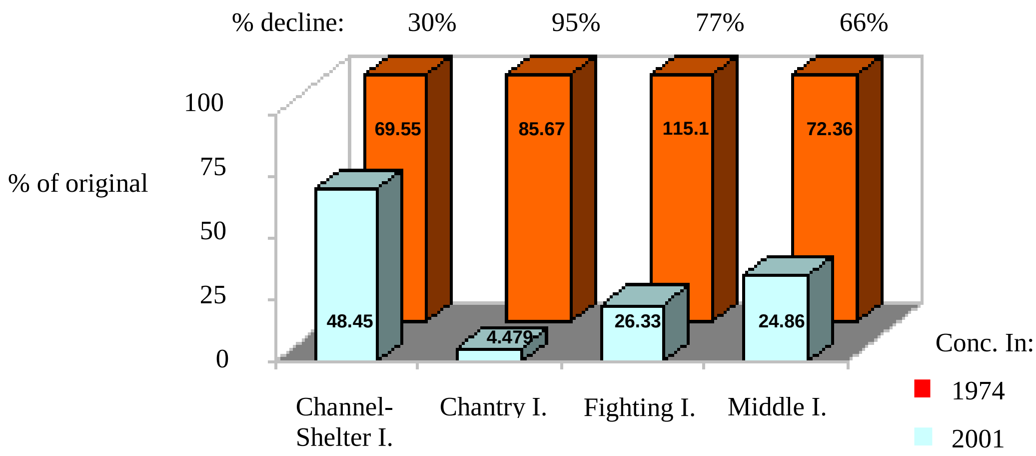
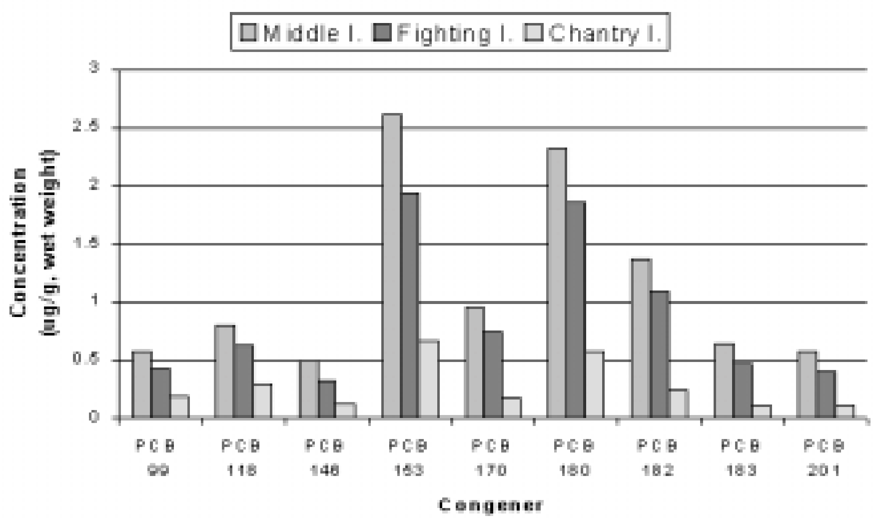


Figure 7. Top 9 PCB congeners at Middle I., Fighting I., and Chantry I., 1994.



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APPENDIX 19. CONTAMINANTS AND SNAPPING TURTLES: LAKE ST. CLAIR, THE DETROIT RIVER AND WESTERN LAKE ERIE

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Introduction

The reproduction and health of wildlife may be profoundly affected by polychlorinated biphenyls (PCBs). PCBs are widespread contaminants that are lipophilic and persistent. These chemicals bioaccumulate through the food web (Hoffman et al. 1996) and are potential endocrine-modulating substances (Koval et al. 1987). Endocrine systems control numerous functions, including reproduction and development. Reduced reproductive success and embryonic mortality from dietary exposure to PCBs is well documented in birds (e.g., Fernie et al. 2001a, b; Gilbertson et al. 1991; Hoffman et al. 1996) and has been shown to alter developmental growth of nestling birds (e.g., Fernie et al., in press).

Wild snapping turtles (*Chelydra serpentina*) are exposed to multiple contaminants, including PCBs. This species has served as an indicator of local contamination (Hebert et al. 1993, Bishop et al. 1998, de Solla et al. 2001). Organochlorine contamination may be high in the tissues, eggs and plasma of snapping turtles because of their longevity, widespread distribution, and diet consisting mostly of fish (e.g., Bishop et al. 1996, de Solla et al. 1998).

This study involves the snapping turtles in selected Canadian Areas of Concern (AOCs) of the lower Great Lakes. It is being conducted as part of a new initiative of Environment Canada which seeks to assess the health of wildlife and fish in Canadian AOCs of the lower Great Lakes. The goal of my study is to assess the reproductive success, development, and selected physiological parameters of snapping turtles, including adults, hatchlings and young.

Methods

In 2001, adult snapping turtles were live-trapped in the St. Clair AOC, the Detroit River AOC (Turkey Creek), the Wheatley Harbour AOC (Hillman Marsh, Muddy Creek, Wheatley Provincial Park), and two reference sites (Tiny Marsh and Algonquin Park, ON). Morphometric measurements and a blood-sample were taken from each adult which was then individually marked using traditional notching of the carapace. Adults were released immediately after processing. Clinical chemistry and vitellogenin were assayed in the plasma of adult male snapping turtles by the National Wildlife Research Centre (Hull, PQ).

Clutches of snapping turtle eggs were also collected at the same sites in 2001. Eggs were artificially incubated in a controlled environment at the University of Guelph. Clutch size, hatching success, hatchling deformities, size and development were assessed. Hatchlings used in the developmental study were housed individually, fed *ad libitum*, and their mass and length of carapace and preclocal area determined once every two weeks until 56 days of age. Young turtles were euthanized to determine hepatic biomarkers, immune function, and stress response (results not reported here).

Results

Compared to reference site clutches, clutch size in terms of weight (P = 0.01) and number of eggs (P = 0.02) was larger at the Detroit River and Wheatley Harbour AOCs but smaller at the St. Clair AOC. The smaller clutch size of the latter site is most likely a function of localized hunting pressure in the surrounding area. The larger clutch sizes at the other two AOCs may also be a (partial) function of latitude compared to the more northern reference sites.

With the exception of the Detroit River AOC which had high hatching success (74%), there was poorer hatching success at the St Clair (48%) and Wheatley Harbour (12%) AOCs than at the reference sites (65%) (Chi-square = 170.7 df=3 P = 0.0001). There were no differences among the AOCs in terms of hatchling survival which exceeded 92% at all sites. At Wheatley Provincial Park, approximately 2 km from the Wheatley Harbour AOC, only two of 94 eggs hatched and survived from the two clutches collected there. There were no signs of egg laying at the Wheatley Harbour AOC as noted in a previous study of approximately 10 years ago.

The rate of hatchling deformities was comparable between AOCs and reference sites, with approximately 26% of snapping turtle hatchlings having some kind of deformity. Hatchling females (n = 114, P < 0.0001) and males (n = 153, P < 0.0001) were heavier at all three AOCs compared to reference sites. Throughout the developmental period, these AOC hatchlings continued to be significantly heavier particularly those from the Wheatley AOC (males and females, Ps < 0.0001). The same trends were observed in carapace growth for hatchlings and throughout the developmental period. However, enhanced changes from the normal range of animals may be as detrimental as suppressions because of the additional energetic demands on the animal.

Changes in the physiology and sexually-dimorphic morphology of adult male snapping turtles was also observed when comparing turtles from AOC sites to those from reference sites. Clinical chemistry results indicate that the physiology of male snapping turtles is being altered in AOCs by contaminants and/or nutrition, or possibly some other unknown factor. While adult males from the Wheatley Harbour AOC had the highest concentrations of magnesium, total proteins, urea, amylase, and triglycerides, males from the St. Clair AOC had the lowest concentrations of plasma total proteins and urea; males from both AOCs had the lowest concentrations of alkaline phosphatase and total antioxidants. Furthermore, adult male snapping turtles from all AOCs had lower concentrations of calcium and globulin compared to those adult males from the reference site.

Vitellogenin is an enzyme produced by females during egg development; when observed in male animals, it suggests that the animal has been exposed to estrogenic compounds. Concentrations of vitellogenin were recorded in the plasma of three out of 20 males (15%) at the Wheatley Harbour AOC; the sex of these males was confirmed. In addition, vitellogenin was observed in one turtle, possibly a male, at the Detroit River AOC. Consistent with these vitellogenin observations, the sexually-dimorphic morphology of male snapping turtles was altered in the AOCs (adults - Detroit River only; hatchling males: St. Clair and Wheatley Harbour AOCs); this morphology involves the usually positive relationship between carapace length and preclocal area.

Conclusions and Recommendations

The results of this study indicate that the reproductive success, development of young, and physiology and morphology of adult male snapping turtles differs in three Canadian AOCs (St. Clair, Detroit River, Wheatley Harbour AOCs) compared to those from the selected reference sites. Unfortunately, at this time we do not have contaminant concentrations from the plasma of the adults or the eggs, so inferences regarding possible relationships with contaminants and these endpoints are impossible to make.

The Canadian Wildlife Service is evaluating the implementation of a longer-term monitoring program involving the snapping turtle. This study is being used to assess appropriate endpoints and develop methodologies which will deliver suitable information. The artificial incubation and raising of young turtles is labor-intensive and requires three months for each phase (incubation, raising). Furthermore, egg laying by snapping turtles occurs across Ontario within two to three weeks in June; consequently, there are logistical problems involved in collecting snapping turtle eggs across such a large geographical area in such a short time period. In comparison, the collection of blood samples from snapping turtles is also labor intensive but requires a smaller time investment compared to artificial incubation (dependent on the number of sites involved and weather). Both eggs and adult blood samples appear to provide suitable information relevant to contaminant monitoring programs.

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APPENDIX 20. BIOMONITORS, SURFICIAL SEDIMENTS, AND FOOD WEB DATASETS ON THE DETROIT RIVER

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Introduction and Background

The following presentation provides an overview of monitoring datasets for PCBs generated from the Detroit River Modeling and Management Framework (DRMMF), an Environment Canada sponsored program initiated between 1999 and 2001. The fundamental goal of the program was to integrate monitoring datasets and to develop a general modeling framework to help address delisting targets for the Detroit River Area of Concern. Critical components of the program included surveys of environmental contamination in water (mussel biomonitors), sediments and biota. These surveys were used as validation data sets for hydraulic and food web bioaccumulation models developed as part of the program. The project emphasized PCBs and mercury, as these contaminants were identified by the Detroit River Canadian Cleanup committee as priorities for monitoring and modeling efforts by the group. An electronic copy of the interpretive report can be found at www.uwindsor.ca/dreams.

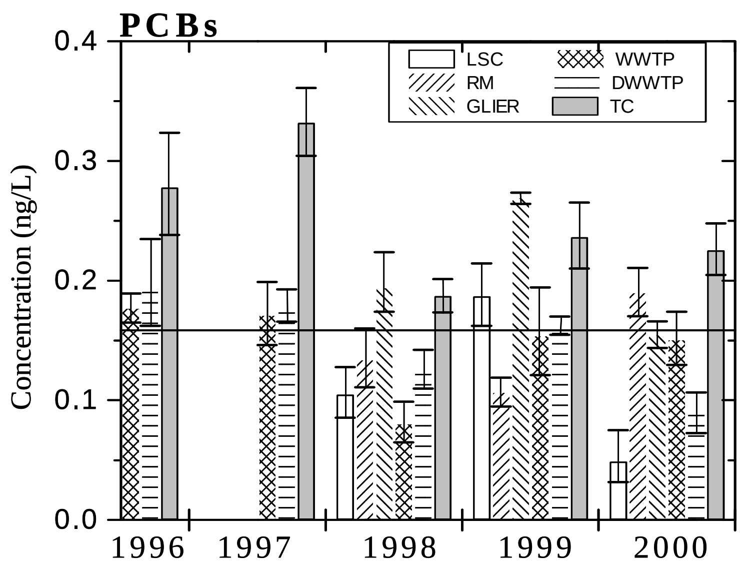
Results/Discussion

PCBs in Detroit River Water. Data on PCB concentrations in water were derived from studies conducted by the Great Lakes Institute and sponsored by the City of Windsor during 1996 to 2001. The studies used freshwater mussels, *Elliptio complanata*, as biomonitors of organic contaminants in the water column. Biomonitors involve deploying animals (caged mussels collected from a reference site) at a specific location and allowing them to filter water over an extended period of time (21 d to several months). Recent studies have calibrated *E. complanata* as a biomonitor by determining the steady state organism/water bioconcentration factor (Russell and Gobas 1989) and elimination rate constants (Gewurtz et al 2002; O'Rourke et al 2002) for a series of organic compounds. This permitted calculation of average water concentrations based on the chemical concentration measured in mussel tissues and the duration of time the biomonitor was deployed within the water column.

PCBs were detected in all 240 mussel samples deployed at five temporally replicated sites in the Detroit River between 1996 and 2000. Extrapolated PCB concentrations in water ranged from 0.01 to 1.0 ng/L and exhibited a river-wide geometric mean concentration of 0.16 ng/L. Trends for PCB concentrations in water are shown in Figure 1. Differences among PCB concentrations found at the various sites were low and remained stable over time. These data indicate that average PCB concentrations in water have not changed during the past 5 years. In 1998 the biomonitoring study was extended to include a total of ten stations in the Detroit River. Average PCB concentrations at each of these locations are summarized in Figure 2. Also included in the figure are PCB water concentrations derived using traditional analytical techniques. Both mussel biomonitors and tranditional analytical methods yielded comparable results. Spatial trends among PCB water concentrations in the Detroit River were more notable for their similarities than their differences. With the exception of a low PCB concentration near

Fighting Island and elevated concentrations in the Trenton Channel, all sites showed similar concentrations. The PCB concentration in Trenton Channel waters averaged 0.72 ng/L compared to the river-wide average of 0.16 ng/L. The very low PCB concentration in the Fighting Island Channel likely reflects a plume of clean water originating in Lake Huron that follows the dredged channels.

Figure 1. Trends in polychlorinated biphenyl concentrations in water of the Detroit River. Bars represent annual geometric mean concentrations during May to Nov. for each year. LSC = Lake St. Clair, RM = Riverside Marina, GLIER = Great Lakes Institute Dock, WWTP = West Windsor Treatment Plant Outfall, DWWTP = 500 m downstream of WWTP; TC = Turkey Creek Outlet.



Excluding the Fighting Island Channel site, the data indicate that PCB concentrations in water remain constant along the entire Canadian shore of the river and do not exhibit pronounced upstream/downstream gradients.

Figure 2. PCB concentrations (ng/L) in water of the Detroit River during 1998. Striped columns indicate geometric mean PCBs in water from mussel biomonitoring studies. Grey columns indicate mean PCB concentrations in water based on traditional analytical techniques (Froese et al. 1997; Environment Canada). LSC = Lake St. Clair, RM = Riverside Marina, GLIER = Great Lakes Institute, WWTP = West Windsor Treatment Plant, DWWTP = downstream of WWTP; TC = Turkey Creek Outlet, GI = Grass Island, FI = Fighting Island, TT = Trenton Channel, DDR = Downstream of Detroit River, MSI = Middle Sister Island, Lake Erie.

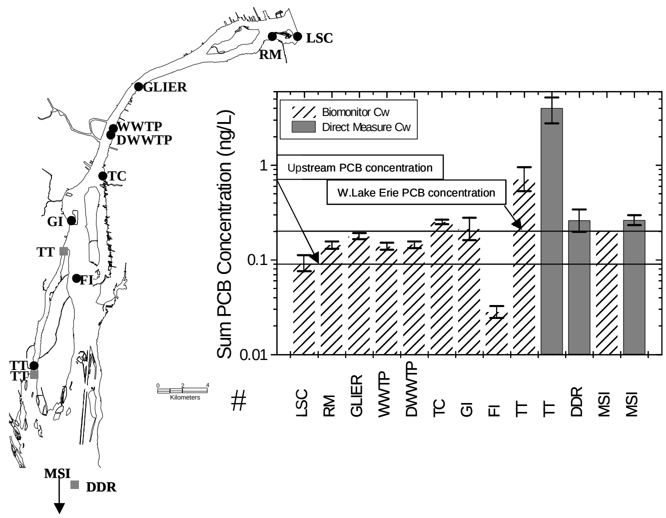
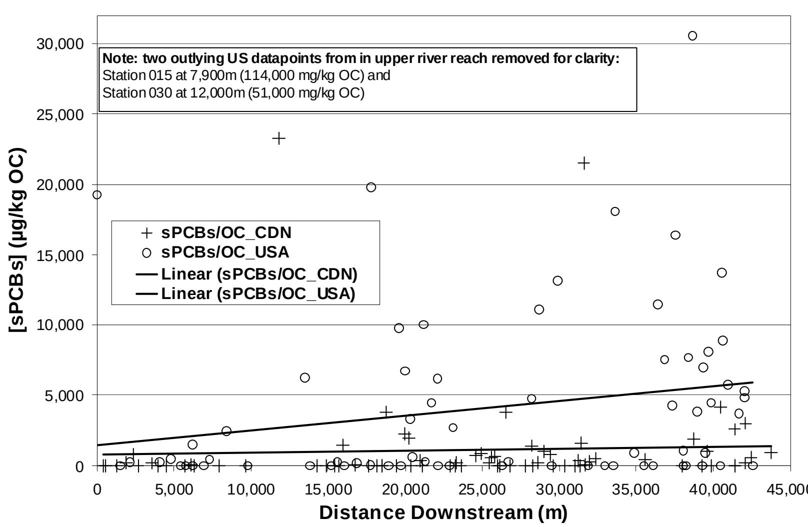


Figure 3. Total PCB concentrations ($\mu g \cdot g^{-1}$ OC wt.) in surficial sediments of the Detroit River. Cross symbols indicate sample sites at U.S. stations of the river, circles are Canadian stations. Bottom axis refers to the minimum distance (m) between Detroit River headwaters (Lake St. Clair) and a given sampling station.



PCBs in Detroit River Sediments. Contaminated sediments were identified as a key problem in the Detroit River (UGLCCS 1988; Detroit River Update Report 1999). A comprehensive, river-wide surficial sediment survey was conducted in 1999 that included 150 stations randomly distributed throughout the river. Ontario MOE sediment quality guidelines (Lowest Observed Effect Level = 0.07 mg/kg dry weight) for PCBs were exceeded at 33 of 150 stations in the river. Only six of these sites were in Canadian waters with the majority of elevated sediment PCB concentrations being associated with downstream U.S. sites (Trenton Channel and receiving waters). Figure 3 shows the relationship between PCB concentrations in surficial sediments relative to the sample distance from the river's headwaters. With the exception of two U.S. stations in the upper river reach (having high PCB values), PCB concentrations in surficial sediments on the U.S. side exhibit a significant increasing trend from upstream to downstream portions of the river. PCB concentrations in surficial sediments along the Canadian shoreline remain low, except for small clusters of moderately elevated concentrations around Goyer's Marina and downstream of Amherstburg. The Detroit River was divided into 11 model zones to facilitate a sediment mass balance and to apply food web bioaccumulation models. Figure 4 identifies the boundaries of each model region as well as geometric mean sediment PCB concentrations in bulk sediments and on an organic carbon normalized basis. As indicated previously, highest sediment PCB concentrations were associated with region 9 (Trenton Channel) and 11 (downstream of Trenton Channel).

The mass of sediment PCBs within each model zone was computed using geometric mean bulk sediment PCB concentrations at each area, the surface area of the zone and assuming a homogenous PCB concentration to a depth of 10 cm. The latter depth was chosen because it is representative of the integrated depth of the grab sampler used in the sediment survey and because this depth is considered representative of sediments that are both biologically active and available for periodic resuspension during disturbance events. Table 1 summarizes the PCB mass balance in surficial sediments of the Detroit River. A total PCB mass of 450 kg of was estimated for the upper 10 cm of surficial sediments in the entire river. From Table 1, zone 11, located downstream of Trenton Channel, contributes upwards of 62% of the total PCB mass balance for the system. Zone 9 (Trenton Channel) is also notable in that in contributes a high percentage of total PCBs in sediments relative to its aerial surface.

PCBs in Detroit River Biota. Biological surveys were performed to sample representative food web components (benthic invertebrates, forage fish, pelagic fish, piscivores and benthic feeding fish) from the Detroit River. This database was aimed primarily at identifying factors governing contaminant transfer through the Detroit River food web, assessing appropriate organisms to be used as biomonitors of local environmental quality, and validating a bioaccumulation model of the Detroit River.

Figure 4. Location of 11 modeling zones in the Detroit River. Symbols on map indicate sediment sampling locations. Expanded symbols indicate area where sediment concentrations exceeded the OMOE LEL level of 0.07 ug/g dry wt. Right graphics indicate geometric mean surificial sediment concentrations (ng/g wet wt upper graphic and µg/g OC wt lower graphic) within each region.

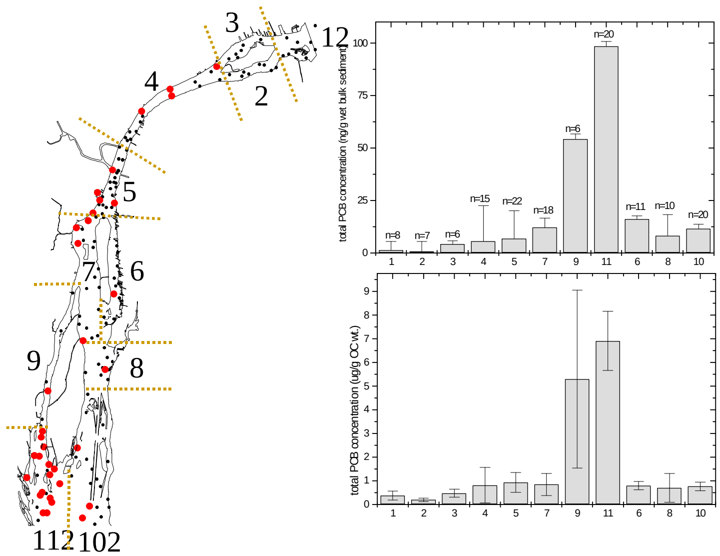


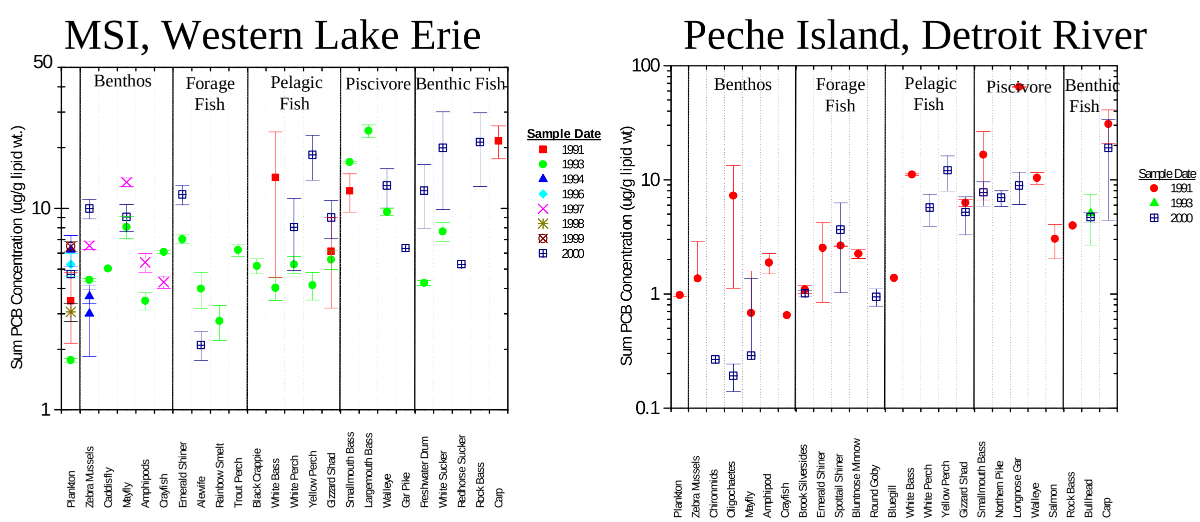
Table 1. PCB mass in top 10 cm of surficial sediments from eleven model zones of the Detroit River.

Zones	Geomean Conc. (g/m^3)	Zone Area (m^2)	Depth (m)	PCB Mass (kg)	% Area of Zone	% PCB Mass in Zone
1	0.002053	5.40E+06	0.1	1.1	4.80	0.25
2	0.001146	3.40E+06	0.1	0.4	3.02	0.09
3	0.006383	3.70E+06	0.1	2.4	3.29	0.52
4	0.008425	7.00E+06	0.1	5.9	6.23	1.31
5	0.010109	7.10E+06	0.1	7.2	6.32	1.60
6	0.024091	8.50E+06	0.1	20.5	7.56	4.55
7	0.019159	1.43E+07	0.1	27.4	12.72	6.09
8	0.014214	7.60E+06	0.1	10.8	6.72	2.40
9	0.082819	4.80E+06	0.1	39.8	4.27	8.84
10	0.017499	3.19E+07	0.1	55.8	28.38	12.41
11	0.149049	1.87E+07	0.1	**278.7**	**16.64**	**61.95**
Total				449.9		

The food web sampling sites included three Canadian sites (Peche Island, the Turkey Creek Outlet, Turkey Island), one U.S. site (Celeron Island) and a downstream site in western Lake Erie (Middle Sister Island). PCBs were detected in all 202 biota samples analyzed from the five study locations. The highest PCB concentrations occurred in carp (> 47 cm long) from Turkey Creek Outlet, Turkey Island and Celeron Island and longnose gar (>56 cm long) from Turkey Creek Outlet and Middle Sister Island. PCB concentrations in dorsal muscle of the above samples exceeded the 0.5 mg/kg wet wt. criteria (maximum measured concentration = 4.7 mg/kg wet wt.) used by OMOE to establish fish consumption advisory information for sport fish. Forty six percent of biota samples (including forage fish and benthic invertebrates) exceeded the IJC PCB tissue residue objective for the protection of fish consuming birds and wildlife (0.100 mg/kg wet wt.). PCB concentrations in benthic invertebrates and forage fish were positively correlated with surficial sediment concentrations at the sample collection site. Such a correlation was not evident for larger fish (>100 g by weight) and is a result of the greater spatial integration of exposures by these larger organisms.

Two monitoring stations (Peche Island and Middle Sister Island) were the same as those employed in food web surveys performed in 1991-1992 (Russell *et al*. 1999; Koslowski *et al.* 1994; Morrison *et al*. 1996). This correspondence permitted an evaluation of PCB concentrations in river biota over time. Figure 5 summarizes trends in PCB concentrations in different aquatic species at Peche Island and Middle Sister Island between 1991 and 2001. In each of these years, PCBs were observed to biomagnify through the food chain. The highest concentrations appeared in pelagic, piscivorous and benthic fish species; the lowest concentrations were in benthic invertebrates and forage fish. Both data sets indicate that PCB concentrations in Detroit River biota have not changed over the last 15 years. The data are consistent with temporal trends reported for water.

Figure 5. PCB concentrations (ug/g lipid wt.) in western Lake Erie and Detroit River (Peche Island) biota during 1991 and 2000.



Summary and Conclusions

PCBs were determined in water, surficial sediments and biota of the Detroit River during 1999 – 2001. Spatial trends of PCBs in water indicate similar concentrations along the Canadian shoreline from upstream to downstream locations. Only Trenton Channel exhibited elevated concentrations in water (4.5 fold higher than the river wide geometric mean), while dredged channels exhibited very low residue levels. There were no changes in PCB concentrations in water at temporally replicated monitoring stations during 1996 to 2000. PCBs in surficial sediments exhibited a significant increasing trend from upstream to downstream sampling locations along the U.S. shoreline but remained low on the Canadian side of the River. Mass balance estimates indicate that the upper 10 cm of surficial sediments contain approximately 450 kg of PCBs. Greater than 62% of the river PCB mass was concentrated in a 17% area of the river immediately downstream of the Trenton Channel. Maximum PCB concentrations in benthic fish (carp) and forage fish were similar to PCB concentrations reported for the same species during 1985 (UGLCCS 1988). PCB concentrations in biota were also found to be similar at two temporally replicated monitoring stations between 1991 to 2000. These results validate the observations made for water, that PCB concentrations in ecosystem indicators have remained stable during the past ten years.

Acknowledgement

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APPENDIX 21. SIMULATION OF SEDIMENT DYNAMICS IN DETROIT RIVER CAUSED BY WIND-GENERATED WATER LEVEL CHANGES IN LAKE ERIE AND IMPLICATIONS TO PCB CONTAMINATION

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Summary

Wind-generated water level changes in Lake Erie cause significant velocity fluctuations in Detroit River typically over a 24- to 48-hour period. A fully calibrated three-dimensional model using the Curvilinear Three-Dimensional Hydrodynamic (CH3D) model has been developed to determine changes in flow velocity with changing water elevation in the two lakes. Depositional and erosional areas in Detroit River under average water level conditions and during wind events are determined using sediment transport algorithms in CH3D. Return intervals for different magnitude events are determined using a frequency analysis of 32 years of water level data. Modeling results show that some areas in the river are net depositional areas where continued burial is expected and can provide long-term storage of present or historic sediment contamination. Other areas will clearly not experience net deposition of silt-sized material even during average flow. Transition zones exist where deposition occurs for much of the time with significant resuspension during high flow events. These areas may provide temporary storage of PCB contaminated sediments that may eventually be flushed out of the river system into Lake Erie.

Introduction

Detroit River, the connecting channel between Lake St. Clair and Lake Erie, has been designated an Area of Concern (AOC) by the International Joint Commission (IJC) for several reasons including elevated contaminant levels in water, sediment, and biota. Major chemicals of interest in Detroit River include polyaromatic hydrocarbons (PAH's), polychlorinated biphenyls (PCB's), mercury, and possibly arsenic (e.g., Haffner et al. 2002, Kannan et al. 2001). Detroit River is expected to be a major source of chemical loading of these compounds to Lake Erie but these loadings remain poorly quantified. Movement of contaminants in Detroit River is largely associated with movement of contaminated sediment (Haffner et al. 2002). Thus, improved understanding of sediment dynamics in Detroit River is necessary to quantify Lake Erie loadings. Fate of contaminated sediment from point and non-point sources along the river (Lake St. Clair, tributaries, waste treatment discharge, bulk storage facilities etc) is also important to assess remedial measures. Because of Detroit River's size and complexity, this task is nontrivial. A numerical modeling framework is being developed to assist management of remedial efforts within the Detroit River AOC to move to delisting of the AOC's impaired beneficial uses.

Assessment of dynamic sediment conditions due to changes in flow velocity is important for management of dredged material and selection sediment remedial options. Sediments may present a long-term source or sink of contaminants in the Detroit River AOC depending on their stability. Periodic water level changes in Lake Erie can erode sediments that are deposited during average flow conditions making what seem to be stable sediments unstable. Analysis of yearly maximum wind-generated water-level changes is included to provide boundary conditions for the hydraulic model to assess erosion during a 20-year wind event.

Model Details

Raw river bathymetry was acquired from a survey conducted in 2000 by National Oceanic and Atmospheric Administration (NOAA) and post-processed using in-house codes (resolution within transect approximately 6 m and distance between transects approximately 100 m). Water level data in Lake St. Clair and Lake Erie was also from NOAA. Acoustic Doppler current profiler data at 42 transects collected in spring, summer, and fall of 1996-1999 was provided by USACE and post-processed to provide two-dimensional velocity fields for hydraulic model calibration. River boundary information was determined using rectified aerial photography from USACE.

Surface-Water Modeling System (SMS) 8.0 (Environmental Modeling Systems, Inc.) was used to generate the grids and interpolate grid node depth (bottom location) following permission from USACE to use the interface. The grid has 128,00 active cells and ten vertical layers were used. Grid size is approximately 40 m.

Sediment transport model

To assess the impact of wind-generated water level changes in Lake Erie on sediment resuspension, a stable sediment distribution was first generated using steady flow conditions using average water levels prior to a selected wind event. Each cell in the grid was assigned three sediment layers with the top (2 cm thick), middle (2 cm thick) and bottom (100 m thick) layers having grain sizes equal to 30 µm (fine silt), 300 µm (coarse silt), and 10 mm (medium gravel), respectively. This sequence of layers would allow removal of progressively larger material until a stable material was reached.

Model Results

Water level frequency analysis

Thirty two years of hourly water level data from the Fermi Power Plant water level gauge, Lake Erie, Michigan (NOAA) was analyzed to find the annual maximum drop in water level over a 24-hour period from the average water level during the previous 15 days. A frequency analysis of the data was conducted to determine the return interval for a given water level drop. Data is log-normally distributed and can be used with a high level of confidence to ascertain the water level drop for an event with a return interval less than 30 years. Water level drops of 1.25 and 1.8 m is expected for 2-year and 20-year events, respectively. The water level change between Lake St. Clair and Lake Erie is typically 0.7 m, which is more than doubled during the 2-year event and more than tripled during a 20-year event, suggesting that resuspension during these events may be significant.

Hydraulic model simulation results

Calibration results provided an average relative error of 10% between measured and calculated velocities. Calibrated results were considered acceptable. A 20-year wind event was chosen for illustrating occurrence of sediment resuspension. Rapid drop in Lake St. Clair's water level indicates rapid draining of the lake in response to Lake Erie's water level change. Near-bottom velocity results are shown in Figure 1. Several areas clearly experience large increase in flow velocities during the event. Recent sediment sampling of the Grosse Ile area has identified it as heavily contaminated with PCBs and PAHs (Haffner et al. 2002). PAH concentrations increase by one to two orders of magnitude from surface to several centimeters below surface. The simulation indicates that this area is subject to periodic increases in flow velocity that may expose buried contaminated sediment.

Sediment transport simulation results

The changes in flow velocity during a wind-induced water level change in Lake Erie cause pronounced changes in stability of silt-sized sediment. The upper reaches of the river are predominantly sand, gravel, or consolidated material resistant to erosion, with some coarse silt areas, and occasional small pockets of fine silt. This area remains largely unaffected by increase in flow. Large areas of fine and coarse silt exist south and east of Fighting Island and some areas experience resuspension during high flow events. Trenton Channel, west of Grosse Ile is predominantly coarse silt, much of which may be resuspended during high flows. As Trenton Channel widens at the south end of Grosse Ile, finer materials are more stable and deposition of fine and coarse silts occurs in the vicinity of Celeron Island. Figure 2 provides a comparison of stable bottom type at the lower reach of the river during average steady conditions and during a 20-year wind event. Fine silt is removed from much of the area around Celeron Island during the event, leaving only a small area in the lee of the island. Fine silt would be stable in the area around Celeron Island during average flow conditions and presumably this size fraction would build up if a source of these particles existed upstream with potential for periodic resuspension.

Figure 1. Near-bottom flow velocity for lower section of Detroit River (a) during stable lake levels and (b) at peak of wind event. Lake Erie forms the lower boundary.

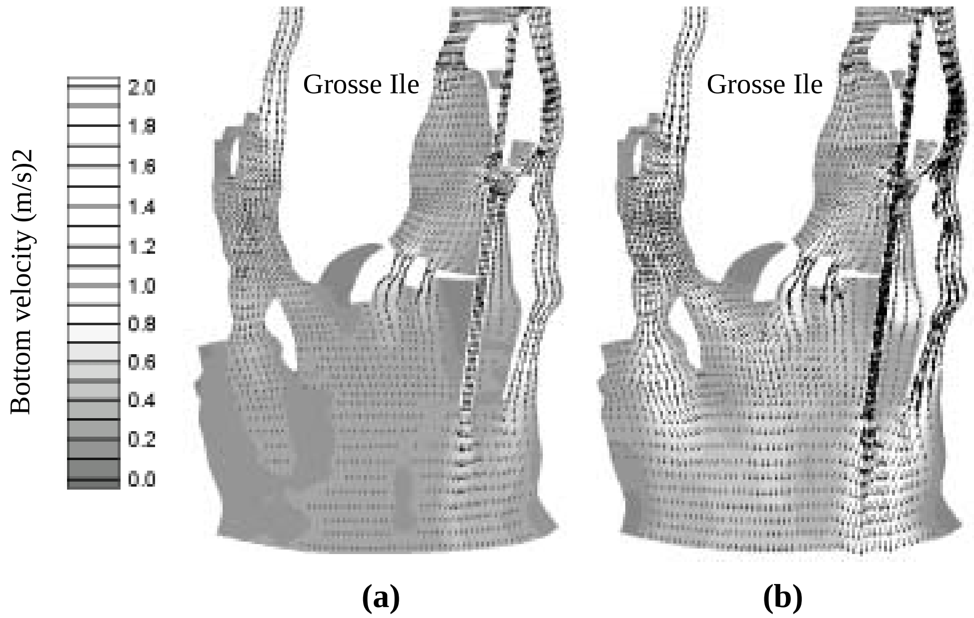
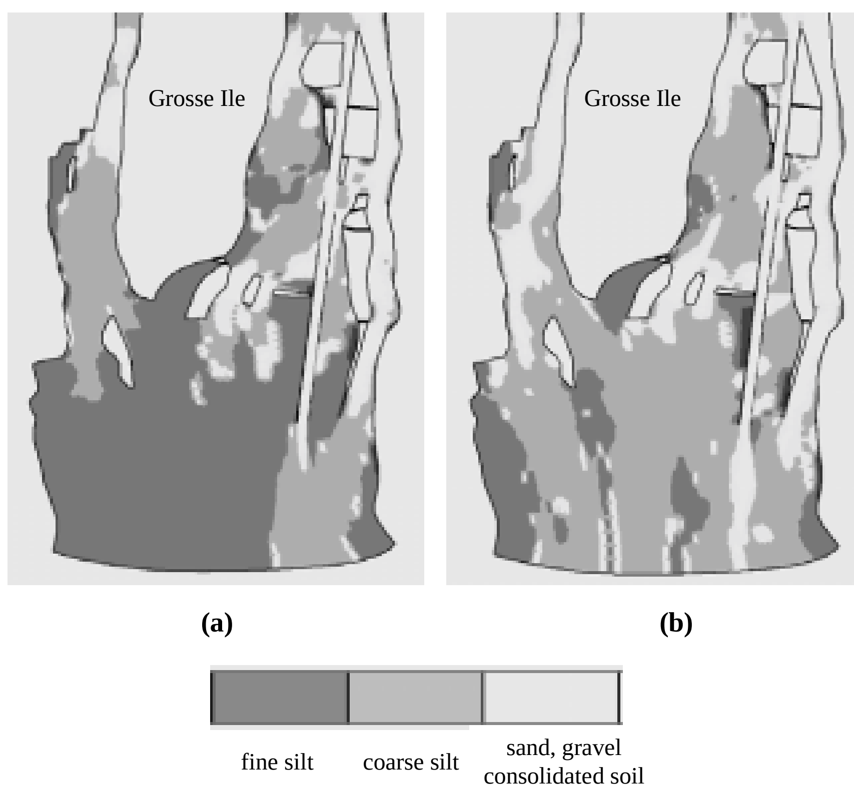


Figure 2. Simulated stable bottom type for lower Detroit River a) during average flow conditions and b) during a wind-induced lake level drop with 20-year return interval in Lake Erie.



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