Final Report to Michigan Sea Grant Submitted by:

Kashian, D. R.,[1] K. Drouillard[2], D. Haffner[2], A. Krause[3], Z. Liu[3], and L. Sano[4]

What are the Causes, Consequences and Correctives of fish contamination in the Detroit River AOC that cause health consumption advisories?

[1]Department of Biological Sciences, Wayne State University, Detroit, MI, USA
[2]Great Lakes Institute for Environmental Research (GLIER), University of Windsor, Windsor, ON, Canada
[3]Environmental Sciences, University of Toledo, Toledo, OH, USA
[4]Cooperative Institute of Limnology and Ecosystem Research, University of Michigan, Ann Arbor, MI, USA.

MICHU-10-202

Table of Contents

CHAPTER 1: INTRODUCTION

BACKGROUND

The consumption of fish is often touted for its health benefits, as fish can be a high quality source of protein and can provide an important source of omega-3 fatty acids, both of which support cardiovascular health and brain development. Fish consumption, however, is not without risks, as persistent environmental contaminants such as mercury, dioxin, polychlorinated biphenyls, and others are often found in fish at levels that may pose human health risks.

An important source of consumable fish in the U.S. is that caught by sport fishers, both for recreational and subsistence purposes. In many states, several of these recreational fish species are under fish consumption advisories, which are designed to reduce human health risks associated with eating contaminated fish by providing specific guidelines on the amount and type of certain fish that should be consumed by different sub-groups of people. In the U.S., the number of state fish advisories due to contaminants has more than doubled over the last 15 years and in 2006 the National Listing of Fish Advisories reported that approximately 65% of the U.S. coastline (except Alaska) is under some sort of consumption advisory.

The Detroit River remains under several fish consumption advisories, which are beneficial use impairments that both impact human health and affect economic revenue. In terms of the former, there are consumption restrictions for various fish species that apply to sensitive sub-groups, such as children and women of childbearing age. In terms of the latter, consumption advisories on highly prized fish species such as walleye and yellow perch likely impact economic revenue of the region (Johnson 2000).

The most commonly cited contaminants in Detroit River fish are mercury, polychlorinated biphenyls (PCBs) and dioxin. Polychlorinated biphenyls contribute or are solely responsible for advisories on all of the fish listed in the Michigan and Ontario advisories for the Detroit River. Polychlorinated biphenyls are among the most widespread environmental pollutants and a prominent contaminant of the Great Lakes basin, they bioaccumulate in fish tissues and in fish-eating humans due to their resistance to biodegradation and lipophilic properties. PCBs are also known to cross the placenta and to be excreted into the mother's milk, thus predisposing the infant to potentially adverse health effects.

Despite the critical importance of these advisories, little progress has been made in developing effective management strategies. For example, although sediment remediation efforts in the Detroit River have totaled more than $120 million dollars, there is little evidence of ecosystem improvement (Heidtke et al. 2003). Many uncertainties also remain regarding the primary drivers of these advisories, with key uncertainties including the relative contribution of sediment hot spots, the role of point versus non-point contaminant sources, and the appropriateness of tissue trigger-levels in identifying threshold action levels for consumption advisories. Because of these complexities, solutions for remedying consumption advisories will require novel approaches directed at both decreasing body burden levels in fish over the long-term and reducing human health risks in the short- and long-term.

Using an Integrated Assessment (IA) framework, we consolidated and utilized existing data from the Detroit River to develop models that both identify possible drivers of elevated fish contaminant body burdens, and to facilitate a more risk-based approach of tissue trigger-levels for consumption advisories. This integrated assessment approach was particularly useful for consumption advisories as it provided the ability to integrate and organize complex data in a manner that can help inform management decisions.

In addition, the IA framework explicitly fosters collaboration and participation of multiple interested groups. We have capitalized on this component of IAs, by seeking the active participation of different stakeholder groups in developing logic models that identify the goals of the scientific assessment and the connections between the science and management or policy outcomes. This science-policy connection was the focus of workshops designed to evaluate frameworks identifying the goals and desired outcomes from the scientific assessment component of the IA. We approached this IA with the following objectives:

1) Synthesize and summarize **the status and trends** of fish contaminant levels and advisories in the Detroit River, through an assessment of the trends in the data as well as documentation of the history of the fish advisory in the river (Canadian and U.S.).

2) Describe the abiotic, biotic, and human health **causes and consequences** of fish consumption advisories, with an emphasis on model simulation and explanatory analyses. This effort will focus on the environmental conditions that contribute to fish consumption advisories in addition to other factors that may exacerbate human health risks.

3) Identify the **key uncertainties** regarding the drivers of consumption advisories for use in prioritizing future research and monitoring efforts and in helping guide management and policy directives.

4) Utilize information on the causes and consequences of consumption advisories for providing **technical guidance** in implementing policy and management options. This will include a focus on short-term measures that reduce direct threats to human health and longer-term objectives to reduce overall body burden of fish in the Detroit River relative to reference areas.

THE DETROIT RIVER FISH CONSUMPTION ADVIORY (FCA) IA PROCESS:

OVERVIEW: The FCA-IA process was initiated in 2007 when the project PIs met for a planning meeting and began the process of: identifying relevant stakeholders (Chapter 2); identifying mechanisms to collect and coordinate data for the Detroit River; developing a web-page (http://www.ciler.snre.umich.edu/fca/); recruiting graduate students; coordinating data analysis; developing a survey to assess connectivity among the stakeholders (Appendix 2.1), and planning the first stakeholder workshop (Chapter 2). At this time we also identified the need to bring in an additional consultant Dr. Branda Nowell with North Carolina State University (NCSU) a community psychologist whose expertise is in examining the social networks of non-profit organizations. Following this meeting two MS graduate students were recruited to work on a Fish Consumption Hazard Assessment Model (Chapter 5) and a spatial modification of modeling PCB transfer in the food web of Detroit River (Chapter 6). In addition, a graduate student team was recruited through the University of Michigan to address Environmental Justice Issues Related to Fish Consumption Advisories on the Detroit River (Appendix D). Through this process we were responsive to the requested needs of the stakeholders and developed a user friendly website where we made available to them the products of this IA. Including a bibliography that that we developed in response to a request regarding the challenges by non-academic institutions to find relevant articles on this topic (Appendix A). Our bibliography provides approximately 200 articles organized into articles related to PCBs in fish and humans as they related to fish consumption advisories. Additional materials available via the project web-site include all presentations from the workshops, data sets used in our modeling efforts, links to both Michigan's and Ontario's advisory, links to the various stakeholder organizations, and workshop outcomes (http://www.ciler.snre.umich.edu/fca/index.php).

DATA ACQUISITION: A critical element of this project was to synthesize and summarize available information and data related to fish consumption advisories in the Detroit River. This was accomplished by gleaning information from the scientific literature, reports, and available datasets. In addition, during the first workshop, and as part of the survey we solicited information regarding the location of data sets from our identified stakeholders. Once data sets were obtained, and if agreed upon by the data owner, they were posted on the project website as to make the data available to both project PIs and stakeholders (.http://www.ciler.snre.umich.edu/fca/data_sets.php). Data sets are derived from both Canadian and U.S. research efforts and all data used, regardless of source, is applicable to the whole river.

STAKEHOLDER WORKSHOPS: The stakeholder process began by identifying key informants who could assist us in identifying the relevant stakeholders for this project. We defined relevant stakeholders as any public, private or community organization that is concerned or involved, either directly or indirectly, with the release of contaminants, with developing consumption advisories, or that are affected by or concerned about fish contamination in the Detroit River system. The identification of key informants was accomplished by a coordinated effort among the project PIs working with Ms. Mary Bohling (Michigan Sea Grant), Dr. Brand Nowell (NCSU) and Dr. Rose Ellison (USEPA). This process is described in detail in Chapter 2. Key informants were interviewed as to the perceived capacity to work on issues related tofish consumption advisories in the Detroit River, and interview results were used to aid in the design of our workshop series. The first workshop was held on Nov 7, 2007 with the goal to unite stakeholder interests and expertise with a scientific assessment of drivers of fish consumption advisories in the Detroit River in order to inform policy and management practices. Objectives for this first workshop were to facilitate networking and information sharing and to foster a greater shared understanding of the issues associated with water contamination in the Detroit River. Results from this workshop and presentation are all available on line (http://www.ciler.snre.umich.edu/fca/workshop01f.php) and explained in detail in Chapter 2. The second workshop was help on August 5, 2008 with the primary outcome goal was to develop working groups to help address the top key questions identified in workshop one. A secondary outcome goal was to revise stakeholder roles. Workshop results and presentations are available on-line (http://www.ciler.snre.umich.edu/fca/workshop02f.php), and described in detail in Chapter 2. As part of the outcome from workshop two several working groups were formed with the intent to meet regularly and accomplish the goals they identified (Chapter 2). Sue Manente from the Michigan Department of Community Health (MDCH) led a working group committed to addressing one of the key objectives identified in workshop 1 (How can we increase public awareness of FCA?). This group was able to build on several close partnerships that formed during the first year of the IA project; Specifically, Sea Grant, Michigan State, and the Department of Community Health developed and submitted three proposals related to the issues identified in our project to secure additional funding.

- Read, J., M. Bohling, G. Habron, O. Jolliet, S. Joseph, and D. Kashian. Assessing Communication Barriers and Risk Associated with Fish Consumption among Great Lakes Underserved Populations: Case-studies in the Detroit River and Saginaw River / Bay Areas of Concern. To: NOAA/Oceans and Human Health Initiative. Request $729,495 over 3 years. (*Not-funded)*

- Kashian, D., A. Krause, K. Drouillard, D.Haffner, and L. Sano. Addressing the causes, consequences and correctives of fish contamination in the Detroit River that cause health consumption advisories via an Integrated Assessment. To: Environmental Protection Agency. Request: $24,875 over 1 year. (*Not-funded-program cancelled due to budget cuts*)

- Michigan Department of Community Health, Division of Environmental Health Expanding Audience-Oriented Fish Consumption Advisories to Great Lakes Areas of Concern. Request $10,000 over 1 year. Submitted by: Kory Groetsch, MDCH. Letter of support provided by Donna Kashian on behalf of entire IA-Detroit River FCA team. *(Funded)*

Only the MDCH project recived funding from this year one effort. We feel it was in part the funding from the MDCH grant that facilitated the success of this group. The efforts from this group are described in detail in Chapter 2.

A second successful working group was related to addressing another key objective identified in workshop 1 (Where are the sources of contaminant in the basin that are high enough to translate into a FCA?), was led by project PI Dr. Ken Drouillard and is described in detail in Chapter 2, and results are presented in Chapters 5 and 6.

WORKSHOP OVERVIEWS

<u>Workshop 1: Detroit River Fish Consumption Guides: Navigating the Issues</u>

Meeting 1 Objectives:

- *Share information* with other key stakeholders (e.g., policy makers, regulatory agencies, end user groups, researchers) about your organization/program and your role in the management or use of the Detroit River including your priorities, constraints, and needs;

- *Learn* from other stakeholders about their roles, priorities and constraints and how your organization fits within this broader system of stakeholders in the Detroit River;
- *Network*, develop new contacts, and possibly identify new opportunities for collaboration;
- *Develop a greater awareness* of the system surrounding contaminants and human health effects and your organization's place within this system;
- *Participate in identifying opportunities* for reducing uncertainties regarding consumption advisories and for maximizing the effectiveness and efficiency of future management efforts.

Meeting 1 Outcomes:
<u>A stakeholder consensus of the top five issues related to Fish Consumption Advisories in the Detroit River.</u> These issues were used to guide the next workshops and subgroup goals.

1) How can we increase public awareness of FCA?
   - How can we make FCA a higher priority within agencies?
   - Why is so much money spent on research and monitoring but not on dissemination of knowledge?
2) Do the fish collected for contaminant analysis represent the population of fish accurately?
3) What are the contaminant levels of fish not included in the advisory that are consumed from the Detroit River?
4) Where are the sources of contaminant in the basin that are high enough to translate into a FCA?
5) Are we appropriately measuring emerging contaminants?
6) <u>A list of available **databases** related to contaminants and human health effects in the Detroit River.</u> We used the responses in the pre-survey to contact people about databases if they had indicated in the survey that their organization had data. These databases are described in detail on the project website (.http://www.ciler.snre.umich.edu/fca/data_sets.php). If the file was not available to download, then a website to download the data was linked to the description or a contact name and information was listed after the description.

Data sets acquired include:

1) Sediment chemistry studies (PCBs, PAHs, organochlorines pesticides, mercury and heavy metals) and benthic community assessments throughout the Huron-Erie corridor. Sediment quality surveys from U.S. and Canadian waters of the St. Clair River, Walpole Delta, Lake St. Clair and Detroit River during 2004-2005. The survey included 115 sampling sites. Environment Canada's Great Lakes Sustainability Fund and Ontario-Contributed Canada-Ontario Agreement Funds sponsored these data sets.

2) Sediment chemistry studies in the Detroit River. During 1999, a detailed sediment chemistry assessment (PCBs, PAHs, organochlorine pesticides, mercury and heavy metals) was performed in the Detroit River. One hundred and forty seven samples were collected from all portions of U.S. and Canadian waters. Twenty stations were resampled in 2005 as part of the Huron-Erie corridor assessment described above. The Detroit River Canadian Cleanup Committee under funding from Environment Canada's Great lakes Sustainability Fund sponsored the 1999 data.

3) Sediment chemistry studies in the Detroit River 1985-1988. Historical surveys of Detroit River sediment quality are provided through the Upper Great Lakes Connecting Channels Study. This study encompassed all waters of the Detroit River, with special emphasis on Trenton Channel.

4) Water chemistry studies in the Detroit River. Between 2000-2005, Environment Canada collected water samples (trace metal and large volume water samples) at three locations in the Detroit River (Trenton Channel, Amherstburg Channel and North Peche Island). Trace metal sampling was performed at an additional two sites (Sugar Island and Livingston Channel) during 2003-2005. Samples were collected at monthly intervals during the open water season. Analytes included PCBs, PAHs, organochlorine pesticides, dioxins & furans, chlorinated naphtahlens, polybrominated diphenyl ethers, trace elements and total mercury. This data was obtained from Mr. Robert McCrea, National Water Research Institute, Environment Canada.

5) Mussel biomonitoring studies in the Detroit River. The Corporation for the City of Windsor has conducted a mussel biomonitoring study at 5 locations in upper portion of the Canadian side of the Detroit River between 1996-2005. Mussels are collected each year from a reference location, transplanted at the biomonitoring site in steel cages, and sampled at monthly intervals to determine uptake of bioaccumulative contaminants (PCBs, organochlorine pesticides and PAHs). Mussel biomonitors have recently been calibrated (O'Rourk et al 2004), allowing the estimation of bioavailable water residues from tissue accumulated contaminant levels. Mr. Kit Woods, City of Windsor Pollution Control is responsible for this data set. Drs Haffner and Drouillard are responsible for supplemental mussel biomonitor data sets conducted in U. S. and Canadian waters throughout the Detroit River and Huron-Erie corridor in 1998, 2002 and 2005.

6) Food web sampling at Peche Island and Middle Sister Island (w. L. Erie) 1990, 2001. Samples of net plankton, benthic invertebrates, forage fish, piscivores and benthic feeding fish were collected and analyzed for PCBs and organochlorine pesticides at Peche Island and Middle Sister Island during 1990 and 2001.

7) Food web collections at Peche Island, Turkey Island and Celeron Island (2001-2002). Approximately 200 samples consisting of benthic invertebrates, forage fish, pelagic fish, piscivores and benthic feeding fish were collected as part of an assessment of food web contamination in the Detroit River. The collections and analyses were sponsored by the Detroit River Canadian Cleanup Committee and funded by The Great Lakes Sustainability Fund (Environment Canada).

8) Western Lake Erie Walleye Sampling Program (1976-2003). Department of Fisheries and Oceans Canada, has implemented a walleye sampling program for contaminants. For approximately twenty years, 4 fish/yr have been collected from western Lake Erie (Middle Sister Island). Contaminant analysis included PCBs and organochlorine pesticides for each year, and total mercury concentrations for selected years. Mr. Mike Whittle is responsible for this dataset. The DFO walleye contaminant data set was donated to the Great Lakes Institute under a collaborative relationship between Drs. Drouillard, Haffner and Mr. Whittle.

9) Ontario Ministry of Environment Sport Fish Monitoring Program, (1977-present). The Ontario Sport Fish Monitoring Program collects fish samples from a given system for contaminant analysis over approximately 4-year intervals. Dr. Wolfgang Schneider is responsible for this dataset. Dr. Haffner has access to the Ontario fish contaminant data for the Detroit River, through his membership on the Detroit River Canadian Cleanup Committee.

10) Ontario Ministry of Environment Spottail Shiner Program. (1977-present). Young of the year spottail shiners were collected from Ontario Areas of Concern and their tributaries at irregular intervals between 1985-present. Dr. Haffner has access to the Ontario fish contaminant data for the Detroit River, through his membership on the Detroit River Canadian Cleanup Committee. Additional forage fish samples from eight stations (U.S. and Canadian waters) of the Detroit River were collected as part of a river-wide survey of PCBs/OC pesticides and total mercury in 2005. The Ontario Ministry of the Environment sponsored this data.

11) The Michigan Department of Environmental Quality (MDEQ) long-term monitoring data (1990-2001). The state of Michigan has whole fish contaminant data for walleye and carp for the years of 1990, 1992, 1994, 1996, 1998, and 2001.

12) The Michigan Department of Community Health (1985-2005). The MDCH has fish tissue data sets used for setting consumption advisories. Their own laboratory runs samples and fish consumption advisories are based on these fillet data. These data generally consist of fillet samples from different fish species (usually 10 bottom fish species, such as carp, and 10 top predators, including walleye, largemouth bass, and northern pike). The data are analyzed for a range of contaminants (mercury, PCBs, chlordane, dioxin).

13) The Fish and Wildlife Nutrition Project (2000). Health Canada conducted surveys of shoreline fishers on the Canadian side of the Detroit River to determine fish consumption habits of shoreline fishers. These data are available in report form from the Health Canada (GLIER 2003).

Workshop 2: Fish Consumption Advisories in the Detroit River: A Canadian and US Partnering Opportunity.

Meeting 2 Objectives: The primary outcome goal for this workshop was to develop working groups that help to address the top key questions identified in the last workshop. A secondary outcome goal was to revise the stakeholder roles.

Meeting 2 Outcomes:

1. The revision of stakeholder roles.

- **Economic Development:** Those that have a vested interest in the economic development, tourism and promotion of the Detroit River and its adjacent lands as a valued natural resources

- **Regulatory Compliance:** Those who set contaminant policy or regulate the input of contaminants in the Detroit River, such as through enforcement or permits and those who collect their own data to demonstrate compliance.

- **Monitoring and Research:** Those who collect data on the ecological system in the Detroit River. Such data can be used for research, management, and/or conservation purposes, including for setting trigger levels.

- **Policy on Fish Consumption Advisories:** Those who are involved in planning and information gathering to carry policy out on setting the trigger levels for fish contaminant advisories in the Detroit River.

- **Education and Outreach on Fish Consumption Advisories:** Those who provide information on Fish Consumption Advisories related to fish populations found in the Detroit River.

- **Stewards:** Those who are involved in conservation related to the Detroit River.

2. The development of 4 working groups: Outreach, Food Web, Environmental Justice, and BUIs.

3. The establishment of a Google Groups website for FCAs in the Detroit River.

Working Group Workshops:

Two of the working groups mentioned above in the outcomes of workshop two, the *Outreach and Food Web Group* were active in reaching their objectives (Chapter 2).

Outreach group objectives:

1. Provide user friendly materials to fish consumers
    - Emphasis on at-risk population
        - Women of childbearing age, children
        - Low income, urban fish consumers eating contaminated fish
2. Help consumers make healthier choices about a local food source
3. Distribute materials to reach intended audience

Outreach group Outcomes (products):

- Brochure: "Eat Safe Fish in the Detroit Area: A guide to buying and catching fish that are healthy for you and your family" (Appendix 2-5).

- Flier: "Best Spots for Catfish in the Detroit Area" (Appendix 2-6).

- <u>Sign to be posted along the Detroit River on the US side "Eating Fish from the Detroit River" (Appendix 2-7).</u>

- Participation in River Days in Detroit where outreach materials were distributed and evaluated by the community.

Food Web group objectives:

The goal of this working group was to continue development of a Detroit River food web model that used water and sediment PCB inputs to predict individual fish PCB body burdens for a suite of fish species. This work is described in detail in Chapters 5 and 6.

Food Web Group Outcomes:

1. A risk analysis of PCB body burdens in fish, including those not included in the advisories.

2. A spatial integration of water and sediment inputs for predicting PCB body burdens in fish.

<u>Workshop 3: Fish Consumption Advisories in the Detroit River: Progress Towards a Solution</u>

Meeting 3 Objectives: The objectives of workshop three were to provide an overview of the project outcomes in addressing key issues related to fish consumption advisories on the Detroit River, to discuss the next priorities for FCAs in the Detroit River, and to identify funding opportunities to support future high priority efforts.

Meeting 3 Outcomes:

1. Development of three working groups to continue work beyond the project end: Public Outreach, Fish Monitoring Coordination, and Contaminant and Pollution Prevention.

2. Survey assessment of integrated assessment process (see Assessment section).

3. Organized a proposal submission for the Great Lakes Restoration Initiative sponsored by the Environmental Protection Agency.

    Michigan Department of Community Health. Enhanced Michigan Fish Contaminant Monitoring and Advisories. Request $411,232 over 1 year. Submitted by Linda D. Dykema. ***(Selected for Funding)***

DOCUMENTATION OF STATUS AND TRENDS OF FISH CONSUMPTION ADVISORIES: A REVIEW OF STATE-LEVEL APPROACHES

In the United State, individual states have primary responsibility for implementing their own FCAs, including assessing contaminant levels in fish, setting advisory trigger levels, and implementing outreach efforts. This has yielded a system with substantial state-by-state variations. For the most part, FCA assessments involve overlapping regulatory responsibilities of health, conservation, and natural resources agencies. In most instances, natural resource agencies are responsible for collecting the fish used for contaminant analysis, while either the same agency or a separate one will analyze the tissue for contaminants. The resulting tissue contaminant level information is then analyzed by a human health (or natural resource) department in order to set the advisory level. This is usually done in biennial assessments of state-wide water quality, but can vary depending on mandates and funding levels. Here we document the status and trends FCAs across the states and provide a synthesis and summary of the available information and data related to FCAs to provide a comprehensive document that structures the current state of knowledge about these advisories (Chapter 3). We document the efforts among the Great Lakes States to coordinate, streamline, and standardize their approach to FCAs for PCBs through the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory. We present the similarities and differences among the Great Lakes states in following this protocol. In addition, Chapter 3 moves beyond a comparison of the Great Lakes region and also reviews the status and trends of the advisories across the United States as the related to PCBs.

DEALING WITH UNCERTAINTY IN FISH CONSUMPTION ADVISORIES IN THE DETROIT RIVER:

The identification of **key uncertainties** regarding the drivers of consumption advisories can be used to prioritize future research and monitoring efforts and help guide management and policy directives. The fish consumption advisory process is characterized by uncertainty: Managers and regulators must combine the best available science on human health effects with information on contaminant concentration in recreational fish and risk factors of a general public to decide when and how to issue an advisory. We evaluated the literature to both 1) assess the type of information available to improve the advisory process and 2) evaluate the use of probabilistic approaches for consumption advisories. Available information on the concentration of polychlorinated biphenyls (PCBs) in fish indicate high variability in some fish populations, including cases of sex-based differences in contaminant levels (Chapter 4). The results indicate variation in PCB concentrations in fish can strongly affect key factors related to human exposure, including the chronic daily intake for PCBs and the meal consumption advisories. In addition, ingestion rate of these fish was also an important parameter influencing the level of human health risks. For the Detroit River, the primary recommendation is to improve the sampling regime of the fish population, to improve information about the consumption habits of high risk groups, and to target outreach efforts to those populations with the greatest level of risk and exposure – namely minority subsistence fisherpersons and women of childbearing age and children under the age of 15. Furthermore, one of the key parameters to the advisory process that remains poorly defined is the actual consumption rate for subsistence fisherpeople, especially minority groups. When the original Uniform Protocol guideline was developed, the main sensitive subgroup that was targeted was women of childbearing age and children/infants. This was driven largely by the particular sensitivity of these groups to the toxicity of PCBs. Since this time, however, it has become increasingly recognized that there are other subgroups that may be at higher risk to PCB effects due to their consumption habits. Based on these concerns, we wanted to evaluate the fishing habits on the Detroit River and determine the degree to which subsistence fishing was occurring on the river and if there were inconsistencies among different subgroups or populations . Therefore, through this IA process we sponsored a study on the *Environmental Justice and Fish Consumption Advisories on the Detroit River Area of Concern* (Kalkirtz et al. 2008). The authors addressed whether the most vulnerable populations receive and utilize fish consumption advisory information, and how public information provided by institutions influences anglers. This work was in part, supported by a creel survey in which the behaviors and attitudes of anglers on the Detroit River were assessed in response towards the advisory and their fishing habits. Full details of this project can be found in Appendix D. For example, it was determined there was a discrepancy between the type of fish Caucasians and people of color were eating (Figure 1). This supported the concerns documented in our literature review. In the Detroit River study, people of color were tending to consume more catfish compared with Caucasians.

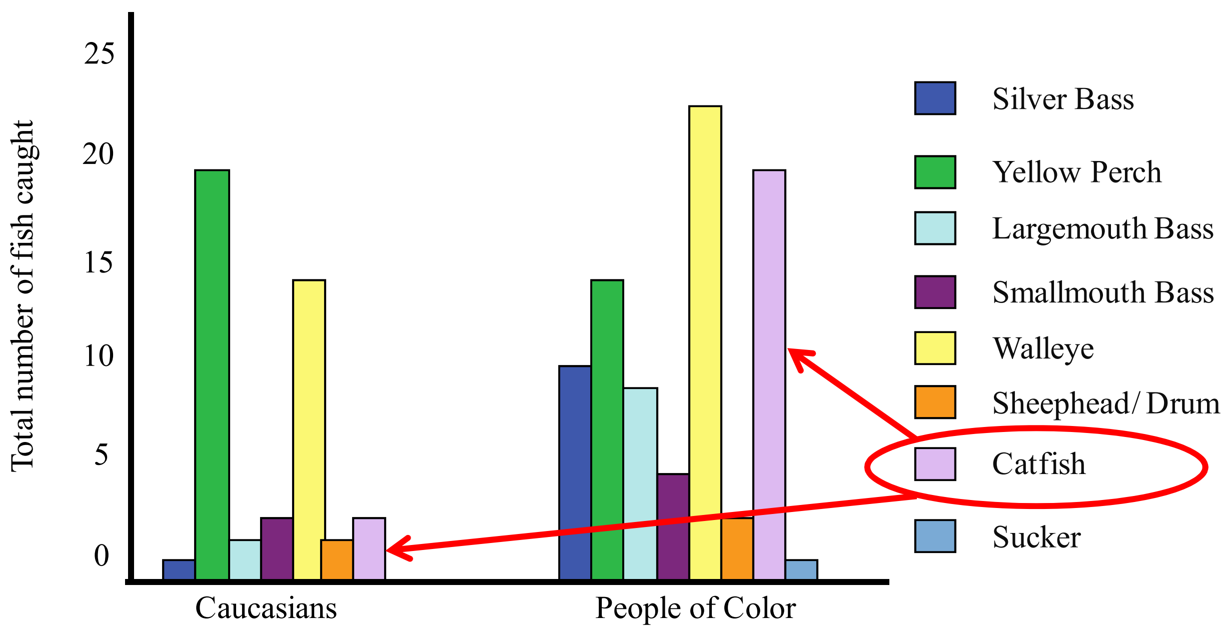


Figure 1. A comparison of eating habits of anglers on the Detroit River, results were obtained from a creel survey administered in 2007 along both the Canadian and US side of the river. Graph taken from (Kalkirtz et al. 2008; Appendix D).

DETROIT RIVER FISH CONSUMPTION HAZARD ASSESSMENT MODEL: A PROBABILISTIC BIOACCUMULATION MODEL TO PREDICT PCB EXPOSURES IN SPORT FISH TO APPLY HAZARD AND RISK ASSESSMENTS FOR FISH CONSUMPTION ADVISORIES IN THE DETROIT RIVER

Background: An important consideration in identifying the causes of consumption advisories in the Detroit River is the relative role of sediment contaminant (i.e., legacy contaminants and hot spots) compared to water concentrations (i.e., current input). Deciphering between these two contaminant sources is further compounded by the mobility of the sport fish populations most of concern. Previous studies using food web bioaccumulation models in the Detroit River have suggested a strong bias with respect to larger, mobile sport fish, which may be due to the movement of fish outside of the modeling region (Drouillard et al. 2003; DRMMF 2003). Bias is the ratio of observed to predicted result. The original model tended to underpredict contaminants in some sections (contaminated sections) for top piscivores and overestimate contaminant levels in the same animals in the cleanest sections of the river. To help identify the drivers of elevated body burdens in these larger sport fish, a probabilistic bioaccumulation model incorporating fish movements will be used to develop a risk-based assessment for identifying potential sediment hotspots that might drive consumption advisories for walleye, a representative sport fish. This food web bioaccumulation model will be used in conjunction with contaminant water concentrations and sediment concentrations to help predict steady-state sport fish contaminant residues for each of 20 modeling zones distributed within the Detroit River and the adjacent Detroit River – Lake St. Clair corridor. Some support for this modeling effort is already provided, but additional funds are required to complete the project.

Objectives: This bioaccumulation model was used to determine: 1) the relative importance of sediment and water contamination as exposure routes to fish; 2) the impact of changes in food web structure and energy flow on fish consumption advisories; and 3) the effects of different target water and sediment concentrations for achieving delisting criteria for sport fish. This will permit a risk-based approach for sport fish consumption advisories (novel for this region and state) and allow for hypothesis testing on the magnitude of sediment concentration and surface area associated with sediment hotspots.

Outcomes: Model results indicate that sediment contamination (highest effect) is the largest driver of fish consumption advisories in the Detroit River, with elevated water and sediment contamination in U.S. nearshore areas, the Trenton Channel (TT) and Downstream of the TT being the largest contributors. Combined high water plus sediment contamination indicates sources of PCBs entering Detroit River continue to occur and therefore are not just from historical sources. Corridor sediment surveys indicate that there is not an upstream source. Elevated water and sediment hot spots are responsible for the most stringent advisories issued in the Detroit River. Advisories are also largely influenced (2nd highest effect) by the fish dorsal muscle lipid content. The lipid content of the dorsal muscle tissue has a strong influence on the level of fish advisory predicted because contaminants like PCBs accumulate predominantly in fat and therefore tissues and/or organisms with higher lipid content will have higher concentrations when expressed on a whole body/wet weight basis. Fish species with high dorsal muscle tissue lipid content include the Channel catfish, carp, gar pike and freshwater drum (muscle lipid content = 3–6.6%). Crappie, yellow perch, northern pike, bowfin, walleye and bullhead all have substantially lower dorsal muscle lipid content (0.1–1%). The spatial movements of fish have a moderate effect as drivers of fish consumption advisories in the Detroit River. Fish residing in hot spots and exhibiting low fish movements are more likely to be drivers. Finally, model results indicate that feeding ecology has a relatively low effect as a driver of fish consumption advisories. Benthic feeding fish are the most highly exposed, followed by piscivores. These results are presented in detail in Chapter 5.

SPATIAL MODIFICATION OF MODELLING PCB TRANSFER IN THE FOOD WEB OF THE DETROIT RIVER

Objectives

The most important mechanism driving the PCB body burdens of fish species utilized by humans is understood to be uptake from the food the fish eat (i.e. biomagnifications). The relative role of different components of the food web in causing these burdens is less clearly characterized.
The Detroit River food web is a network of feeding interactions among spatially distributed

populations of fish, benthic invertebrates, and plankton (DRMMF 2003). These feeding interactions create subsystems of highly interacting populations within the greater system of the Detroit River food web, where weaker feeding interactions occurring between subsystems (Krause et al. 2003). The weaker interactions suggest that the PCB body burdens of taxonomic populations would be more greatly influenced by those other populations within their subsystems than by those in other subsystems (Simon 1962, Krause et al. 2003). We determined the subsystem structure of the spatially-explicit food web in the Detroit River by identifying groups of highly interacting populations of fish, benthic invertebrates, and plankton. We have built upon the current food web bioaccumulation model described in detail in Chapter 5, the ***Detroit River Fish Consumption Hazard Assessment Model,*** which has shown good predictive capability for PCBs based on a relatively complete simulation of PCB flow process. It is a steady state model with an assumption of some level of accumulation based on the average body size of an adult. It assumes that the PCB concentrations in the organisms reflect concentrations in water and sediments in a specific region and that these concentrations remain stable over time. We updated this model to produce more accurate predictions of PCB concentrations in fish and to identify the relative contribution of different river zones to the body burden of PCB in a single fish species. This was done through an evaluation of how different regions of the rivers (zones) from the sediment and water influenced the PCB inputs and resulting PCB body burdens in the fish, which then translate into fish advisories.

Outcomes

A model update was accomplished in that we were able to improve the predictions for 17.3% of the observed data where the non-spatial model underpredicted PCB body burdens. The spatial modification of diet composition, which was quantified by the zone specific adjustment probabilities, should improve the probability of identifying the relative contribution of river zones to the PCB body burdens in the fish species in the future.

PROJECT ASSESSMENT

Project assessment focused on an evaluation of the participatory research process. This was accomplished via a survey of our stakeholders at the beginning of the process and at the end as assessment tools. Results of this survey were used throughout the workshop process, presented at a national research conference, and provided insights into what made a successful working group within this network (Chapter 2). We asked about critical issues related to FCA' s on the Detroit River, and their knowledge about these issues, and the network. At our final workshop we administered a similar post-workshop survey to assess changes in participant critical issues, knowledge, and network ties. It also measured how much participants valued the integrated assessment products. With these tools, we have quantified the impact of the integrated assessment our participants.

REFERENCES

DRMMF Interpretive Report. 2003. Report Submitted to the Detroit River Canadian Cleanup Committee, April 2003. Prepared by the Great Lakes Institute for Environmental Research, University of Windsor, Windsor, ON, Canada.

Drouillard KG. 2003. Use of bioaccumulation models to perform hazard assessments for sport fish consumption advisories in the Detroit River AOC. Workshop Presentation: Staying on Target: A Regional Workshop for Establishing Restoration Targets for Great Lakes Areas of Concern, June 6-7, 2003, Romulus, MI, U.S.A.

Hedtke, TM, J Hartig, B Yu. 2003. Evaluating ecosystem results of PCB control measures within the Detroit River-Western Lake Erie Basin. Great Lakes National Program Office, U.S. Environmental Protection Agency, Chicago, IL, EPA-905-R-03-001, pp. 108-114.

Johnson, TB, RC Haas. 2004. Fish and fisheries of the Detroit River. Detroit River State of the Strait Conference, Dec. 2, University of Windsor, Windsor, ON.

Krause, A.E., K.A. Frank, D.M. Mason, R.E. Ulanowicz, and W.W. Taylor. 2003. Compartments revealed in food-web structure. *Nature.* 426: 282-285.

Kalkirtz, V, M. Martinez, and A. Teague. 2008. *Environmental Justice and Fish Consumption Advisoires on the Detroit River Area of Concern*.M.S. Thesis. University of Micghian, Ann Arbor, MI. U.S.

Simon, H.A. 1962. The architecture of complexity. *Proceedings of the American Philosophical Society*. 106: 467-482.

CHAPTER 2:

DEVELOPMENT, IMPLEMENTATION, AND ASSESSMENT OF STAKEHOLDER WORKSHOP SERIES

ABSTRACT

Integrated assessment is a form of participatory research (van Kerekhoff and Lebel 2006). It engages stakeholders at the organizational level to set shared agendas, goals, and to create support for specific projects. Because of the engagement of decision makers, the research becomes more powerful by integrating its intended audience. For our integrated assessment, we engaged our stakeholder organizations in a series of workshops to increase their capacity to work on issues related to Fish Consumption Advisories in the Detroit River. The first part of this report addresses the development of the workshop series. We assessed their capacity with key informant interviews and a stakeholder network survey. This assessment helped us to create a workshop series appropriate to their current level of capacity. The second part of this report provides details on the implementation of our workshop series. The third part of this report provides an assessment of our workshop series and of the capacity of the stakeholder network.

Through our integrated assessment, we have contributed to increasing the capacity of the stakeholder network related to Detroit River Fish Consumption Advisories. The workshop series provided new ways for stakeholders to work together. The products from the integrated assessment are available for stakeholders to continue their work on key issues. The assessment has highlighted the key elements needed for success on those issues. The Outreach Working Group developed and implemented strong outreach products for shoreline fisherpeople. They also exemplified the key elements needed for successful innovation. These elements should be incorporated by future working groups, including those developed at our final workshop: Public Outreach, Fish Monitoring Coordination, and Contaminant and Pollution Prevention.

SUMMARY OF POTENTIAL ACTIONS

Based on our workshop series, we recommend the following potential actions to the Detroit River FCA stakeholder network:

(1) Have annual or biennial workshops where updated information is exchanged and breakout sessions are incorporated. Have breakout sessions focused on needs assessment (both stakeholder and customer needs), priority issue assessment, network assessment, and working group development. Our integrated assessment has provided templates for guiding these breakout sessions.

(2) Support the development and efforts of working groups. These working groups identify specific goals and the steps to reach those goals related to a top priority issue. For greater working group success, members should focus on value creation for their outcomes/products, strong champion identification, and member diversity of roles. Roles were defined in Workshop

2. Working groups may consider following the guidelines of the Ecosystem Management Initiative (EMI) at the School of Natural Resources, University of Michigan (http://beta.snre.umich.edu/coe/emi).

(3) Continue with quantitative survey assessments of the stakeholder network.

(4) Incorporate a stronger participatory research approach into on-going efforts. A learning approach would increase engagement and power sharing of fisherpeople and Detroit citizens by having them participate in developing research questions, collecting data, and analyzing data. This approach has the greatest potential for solving Detroit River FCA issues.

DEVELOPMENT

Introduction to the workshop series

In our original proposal, we outlined a workshop series developed by the Ecosystem Management Initiative (EMI) at the School of Natural Resources, University of Michigan (http://beta.snre.umich.edu/coe/emi). Our goal was to facilitate stakeholders through this four-stage process with an outcome of an action plan. The first stage (Workshop 1) was to understand what the stakeholders are trying to achieve by creating a “situation map” including a visualization of the relationships between goals, strategies, assets, and threats. The second stage (Workshop 2) is to develop an assessment framework for evaluating progress on an action plan through indicators. The third stage (Workshop 3) is to develop an information work plan on how to gather and interpret the data used in evaluation. The final fourth step (Workshop 4) is to develop an action plan that outlines how stakeholders will use the information in decision-making. We incorporated this workshop series into our scientific research plan, where we outlined how we would acquire all available data related to the Detroit River fish consumption advisories (FCAs; Workshop 1), summarize the status and trends of the data (Workshop 2), analyze the data and have a model simulation to identify key uncertainties in determining the biotic, abiotic, and human health causes and consequences of FCAs (Workshop 3), and finally, develop technical guidance to help guide management initiatives.

When we began our project, we solicited the expertise of a community planner, Dr. Branda Nowell, North Carolina State University, who had been working with Dr. Ann Krause on other project development. Dr. Nowell was interested in working through the EMI process with a natural resource stakeholder group. Prior to starting the workshop series, she suggested that we assess the current stakeholder network, including issue alignment and capacity, through key informant interviews and a survey. This assessment would allow us to design a workshop series that fit the needs of the stakeholders as a group. In addition, we would report the assessment to the stakeholders at the initial workshop.

When identifying key informants, we made it a priority to get a diversity of viewpoints. Thus, we defined 6 different types of stakeholder roles with the assistance of our agency advisor, Dr. Rosanne Ellison, US-EPA (USA):

Regulatory Advisory – government agencies who are involved in any regulatory processes that help set the trigger levels for fish contaminant advisories in the Detroit River and distribute the information to those at risk

Community End Users - non-profit and private community groups that are involved in conservation, sports fishing, or human health risks related to the Detroit River

Monitoring Regulatory – government agencies that collect data on the ecological system in the Detroit River for the purpose of setting regulations

Monitoring Research – university groups or government agencies that collect data on the ecological system in the Detroit River for research purposes

Regulatory Contaminant – government agencies that regulate the input or removal of contaminants in the Detroit River

Industrial Development – private and non-profit groups and government agencies that have a vested interest in the industrial and economic development of the Detroit River and its adjacent land

We asked Dr. Ellison and our co-investigator, Dr. Ken Droulliard, University of Windsor (Canada), to nominate potential key informants where we asked for 4 nominations within each role with 2 nominations per country (U.S. and Canada), for a total of 24 nominations. We contacted nominated individuals for interviews until we had 12 interviews that covered each role in each country. All interviews were conducted over the phone, where informed consent forms were collected prior to the interview. The interviews were semi-structured. Each interviewee was asked a series of questions to identify the important issues and critical drivers related to FCAs, the priorities of their organization related to FCAs, the perceptions on shared priorities among organizations within roles, and the key differences in how people think about this issue and philosophies (Appendix 2.0). All interviews were then transcribed. Drs. Krause and Nowell went through the transcriptions to identify main themes in key issues and concerns, vision and priorities, and capacities to work on key issues.

Based on these interviews, Dr. Nowell advised us to restructure the workshop series, as the proposed EMI workshop series was not appropriate for the current stage of the stakeholder network. Her primary concerns were the lack of issue alignment between organizations, the lack of champions to carry-forward any actions, and the lack of awareness of the roles organizations had related to FCAs. All of these properties indicated low capacity for the stakeholder group to move forward on key issues. She also emphasized that the investigators of the project should not become champions if they were not willing to continue to work with the stakeholders beyond the end of the project. Thus, we decided to facilitate capacity building in the stakeholder network by outlining a new workshop series with the help of Dr. Nowell. The *first workshop outcome goal* was identified as: Stakeholders will gain a greater awareness of the organizational system in which they are embedded in regards to contaminants and fish consumption advisories in the Detroit River. Dr. Ellison strongly supported this goal and it fit with the "lessons learned" section from the Michigan Sea Grant Integrated Assessment workshop at the beginning of the project. This goal would also help to support the scientific goals of the project as well. The *second workshop outcome goals* were identified as: 1. Stakeholders will have normative scenarios based on what they envision is possible for addressing issues related to contaminants and fish consumption advisories given the resources of the organizational system and 2. Stakeholders will have goals and objectives for the next two workshops. Goal 1 fit in with the scientific goals identified of summarizing status and trends and identifying key uncertainties. Goal 2 fit in with the "lessons learned" from the previously mention Sea Grant workshop. *Workshop 3 goal* was identified as: Researchers will provide technical assistance needed for stakeholders to reach their goal for workshop 3. This goal fit with the fourth scientific goal of technical assistance and "lessons learned". For *workshop 4, our goal* was identified as: Stakeholders will have an action plan for how they want to move forward (same as EMI workshop 4). Even with these modifications to fit our stakeholder group, we found, that after workshop 1, we had to continue to adjust these goals according to stakeholder needs.

Workshop Series Preparation

In order to proceed with our workshop series, it was important to provide a clear definition of our stakeholders when communicating about the project. Our definition of our stakeholders was "those organizations, agencies, and groups who are invested in/involved with the issue of contamination in the Detroit River and its human and/or environmental consequences as represented by their recent campaign, mission, research, or population served, or interactions with the Detroit River itself." Our investigative team compiled an initial stakeholder list in consultation with Dr. Ellison. We asked our key informants at the end of our interviews to review the stakeholder list that had been complied thus far (this list had been emailed to them prior to the interview) and to name organizations that should be added to the list based on our stakeholder definition. In addition, we asked for a contact person. A database was constructed to hold the master list of stakeholder organization name and contact person information (name, email, phone number). From the key informant interviews, a stakeholder survey was developed and administered prior to the workshop (Appendix 2.1).

We had to confirm that we had the correct contact person identified for each organization to invite to our workshop and to fill out our stakeholder survey. First, we sent out a "hold the date" email two months prior to the workshop date to the contact person named in our database, which invited them to the workshop and gave the date of the workshop. After this email was sent, we contacted each contact person by phone. The caller verified the organization name (including subcategories in the name, e.g., organization name MDEQ, subcategory Southeast Michigan District Office). The caller then informed the contact person about a survey that would help us to understand the communication network among stakeholders and inform workshop participants about the resources and capacities that exist. The caller asked, "who is the person who best fits the following description for your organization?" The individual in your organization who

- Works most closely with an issue that directly relates to contaminants and/or human health concerns in the Detroit River
- Has the greatest decision making authority regarding that issue within the organization

If the contact person on the phone acknowledged that s/he was that individual, s/he remained the contact person. If s/he named another individual, then the caller collected the title and contact information for the new person. We revised our database by replacing the contact person information with the new name and information.

An email was sent out to the contact person of each stakeholder organization, which included the Internet link to the survey, a username, and password (a paper version of the survey was available upon request). The survey covered three areas: questions about the contact person and their organization, network questions, and issues on the FCAs. The beginning of the survey contained language about informed consent and stated that the survey should only take the contact person only 20 minutes to fill out. The first section had questions regarding a contact person's title, years working for his/her organization, years in current position, years working on the Detroit River, and level of position. It also asked what role s/he regarded his/her organization as taking in terms of FCAs in the Detroit River. For this survey, roles were reduced from 6 types to 5 types and definitions refined.

Industrial and Economic Development: Private and non-profit groups and government agencies that have a vested interest in the industrial and economic development of the Detroit River and its adjacent land or are industrial property owners along the Detroit River.

Regulatory Compliance: Government agencies who set contaminant policy or regulate the input of contaminants in the Detroit River, such as through enforcement or permits. This includes oversight monitoring, particularly for non-point sources. Permitees collect their own data to demonstrate compliance.

Monitoring Research: University groups or government agencies who collect data on the ecological system in the Detroit River for research and/or academic purposes or collect fish for setting trigger levels.

Policy on Fish Consumption Advisories: Government agencies who are involved in planning and information gathering to carry policy out on setting the trigger levels for fish contaminant advisories in the Detroit River, including the distribution of information to those at risk.

Community End Users: non-profit and private community groups who are involved in conservation, sports fishing, or human health risks related to the Detroit River.

For network information, the second section listed all of the stakeholder organizations, arranged by role, and asked the contact person to indicate the following statements for each stakeholder organization:

- My organization has received data or information from this organization/agency at least once over the past 12 months
- My organization has collaborated with (e.g., worked together on joint projects) this organization at least once during the past 12 months
- There are one or more professional relationships that link my organization to the members of this organization such that we would feel comfortable going to them to ask for assistance and/or their organization's support on a project.

The third section asked the contact person to identify up to three issues that are the greatest concern to his/her organization. The list of issues was compiled from the key informant interviews. Follow up phone calls were made to the emails to ensure a high rate of response. High response rates (80%) are essential to correctly analyze network data. For each role, we had the following response rates: 71% for Industrial & Economic Development, 90% for Regulatory Compliance, 100% for Monitoring Research, 86% for Policy on Fish Consumption Advisories, 87% for Community End User, and 35% for State/Provincial Representatives. We dropped state/provincial representatives from our analysis of the survey data because of the low response from state representatives. We felt comfortable with dropping these stakeholders given the difference between them and other stakeholder organizations. State/Provincial Representatives are elected officials that don't represent "organizations". Few ties existed between them and other organizations based on our survey network data. The overall response rate was very high (87%).

The results of this stakeholder survey were key in our integrated assessment. We incorporated the results into the afternoon session of Workshop 1 and used them throughout the workshop series (see Implementation and Assessment section for more detail). They were also reported in an oral presentation at the International Association for Great Lakes Research 2009 conference at the University of Toledo, OH and at the Michigan Sea Grant Integrated Assessment Workshop in June 2010.

Another key feature of our workshops was fully engaging the stakeholders, which led to tangible products and increased capacity. To engage the participants, we developed break-out group activities where the activities were scripted with specific questions for stakeholders to address and discuss. Participant responses were recorded on tear sheets by graduate student and investigator recorders (scribes) so that all members of the break-out group had an equal chance to contribute without the burden of also recording the group discussion. Responses from these tear sheets transcribed and posted on our website for future use by investigators and stakeholders. Break-out groups were used for two primary reasons: 1. More topics/issues could be covered in the same amount of time and 2. More voices could contribute to the conversation. Breakout groups would then report back to the larger group for a broad discussion of the topic. Another engagement activity we included was dot voting on issues. Each participant was given sticky dots that they could place on what they felt were the most important issues brought up by all of the break-out groups. This technique allowed us to get a group consensus where every participant contributed to that consensus equally. As a general rule, we reduced the time and number of presentations given in workshops. Time slots for presentations factored in ample discussion time (10-20 minutes of discussion time). These engagement techniques will be covered in more detail in the next section.

IMPLEMENTATION

Workshop 1

The title of this workshop was "Detroit River Fish Consumption Guides: Navigating the Issues." To carry out our outcome goal for the first workshop (goal: greater stakeholder awareness of the organizational system surrounding FCAs in the Detroit River), we emphasized stakeholder engagement strategies over oral presentations. We had a total of 32 participants in all, who represented all of the stakeholder roles and both countries, at the Belle Isle Nature Zoo in Detroit, MI on November 11, 2007. However, the US was more strongly represented than Canada, where only two participants were from Canada. The workshop was an all day affair, with a catered lunch free to all participants. We started the day with a brief introduction to the project (15 minutes) and introductions of all participants.

Pre-worshop survey (Time 1): Immediately after introductions, we had participants take a pre-workshop series survey (Appendix 2.2). This survey had four parts to it: background information, key issues on the Detroit River, resources and needs of stakeholders, and network questions. The background information asked for generic information, such as age, gender, ethnicity, and degree level. It also mirrored the stakeholder survey in asking for length of time with his/her current organization, years in current position, and years working on Detroit River issues. The key issues asked participants to check up to three of the most critical key issues regarding FCAs in the Detroit River as well as the up to three of the least critical issues. In this section, we also asked a series of questions about how knowledgeable a participant felt s/he was about specific issues. Again, all of these issues were based on information collected during the key informant interviews. They were asked about their level of knowledge about the network as well. In the resources section, we asked about the level of agreement regarding statements about his/her familiarity of the resources distributed in the stakeholder network. It asked for participants to give his/her top 3 important needs for working on FCAs in the Detroit River. A third question asked if his/her organization collected data and if so, what type of data. Finally, this section asked who the primary customers were of the services his/her organization provided. The final section had the participants check frequency of interaction with the other participants of the workshop in terms of whom were considered to be close professional colleagues (Once or twice a year, monthly or weekly) and whom provided information and/or data related to FCAs in the Detroit River. This survey served as a Time 1 capture of where our participants were prior to the workshop series so that we could conduct a longitudinal assessment of how participant knowledge, attitudes, and networks changed from the beginning to the ending our process. In addition, we were able to use responses in the resource section to provide products to our stakeholders.

Morning Break-Out Session: After a short break, we asked participants to self select into three different groups for break-out groups in the afternoon. The three groups represented the three different systems related to FCAs in the Detroit River and were color-coded.

Contaminant Regulation and Management	**(GREEN)**
This group will focus on the sources and management of contaminants in the Detroit river that lead to the need for fish consumption advisory. They will be involved in mapping the current management system and discussing issues and key uncertainties related to sources of contamination and its regulation in the Detroit River	
River Food Web System	**(YELLOW)**

This group will focus on the processes through which contaminants work their way through the food web into the fish that people eat. They will be involved in mapping the food web in the river, including spatial considerations. They will discuss data sources, issues, and key uncertainties related to bioaccumulation of contaminants in the food web.

FCA Policy and its End Users Group (BLUE)

This group will focus on fish consumption advisories and the target users. They will be involved in mapping the process of setting fish consumption advisories in the US and in Canada and the distribution of those advisories to target end users.

The participants were asked to select a sheet of dot stickers of the color of the group they wished to participate in and place one of the dots onto their nametags so that they could be easily identified by their selected group.

Next activity in the morning had participants focus on learning about other organizations who play a role in the Detroit River and educating others about the work of their organization as it relates to the Detroit River. They were asked to divide into six groups by picking a group where they did not know many of the people and each group had to have no more than 3 people with the same color dot on their nametag. Within the group, participants were asked to pair with someone else in the group that they did not know and who had a different color dot than them. The paired participants then interviewed each other with the following questions:

- *What do you do?*
    - What is your program's function as it relates to PCB/Hg contaminants in the Detroit River and/or their impact on human health?
    - What is your job as it relates to this function?
- *What are some of the things that make carrying out this function difficult?*
    - What are your biggest challenges you face in trying to carry out this function?
- *Who and what do you rely on to carry out this function?*
    - Who do you collaborate with? In what ways?
    - What informs your work or activities as they relate to the Detroit River?
- *What, if any, are common misperceptions you encounter about your organization and its role?*
    - Are there important elements of your organization and its function, constraints, abilities, and/or limitations that people often don't know or misunderstand? What are they?
- *In what ways, if any, do you serve as a resource for other stakeholders who are working on issues related to PCB/Hg contamination and/or its human impacts? To whom and in what ways?*

After the interviews, each participant in a group introduced his/her interviewee to the other group members by relating back responses to the interview questions. After this breakout session, participants regrouped based on their system group (color group). They each shared three new things that they learned from the interview activity.

Afternoon reflection and Network presentation: The afternoon session was focused on the FCA network. First, participants were asked to reflect individually on the FCA network by answering the following questions on a sheet of paper:

- What types of information and resources need to flow through the network in order for it to function effectively?
- In what areas is it most important for coordination among organizations and agencies? Around what?
- In what parts of the network would you be especially concerned about seeing tight linkages between organizations and agencies? Why?

After this, Dr. Nowell presented the results of the stakeholder network analysis and facilitated a discussion of these results (see Assessment section for methodology and detailed analysis). Her main points were that more interactions occurred within countries than between countries, and that those organizations with relatively new contact people were not embedded in the broader network. She discussed the issue alignment between the two countries, where organizations in the US and in Canada only shared one issue in their top three issues but differed in the other two. These issues were:

- For Canadian organizations:
    - Reducing public fear of utilizing the Detroit river as a resource resulting from beneficial use impairments
    - Securing the funds to ensure more consistent monitoring of the river
    - Reducing the introduction of new contaminants through improving regulation and monitoring of point and non point source contaminants
- For US organizations:
    - Removing existing contaminants in the sediments of the Detroit River
    - Reducing the introduction of new contaminants through improving regulation and monitoring of point and non point source contaminants
    - Within your country, increasing coordination among local, state/provincial, and federal government authorities in planning along the Detroit River

Afternoon Breakout Session: After the discussion, participants went to the assigned location of their color/system group. Each group had a graduate student scribe and an investigator-facilitator. To get started, each participant in introduced him/herself to the group and stated what their organizations' function/interests were as they related to contaminants in the Detroit River and/or their impact on human health. Then, each system had *goals* they had to address during their breakout time, including the development of a *system map*. After discussion, each system group was to come up with a *list of key questions/issues* related to their system. Participants voted for their top five questions by placing one of their dot stickers next to the question for which they were voting. The five questions that had the most dots were identified as the top five issues of the stakeholder network.

Contaminant Regulation and Management System Goals

1. To identify key sources of contaminants and assumptions about relative contributions of contaminants.

2. To create a system map of the stakeholders and their role in managing contaminants.

3. To identify the following: strengths and opportunities.

River Food Web System Goals

1. Create a system map of key sources of PCBs/mercury contaminants in the river system and how they bioaccumulate to fish through the river system into advisory fish.

2. Identify for the key boxes/arrows in the map what is known and what is unknown.

3. Identify the following: What don't we know about this system that inhibits our ability to take action? What information is needed and what form would it need to take to be useful? How could it be use?

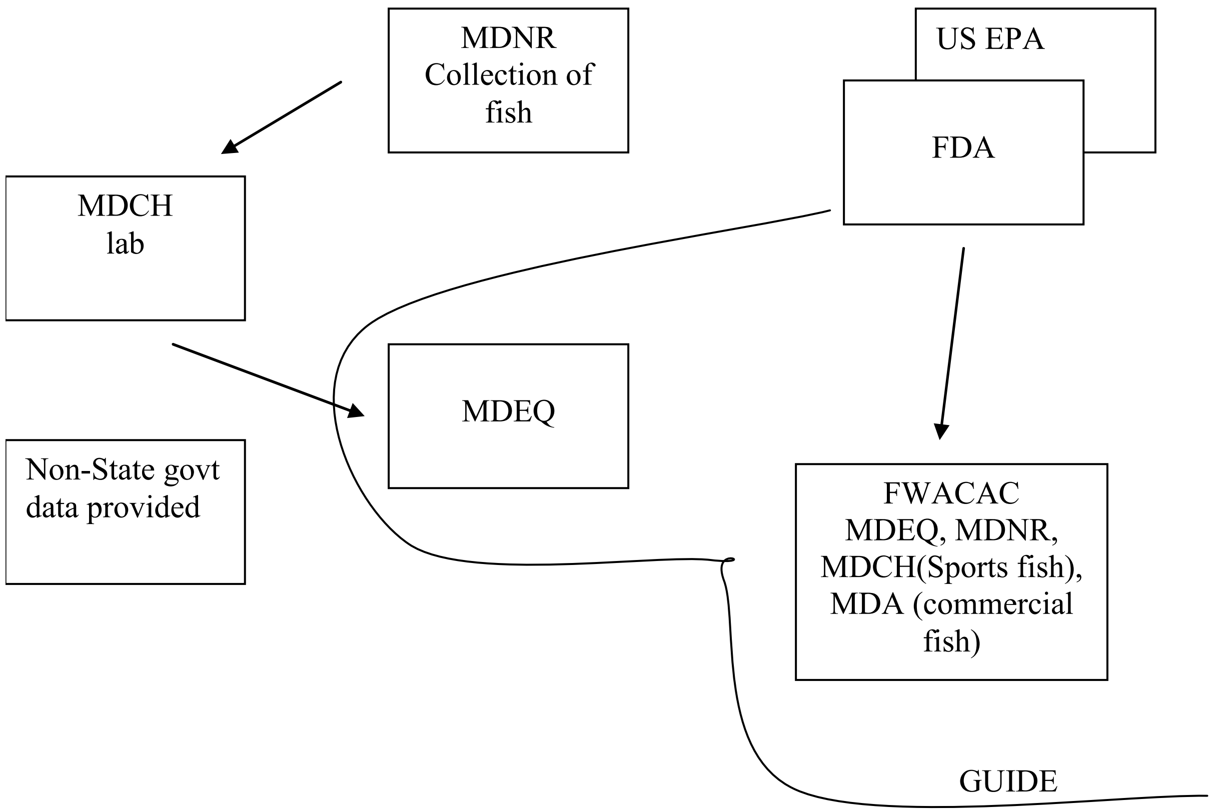
FCA Policy and its End Users System Goals

1. To map the roles of FCAs in the overall system and the drivers of different perspectives concerning their use and the most appropriate methodology for determining FCAs

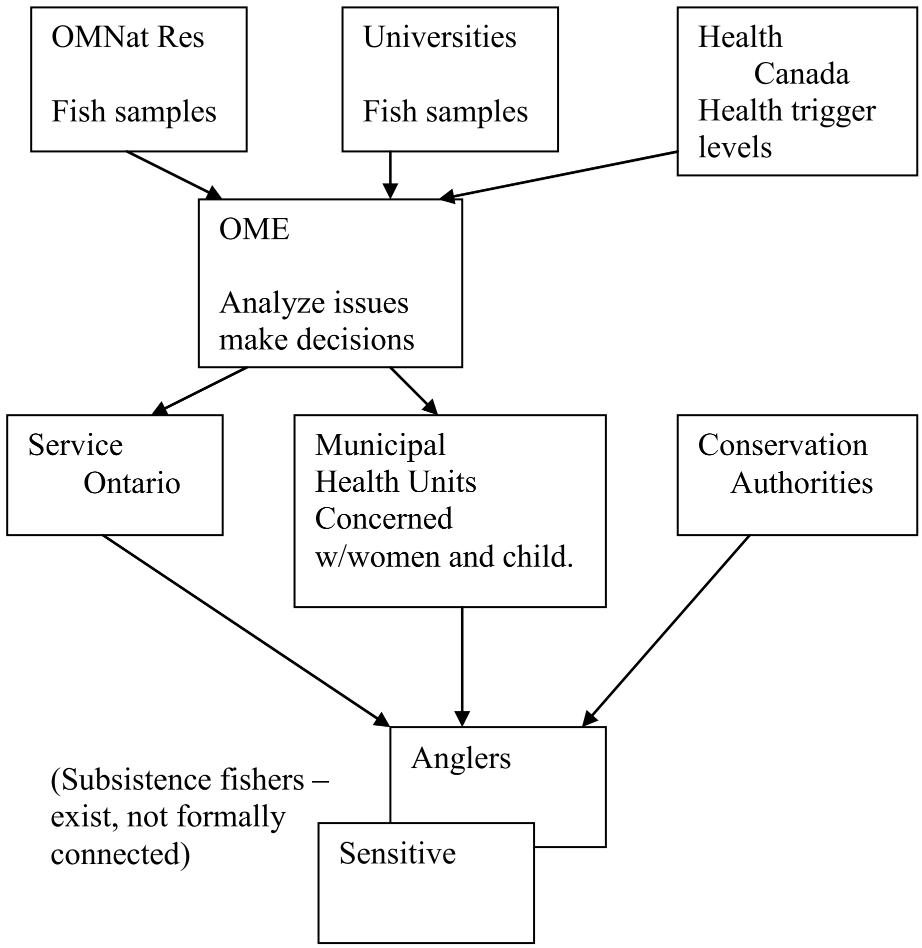
2. To create a system map of the underlying system and the drivers that may lead to negative health outcomes for end users

3. To identify the following: What don't we know about this system that inhibits the FCA process and outcome and thus our ability to take action? Are there short-term or long-term measures that can be taken to reduce human health effects beyond reduction of contaminants in the environment? What information is needed and what form would it need to take to be useful?

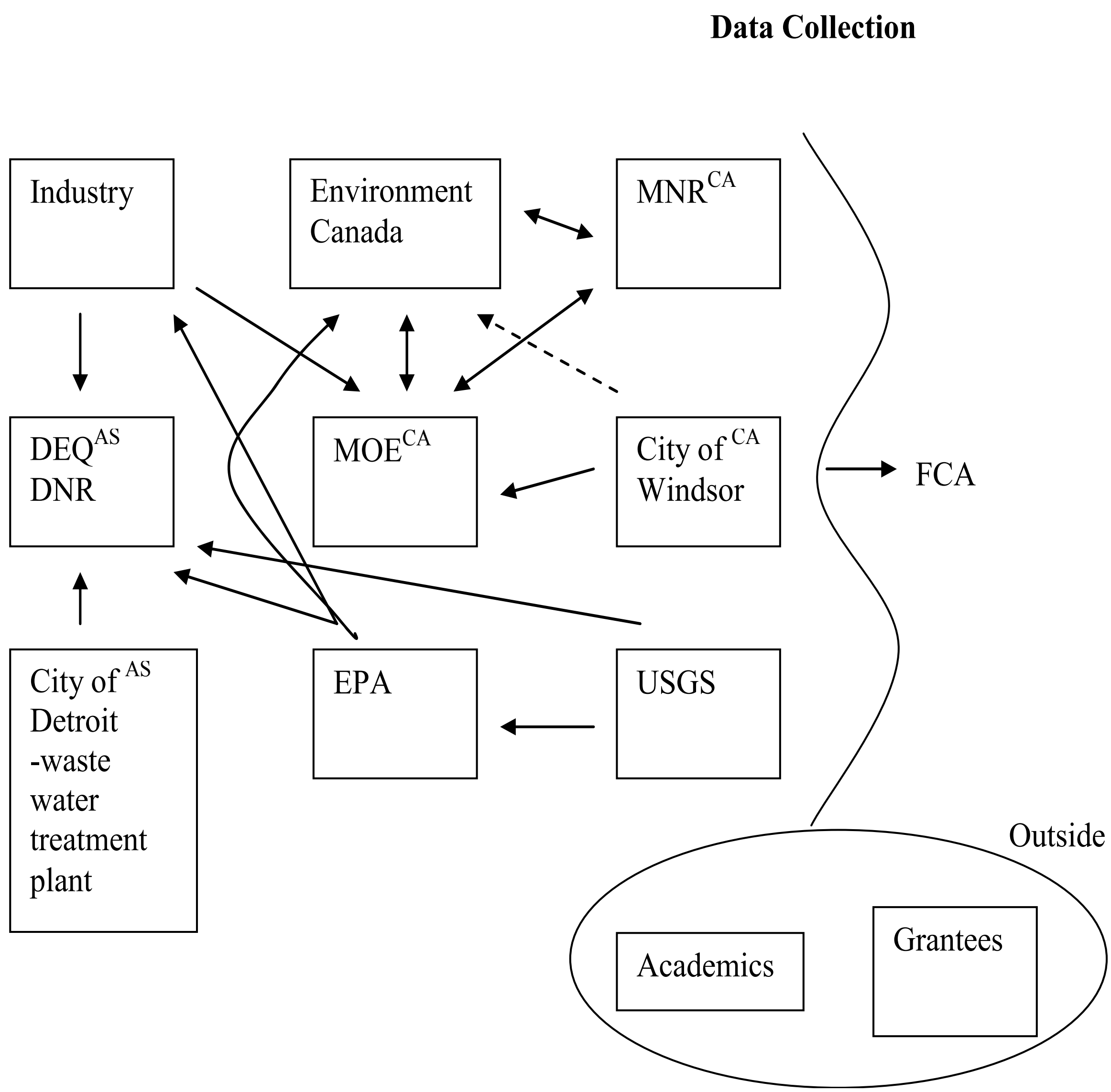
FCA Policy and its End Users System Map for US Setting FCAs



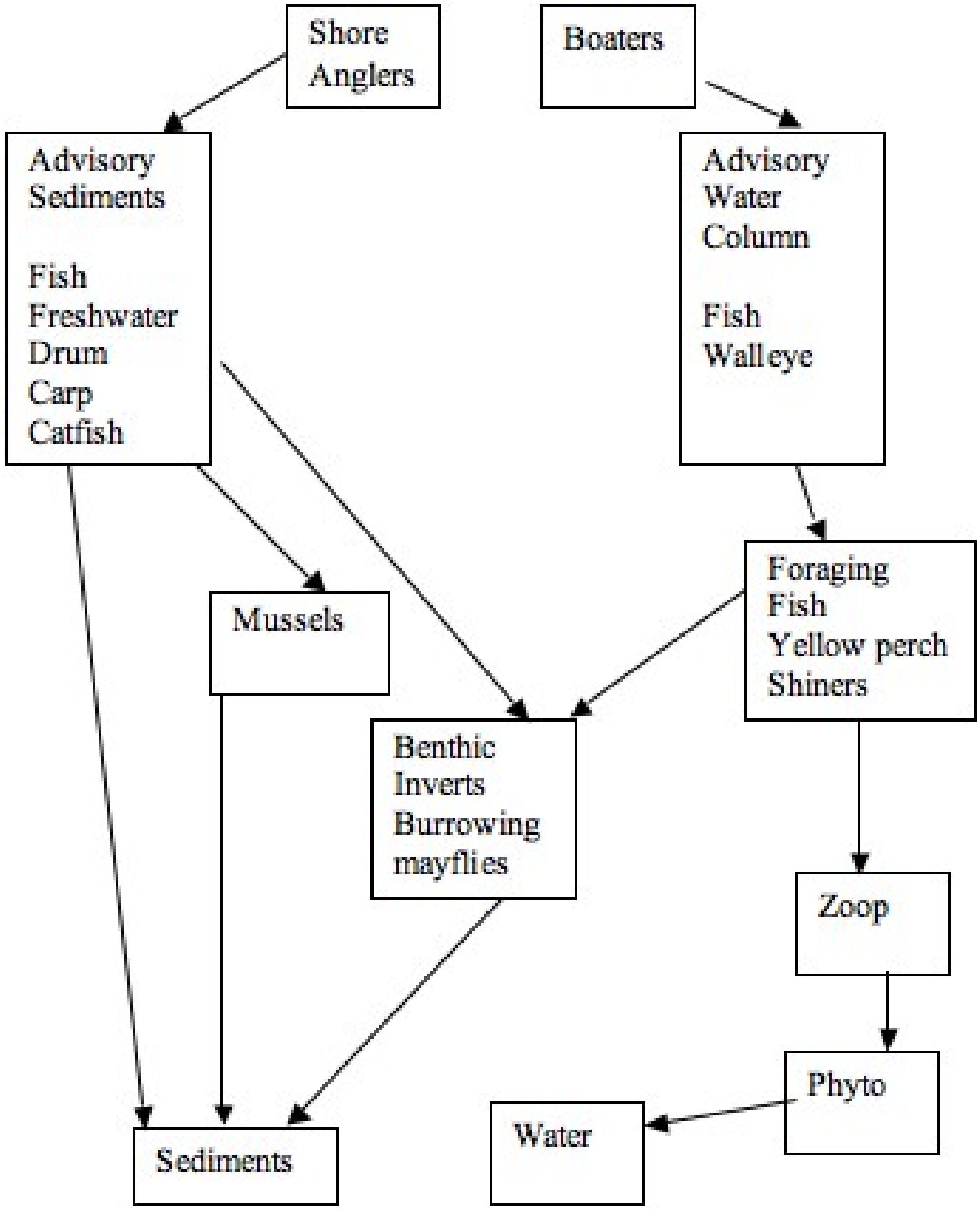
FCA Policy and its End Users System Map for Canada



Contaminant Regulation and Management System Map



River Food Web System Map



Contaminant Regulation and Management System Key Questions

1. Why spend so much money on research and monitoring but not on dissemination of knowledge? (1 blue, 2 green)
2. Where are the sources of contaminants (high enough to translate into FCA) in the basin? (2 blue, 5 green)
3. Why is there still not a lot of consistency and coordination between the U.S. and Canada? (2 blue, 2 green)
4. If the high risk groups had the information would they follow the advisories? (2 blue, 1, green, 2 yellow)
5. How confident are they with the fish they collect representing the population? (3 blue, 3 green, 2 yellow)
6. Synergistic effects of contaminants? (1 blue)
7. Are we appropriately measuring emerging contaminants? (2 blue, 3 green, 2 yellow)

River Food Web System Key Questions

1. What are contaminant levels of fish <u>not</u> on Fish Consumption Advisory list, that are <u>edible</u>? (4 yellow, 1 blue, 3 green)
2. What is the poundage & # of anglers & angler days of fish consumed by shore anglers and Boaters for comparison? (2 yellow)
3. What are transfer efficiencies for different levels in food web? From humans on down. (5 yellow)

FCA Policy and its End Users System Key Questions

1. What priority does the state place on providing fish advisories? (Level of interest on continuing forward from legislature) Willingness to have a long term commitment (5 blue)
2. Can we/should we make FCA a higher profile issue?
3. What can we do to increase public awareness of FCA? (2 blue, 3 green, 1 yellow)
4. How can we make (FCA) a higher priority within agencies/orgs? (1 blue, 1 green)
5. How do we market Detroit River as a fishing destination? (2 blue, 1 red)
6. How can we use FCA to highlight positives of Detroit River and fishing experience? (1 green)
7. What is the message of the FCA – what do we want it to be?
8. What message w/FCA that can agree to/ support?
9. How can we develop focus groups to improve message related to FCA?

Evaluation Survey: At the end of the workshop, participants were given a short evaluation survey (Appendix 2.3). They were asked how useful the workshop was to them overall, what did they find most useful, and which specific parts of the workshop did they find useful. They were asked to rate the location of the workshop and to suggest other program locations. Finally they were asked if there were additional topics they wanted discussed and any additional comments or feedback.

Products from Workshop 1:

1. <u>A stakeholder consensus of the top five issues related to Fish Consumption Advisories in the Detroit River.</u> These issues were used to guide the next workshops and subgroup goals.

1) How can we increase public awareness of FCA?
    - How can we make FCA a higher priority within agencies?
    - Why is so much money spent on research and monitoring but not on dissemination of knowledge?
2) Do the fish collected for contaminant analysis represent the population of fish accurately?
3) What are the contaminant levels of fish not included in the advisory that are consumed from the Detroit River?
4) Where are the sources of contaminant in the basin that are high enough to translate into a FCA?
5) Are we appropriately measuring emerging contaminants?

2. <u>A list of available databases related to contaminants and human health effects in the Detroit River.</u> We used the responses in the pre-survey to contact people about databases if they had indicated in the survey that their organization had data. These databases were described in detail on the project website. If the file was not available to download, then a website to download the data was linked to the description or a contact name and information was listed after the description.

Workshop 2

This workshop was titled "Fish Consumption Advisories in the Detroit River: A Canadian and US Partnering Opportunity". We modified our original outcome goal for the second workshop to better fit the needs of our stakeholders. The primary outcome goal for this workshop was to develop working groups to address the top key questions identified in the last workshop. A secondary outcome goal was to revise the stakeholder roles. We found from the stakeholder organization survey that only 47% of stakeholder organizations agreed with our assignment of what role their organization had in the network. The remaining responses showed that 26% chose a different role than what we had assigned and 17% suggested alternative roles. This result indicated that a participant discussion was warranted to revise the role names and definitions. Having a clear definition of roles and how organizations fit into those roles is an essential part in assessing the capacity of stakeholders to move forward on key issues. For this reason, we had participants work on better role definition prior to having them develop working groups.

We had a total of 17 participants in all, again, representing all of the stakeholder roles and both countries, at the Great Lakes Institute for Environmental Research, University of Windsor in Windsor, ON. To help to increase the communication between stakeholder organizations in the US and in Canada, we held this workshop in Canada. However, the US was still more strongly represented than Canada, where only four participants were from Canada (exclusive of project co-investigators and graduate students). Eleven of the participants had attended Workshop 1. Again, a catered lunch was provided free to all participants. We started at 9am and ended at 3pm, as survey responses from Workshop 1 evaluations and email feedback indicated that 5pm was too long. Thus, we left the time available after 3pm for working groups to continue with their work if they wished. Because Drs. Kashian and Sano were unable to attend this workshop, our extension agent, Ms. Mary Bohling, helped Drs. Krause and Drouillard in running the workshop. Dr. Nowell did not attend the workshops 2 & 3 due to her commitments. She was consulted by phone and email on participant activities. For this workshop, we brought in an expert on FCAs and environmental justice from Michigan State University, Dr. Geoffrey Habron.

Morning Session: The morning session consisted of six presentations. We had several reasons for including presentations at this point in the process. First, we needed to update and get feedback from stakeholders on research being conducted by our project team. Second, we were responding to suggestions of more presentations from the evaluation survey in Workshop 1. Third, we wanted to provide information that would help working groups to address the top five stakeholder issues. The first presentation in the morning was by Dr. Krause on stakeholder system awareness, where additional results of the stakeholder survey were presented, including the disparity in the role assignments. A review of the last workshop was presented as well. In response to suggestions made at the last workshop, participants were invited to join the Google Group set up for them. This private Internet site was a place where people could exchange ideas and ask questions about FCAs in the Detroit River. The second presentation updated them on the Integrated Assessment research (this project's research). This presentation by Dr. Ken Drouillard covered two topics: 1. the structure of the existing food web model to predict PCB concentrations in fish and 2. the updates to the water and sediment data that are inputs into that model (see chapter 5). The third presentation covered research conducted by a team of Masters students from the School of Natural Resources and Environment, University of Michigan, under the supervision of Dr. Donna Kashian. The students surveyed shoreline anglers on their knowledge of the FCAs, what species they caught, and what they took home to eat. They found that people of color, the predominant shoreline angler, took home a higher variety of species to eat than their white counterparts, with an emphasis on catfish (a highly contaminated species). There was also a general lack of knowledge about the FCAs (see chapter 4). The fourth presentation covered the US side of FCAs, what they were, and introduced the beginning of a working group initiated by a $4000 grant to develop education and outreach materials. Mr. Kory Groetsch and Ms. Sue Manente of the Michigan Department of Community Health presented these materials. They also reviewed an outreach project they had recently finished in the Saginaw Bay area. Dr. Satyendra Bhavsar, Ontario Ministry of the Environment, presented on the Canadian FCAs. He connected much of the material back to the top five stakeholder issues (although some of it was for Lake Erie or Ontario the province in general and not specific to the Detroit River).

The final presentation was on the revision of the Area of Concern Beneficial Use Impairments (BUIs), in particular, those BUIs related to FCAs. One of the concerns brought up during the key informant interviews was that FCAs were being used inappropriately for BUIs. The purpose of FCAs is to protect human health and thus, they err on the side of caution and are readjusted as new information is found on levels that impair human health. With the BUIs, a place is considered impaired until FCAs are lifted. Thus, even if much effort has gone into cleaning up legacy contaminants and reducing local sources of contaminants, FCAs may not reflect that effort as they are not sensitive to those types of efforts. There is also misalignment in both the FCAs and BUIs between the US and Canada. A fish species that is considered safe to eat on one side of the river can have an advisory of no consumption or restricted consumption on the other side of the river. What is considered a BUI on one side of the river may very well not be considered a BUI on the other side. We had Ms. Suzan Campbell, Michigan Natural Features Inventory, discuss the US BUIs where she brought up several of these issues. Dr. Doug Haffner, our co-investigator, presented on the Canadian BUIs.

Afternoon Session: For the afternoon session, we once again used breakout groups to reach our workshop goal of developing working groups to address key issues. Our first breakout session focused on revising the stakeholder roles. We had participants self-select into 4 groups. We provided handouts of the stakeholder roles as defined in the stakeholder organization survey. To help focus the discussion and provide inspiration, we provided the key questions and system maps developed by each system group in Workshop 1. The group focused discussion on the following questions:

1. Do the original stakeholder roles need to be revised? What needs to be revised – title, definition, or both?
2.
3. Do any of the original stakeholder roles need to be discarded?

4. Do new roles need to be added? What is the title and definition of the new role(s)?

Assigned scribes recorded participant discussions on tear sheets. After the breakout, the broader group was reconvened for a group discussion on role definitions. Each breakout group reported on what changes they thought were needed and what should stay the same. Then, the group as a whole came up with revised stakeholder roles, which was recorded on a power point presentation on the screen. This discussion was very lively and took longer than planned. The participants developed the following stakeholder roles with associated organizations:

Economic Development: Those that have a vested interest in the economic development, tourism and promotion of the Detroit River and its adjacent lands as a valued natural resources.

<u>US Stakeholder Organizations with an Economic Development role:</u>

Army Corps of Engineers Detroit District
BASF
Detroit Port Authority
DTE Energy
Riverfront East Alliance
Southwest Environmental Solutions
South East Michigan Council Of Governments (SEMCOG)
US Steel

<u>Canadian Stakeholder Organizations with an Economic Development role:</u>

Brighton Beach Power

Regulatory Compliance: Those who set contaminant policy or regulate the input of contaminants in the Detroit River, such as through enforcement or permits and those who collect their own data to demonstrate compliance.

US Stakeholder Organizations with a Regulatory Compliance role:

City of Detroit Department of Water and Sewage
City of Detroit Department of Environmental Affairs
Michigan Department of Environmental Quality Office of the Great Lakes
Michigan Department of Environmental Quality Water Bureau Division
U.S. Environmental Protection Agency
Wayne County Department of the Environment

Canadian Stakeholder Organizations with a Regulatory Compliance role:

City of Windsor, Environmental Services, Pollution Control
City of Windsor Environmental Services, Pollution Control
Detroit River Canadian Cleanup Committee
Environment Canada Restoration Programs Division

Monitoring and Research: Those who collect data on the ecological system in the Detroit River. Such data can be used for research, management, and/or conservation purposes, including for setting trigger levels.

US Stakeholder Organizations with a Monitoring and Research role:

Michigan Department of Natural Resources Fisheries Division
US Environmental Protection Agency Office of Research and Development
US Fish and Wildlife Service Detroit River International Wildlife Refuge
USGS Great Lakes Science Center
Wayne County Department of the Environment

Canadian Stakeholder Organizations with a Monitoring and Research role:

City of Windsor, Environmental Services, Pollution Control
Detroit River Canadian Cleanup Committee
Environment Canada Canadian Wildlife Service
Environment Canada Water Quality Monitoring and Research
Essex Region Conservation Authority
Ontario Ministry of the Environment Sport Fish Contaminant Monitoring Program
Ontario Ministry of Natural Resources Lake Erie Basin Coordinator
University of Windsor, Great Lakes Institute for Environmental Research

Policy on Fish Consumption Advisories: Those who are involved in planning and information gathering to carry policy out on setting the trigger levels for fish contaminant advisories in the Detroit River.

Stakeholder Organizations with a Policy on FCAs role:

Great Lakes Commission

International Joint Commission
Michigan Department of Environmental Quality Surface Water Assessment
Michigan Department of Community Health Division of Environmental Health
Wayne County Department of Public Health
US Environmental Protection Agency Great Lakes National Program Office

<u>Stakeholder Organizations with a Policy on FCAs role:</u>
Department of Fisheries and Oceans Policy and Economics
International Joint Commission
Ontario Ministry of the Environment Sport Fish Contaminant Monitoring Program

Education and Outreach on Fish Consumption Advisories: Those who provide information on Fish Consumption Advisories related to fish populations found in the Detroit River.

<u>US Stakeholder Organizations with an Education and Outreach on FCAs role:</u>
City of Detroit Department of Health
Michigan Department of Community Health Division of Environmental Health
Michigan Sea Grant

<u>Canadian Stakeholder Organizations with an Education and Outreach on FCAs role:</u>
Detroit River Canadian Cleanup Committee
Ontario Ministry of the Environment Sport Fish Contaminant Monitoring Program

Stewards: Those who are involved in conservation related to the Detroit River.

<u>US Stakeholder Organizations with a Steward role:</u>
Detroit International Wildlife Refuge Alliance
Friends of the Detroit River
Michigan Sea Grant
National Wildlife Federation
Sierra Club
The Nature Conservancy
US Fish and Wildlife Service Detroit River International Wildlife Refuge
Wayne County Conservation District

<u>CDN Stakeholder Organizations with a Steward role:</u>
Canadian Detroit Riverkeeper
Canadian Heritage Rivers System
Citizens Environment Alliance
Detroit River Canadian Cleanup Committee
Essex Region Conservation Authority
Environment Canada Canadian Wildlife Service

Fish Consumers: Those who eat fish from the Detroit River.

US Stakeholder Organizations with a Fish Consumer role:

City of Detroit Department of Environmental Affairs
Detroiters Working for Environmental Justice
Michigan Food Policy Council Racial & Ethnic Approaches to Community Health

Canadian Stakeholder Organizations with a Fish Consumer role:

Canadian Environmental Law Association

Recreational Users: Those who use the Detroit River and its adjacent lands for recreational purposes, such as sport fishing.

US Stakeholder Organizations with a Recreational User role:

Michigan Department of Natural Resources Fisheries Division
Detroit Riverfront Conservancy
Michigan Sea Grant
City of Detroit Recreation Department
Detroit Area Steelheaders
Ducks Unlimited

Canadian Stakeholder Organizations with a Recreational User role:

Parks Ontario, Ministry of Natural Resources

Funder: Those who provide funds through grants for activities related to Fish Consumption Advisories.

US Stakeholder Organizations with a Funder role:

Ducks Unlimited
Erb Family Foundation
Michigan Sea Grant
The Nature Conservancy
US Environmental Protection Agency

The next discussion was on what working groups were needed. The first working group identified was easy because Ms. Manente had already introduced the Outreach working group in her presentation and she agreed to lead it. Another working group was identified as the Food Web working group to be lead by our co-investigator, Dr. Drouillard. A third working group was suggested to tackle Environmental Justice for Fish Consumers. Dr. Geoff Habron, Michigan State University, offered to get that group started but not to lead it. Finally, a working group on BUIs in the Detroit River was suggested and Ms. Campbell offered to lead that group. We had planned on working groups to convene and discuss a working group plan. However, we had run out of time at that point and participants were leaving, so there were very few left to discuss these plans. The leaders were told that they were in charge of getting their groups organized and working on projects before our final workshop.

Products from Workshop 2:

1. The revision of stakeholder roles.
2. The development of 4 working groups: Outreach, Food Web, Environmental Justice, and BUIs.
3. The establishment of a Google Groups website for FCAs in the Detroit River.

Working Groups

Of our four working groups, the Outreach and Food Web groups met regularly and accomplished their goals. The other two groups did not move forward after Workshop 2. We discuss the reasons on why some groups were successful while others were not in the Assessment section. For now, we will report on the activities of the two successful working groups.

Outreach Working Group

Ms. Sue Manente led this working group. She had already secured funding for developing outreach materials in the Detroit River as Michigan FCAs were only available on the Internet. Dr. Kashian helped to secure this grant by writing a letter of support. In addition, our project was able to match the initial funding ($4,000) to help with the production of outreach materials. Ms. Manente sent out an email invitation to the broader stakeholder network using our stakeholder database to join the group. Along with her partner at the Michigan Department of Community Health, she was able to recruit 11 additional people to work on this project from the stakeholder network and our project. Drs. Kashian and Krause were included in the 11 people as well as the Michigan Sea Grant Extension Agent, Ms. Mary Bohling. The local Community Health departments were also involved (Wayne County and City of Detroit). There was industry involvement through DTE Energy, stewardship involvement through Friends of the Detroit River, and fish consumer involvement with Detroiters Working for Environmental Justice.

The working group had three goals:

4. Provide user friendly materials to fish consumers
    - Emphasis on at-risk population
        - Women of childbearing age, children
        - Low income, urban fish consumers eating contaminated fish
5. Help consumers make healthier choices about a local food source
6. Distribute materials to reach intended audience

There was an emphasis on the environmental justice component based on the results from the UM students' research project.

The working group met several times in Detroit. Ms. Manente would schedule meetings using an on-line Internet tool, MeetingWizard (http://www.meetingwizard.com/). This tool allows the user to present an array of potential dates and times to working group members. Members indicate when they are available in MeetingWizard. The best date and time is easily selected given member availability. Once a date and time are set, MeetingWizard will send out an email announcing the time and date and requests an on-line RSVP. Generally, there was good attendance at these meetings.

There were discussions on what messages were important to convey on outreach materials and on what types of outreach materials should be developed. The important messages were: Fish are part of a healthy diet; Fishing is an important recreational activity; There are fish in the Detroit River that are good food choices; Don't eat catfish and carp from the River; "Cleaner" catfish can be caught locally; Children are most at risk of harm; and Follow fish advisory for wild-caught and purchased fish. The types of outreach materials selected were a sign, a brochure, and a flyer. It was planned that the brochure should contain all of these messages whereas the sign and flyer should contain parts of these messages. Signs should be posted at key parks along the Detroit River shoreline on the US side.

During meetings, the content of the outreach materials were discussed. For specific tasks, a point person would be assigned with other people from the group volunteering to help that point person. Drafts of the outreach materials were sent by email for comment iteratively until all agreed on final products. In addition to the group comment, the materials were made available for public comment during River Days in Detroit (summer 2009). The public comments were incorporated into the materials and added clarity. The group also helped to select appropriate sites along the Detroit River where the signs should be located. The brochures and flyers have been printed and distributed. The signs were installed at 25 locations along the Detroit River.

Perhaps the most innovative aspect of these materials was the development of a graphic, which clearly displayed FCAs. This graphic arranged pictures of fish species along a double arrow. The double arrow had gradations of color that went from green at the top, yellow in the middle, and red at the bottom and had the words "better to eat" at the top and "should not eat" at the bottom. Fish species were then arranged along the arrow depending on what their advisory was. For example, yellow perch and bluegill are at the top whereas catfish and carp were at the bottom. Those who cannot read well in English can easily understand this graphic. The language, "should not eat", specifically selected because it captures the nature of the FCAs, that they are *advisories* and not *laws or rules* (a common misconception revealed by the Environmental Justice project).

Products from Outreach Working Group:

<u>Brochure: "Eat Safe Fish in the Detroit Area: A guide to buying and catching fish that are healthy for you and your family"</u> (see Appendix 2.5). It starts with the statement "Most fish are a healthy food choice, but some have harmful chemicals in them. This brochure will help you make good choices when eating fish." It has a question and answer format about healthiness of fish, why fish may be unsafe to eat, who is at greatest risk, what are some of the health effects, and how much is in a fish meal. It provides a guide on how to trim and cook fish to minimize contamination. The next section gives a guide to mercury advisories in store-bought and restaurant fish. Another section has the graphic described above along with clearly written advisories for those who are at greater risk (women of child bearing age and children) and for the general population. Finally, the back of the brochure has contact information for finding places to fish with less contamination and for ordering more brochures. It also has list the 7 stakeholder organizations involved.

Flyer: "Best Spots for Catfish in the Detroit Area" (see Appendix 2.6). It is in response to the Environmental Justice study findings, where people of color take home and eat catfish on a regular basis. It has a map of 6 alternative places to catch catfish with low contaminant burdens. On the back, it gives detailed information about the 6 sites and how to get additional information.

Sign: "Eating Fish from the Detroit River" (see Appendix 2.7). The primary graphic is the one described in the paragraph above. It also has text and a graphic on how to clean and cook fish. Finally, it lists the alternative fishing places for catfish along with a contact number. It also lists the contact number for more information on the FCAs.

Food Web Working Group

Dr. Drouillard led this working group. The goal of this working group was to continue development of a Detroit River food web model that used water and sediment PCB inputs to predict individual fish PCB body burdens for a suite of fish species. Smaller meetings were held between Dr. Drouillard and Dr. Krause (and their graduate students) both in person and on Skype, Internet video calling software (http://www.skype.com/). Dr. Drouillard selectively contacted people in the stakeholder database to collect water PCB data, sediment PCB data, and fish PCB body burden data. Dr. Krause selectively contacted people in the stakeholder database and other experts for the review of parameter estimates derived from the literature. There was one working group meeting between Workshop 2 and 3 where select stakeholders were invited. The meeting was arranged through MeetingWizard, including available times. Unfortunately, there were a number of cancellations at the last minute so that only 2 people were able to attend, a monitoring research person from the US (Michigan Department of Natural Resources Fisheries Division) and one from Canada (Ontario Ministry of Natural Resources - Fisheries Division). These attendees provided feedback on the modeling efforts.

Because a subgoal of this working group was to develop an interactive model for stakeholders, they also suggested ways to focus the data output and to develop an interactive model for stakeholders. Their suggestions were to focus on 11 indicator species: Brown bullhead, smallmouth bass, rock bass, freshwater drum (sheepshead), blue gill, northern pike, gar pike, catfish (not currently in the food web model), carp, gizzard shad, and white sucker. They suggested having the model outputs focus on providing information relevant to beneficial use impairments of the Detroit River AOC. Outputs should be total body PCB levels and dorsal body PCB levels. Graphs of the distributions of these levels along with the trigger levels would be useful output. This suggestion was taken into account when presenting outputs in Workshop 3. They would like to see a comparison of scenarios on the same graph if possible and hazard assessment results. Scenarios would be about increasing or decreasing sediment and water inputs in each zone separately. The target audience should be those who work on the Remedial Action Plan and those agencies like the Michigan Department of Environmental Quality. They provided suggestions on how to improve the model in the future, such as having a time component for temporal assessments, and having more age classes for fish species of interest. These participants helped to identify experts to review the spatial integration values estimated for the spatial food web model.

Unfortunately, the model development took longer than expect and an interactive model for stakeholder users was not developed by the time the project ended. See Chapters 5 and 6 in this final report for complete details on the products.

Products from Food Web Working Group:

1. A risk analysis of PCB body burdens in fish, including those not included in the advisories.

2. A spatial integration of water and sediment inputs for predicting PCB body burdens in fish.

Workshop 3

This workshop was titled "Fish Consumption Advisories in the Detroit River: Progress Towards a Solution". For our final workshop, we had the following goals: 1. to provide an overview of the outcomes from this project (including the efforts of the stakeholder groups) in addressing key issues related to fish consumption advisories on the Detroit River; 2. to discuss the next priorities for FCAs in the Detroit River; and 3. to identify funding opportunities for supporting future high priority efforts. We had a total of 24 participants in all, again, representing all of the stakeholder roles and both countries. We returned to Belle Isle Nature Zoo in Detroit, MI on January 12, 2010. Again, the US was still more strongly represented than Canada, where only four participants were from Canada (exclusive of project co-investigators and graduate students). Nine of the participants had attended Workshop 1, 9 participants attended Workshop 2, and 7 participants were involved in work groups. We brought in public health experts from Wayne State University to partner with our stakeholders. Again, a catered lunch was provided free to all participants. We started at 9am and ended at 3:15pm. We provided all of the presentations and materials, including the Outreach Working Group products on a flash drive for each participant (where participants were given a flash drive to keep).

Morning Session: There were three presentations given on the products of each working group. First, Ms. Manente presented on "How can we increase public awareness of FCAs?" where she discussed the efforts of the Outreach working group. The sign was available to view. Copies of the flyers and brochures were available for participants to take back to their organization to distribute. Next, Dr. Drouillard presented on "Where are the sources of contaminant in the basin that are high enough to translate into a FCA?" He showed a risk analysis of how trigger levels on FCAs related to the Monte Carlo distributions of predicted PCB levels on key fish species (see Chapter 5). Dr. Krause discussed the spatial enhancement of the model and how the different zones in the river may influence the predicted PCB concentrations of individual fish (see Chapter 6). Finally, Dr. Drouillard presented on "What are the predicted contaminant levels of fish not listed in FCAs?" based on the Monte Carlo simulations (see Chapter 5).

Afternoon Break-out Session 1: After lunch, Dr. Krause briefly reminded participants of the key issues from the stakeholder survey and from Workshop 1. Participants were assigned into 4 breakout groups to ensure diversity of roles. Breakout groups were charged with discussing the following:

1. To identify 1-3 key issues they think the group should focus efforts on. They can use the Key Issues, Survey Issues, or come up with new issues.
2. To develop 1-3 goals for each issue, similar to the example goal of the outreach group.

The issues and goals of each group was brought forward to the larger group. Participants voted for their top 3 issues using dot stickers. The issues and goals were as follows:

<u>Group 1 -</u>

Issues: contaminants levels and analysis.

- source targeting and clean-up.
- public awareness of FCAs.

Goals:

- Increase resolution of contaminants modeling spatial modeling.
- develop "clean-up model."
- capitalize on education efforts and public outreach.

<u>Group 2:</u>

Education and outreach

-how to market most successfully
-Get info to those who need it most
-where to target? Docks, shore fishermen, events
-coordination of messages between US and Canada
-funding to improve public perception

Need good fish data

- fish movement
- collect data during peak fishing times
-possible collaboration with fishermen

<u>Group 3:</u>

Communication

- identify target audiences-how to reach those, EJ.
- effective methods
- promote use of river- message balanced

Goals:

1) Secure funding
2) Developing communication strategy
    - Focus group
    - Method development
3) Outreach implement
    - Public service, Announcements (PSAs)

Ex: TV, Radio, Signs, PSA, Brochures, Rulers, Magnets, Cleaning Boards, Public Events

4) Maintain partnership

Pollution Elimination

1) Secure Funding
2) Enforce existing laws, ex. Diesel filters, scrobecs, non profit sources, remediation- dredge
3) Priority identification
4) Education

Group 4:

Public Awareness (Goals):

- Identify target groups "Big impact" groups.
- Encourage consumption with advisory. Builds advocates with rivers.
- Universal message Encompass all languages.
- Find funding source!

Identify Contaminants/ Sources

- Facilities.
- Water vs. sediments.
- Point vs. non-point sources.

Goals:

1. Further analyze water vs. sediment data.
2. Further narrow sources down to external sources.
3. Eliminate sources.

Appropriate Measurements (Goals):

Move periodic monitoring of new contaminants.

Consider other existing and new contaminants.

Based on voting and goal definition, there were three main themes that emerged: outreach and education, contaminants and pollution prevention, and coordinating fish monitoring between the US and Canada.

Post workshop survey (Time 2): We had participants take a post-workshop series survey (Appendix 2.4). This survey had five parts to it: background information, key issues on the Detroit River, resources of stakeholders, network questions, and outcomes of the integrated assessment. The background information asked for the same information as the pre-survey. The second section on the key issues was also the same. In the resources section, we kept the question about the level of agreement regarding statements about his/her familiarity of the resources distributed in the stakeholder network but removed the remaining questions. Same as the first survey, the fourth section had the participants check frequency of interaction with the other participants of the workshop in terms of those whom were considered to be close professional colleagues (Once or twice a year, monthly or weekly) and of those whom provided information and/or data related to FCAs in the Detroit River. Finally, the fifth section asked how valuable the different products were from the integrated assessment, whether they used the website and if so, how frequently, and how many new connections they think they made through this process. This survey served as a Time 2 capture of where our participants were prior to the workshop series so that we could conduct a longitudinal assessment of how participant knowledge, attitudes, and networks changed from the beginning to the ending our process.

Afternoon Break-out Session 2: To start this session, Ms. Jodee Raines, Erb Foundation, presented on the funding opportunities from her organization. Then, Dr. Krause gave a brief presentation about the Outreach Working Group and key elements she assessed made it successful (see assessment section for full analysis). She emphasized the importance of having a champion, having a diversity of roles, and having good resources, like communication tools and funding to support the goals (Conrad and Daoust 2008). She used the stakeholder analysis network to emphasize important working group dynamics. Participants were allowed to self-select into a breakout group based on the three main themes identified from the earlier session. In an effort to keep the momentum going beyond our project, each group were instructed to come up with the following:

1. Name the goal of the group. List potential champion(s) to help lead a group to achieve the goal. If none come to mind, then how to potentially identify or bring one in. What will be the immediate next step for bringing a champion to the group? Who is in charge of that step?

2. List what roles should be involved (i.e., who needs to be at the table). Who in the group volunteers to recruit individuals to fill those roles?

3. Identify the immediate next step. Who is in charge of taking out that immediate next step?

<u>Public Outreach and Education Working group:</u>

1- Sue (US), Natalie Green (Canada), also local champ Charles Stokes. Need Champion on both sides.

2-Youth Education/ determine audience:
1) Identify target group.
2) Publications/ Material development.
3) Distribution of materials.
    -volunteers to talk to fishermen.
    -Special events, need volunteers.
4) Funding.
5) Evaluation post distribution.

3-Immediate next step:
I. Get stakeholders together
    -conference calls?
    -Identify collaborative opportunities (cross border).
    - who does what.
    -create plan (Natalie has template).
    -more academic stakeholders involved.
II. Secure funding!!!
    -identify sources
    -letter of support across

4- Funding:
    -create master grant proposal

-GLRI grant
-COA
- Erb foundation
-Community foundation

Fish Monitoring Working Group:
Champions:
-Joe (MDEQ), Satyendra > Co-chair goal investigation the PO, coordination of sampling? w/ colleagues

Goal: Networking and info exchange
Key roles and people to include:

- Ken Drouillard–Monitoring and research.
- Tammy Newcomb –Monitoring and research.
- Gary Towns–Monitoring and research(actual collection) recr. Users.
- Bob Reider–Industry.
- Bob Burns – Fish Consumers.
- Gary Williams.
- Kory Groetsch.

Immediate Next Step: Data gaps- where are they?
-Two champions talk to each other (Gary prodding if needed).
Joe and Gary could use MeetingWizard:
a) Meeting to discuss techniques available resources (MDNR, MDNRE, MNR, MDEQ, etc.)
b) Funding from GLRI (Kory) and other resources ?

Contaminant and Pollution Prevention Working Group:
Goals
Higher resolution sedimentary map.
-Develop clean- up base model for FCA.
-How can focused region impact a particular zone.
How will removal of hot spot impact FCA.
-Spawning Locations, habitat improvement, fish health

Products from Workshop 3:

1. Development of three working groups to continue work beyond the project end: Public Outreach, Fish Monitoring Coordination, and Contaminant and Pollution Prevention.
2. Survey assessment of integrated assessment process (see Assessment section).

ASSESSMENT

To evaluate our participatory research process, we relied on surveys at the beginning of the process and at the end as assessment tools. First, we had the survey of stakeholder organizations to assist both investigators and workshop participants in understanding the stakeholder network.

Not only were the results of this survey used throughout the workshop process and presented at a research conference, they allowed insights into what made a successful working group within this network. We report the findings from this survey after the other surveys as a part of our assessment. Second, we administered a pre-workshop survey, which provided information on specific metrics about our participants' perceptions and network at Time 1. In particular, we asked about their most critical issues and their assessment of their knowledge about the issues, the network of organizations, and resource availability in the network. This survey provided information on which organizations were potential contributors to the on-line database. Third, we administered an evaluation survey of Workshop 1. This survey provided us with an assessment of the interactive activities we developed and provided guidance on location and direction of future workshops. Fourth, we administered a post-workshop survey to assess changes in participants' critical issues, knowledge, and network ties. In addition, it measured how much participants valued the integrated assessment products. With these tools, we have quantified the impact of the integrated assessment our participants.

Workshop 1 Evaluation

Our evaluation survey (n=22) indicated that participants found Workshop 1 "quite" useful overall (mean = 4; scale: Not at all = 1 A little = 2 Somewhat = 3 Quite = 4 Very=5). A variety of responses were received of what was the most useful aspect of the workshop, but most comments related to the primary workshop goals of network awareness and getting to know the stakeholders and their roles better. All seven impacts that were measured received at least an average rating of "somewhat" helpful (minimum mean value = 2.9; scale: Not at all = 1 A little = 2 Somewhat =3 Quite a bit = 4 A lot = 5). The most helpful impact was "Develop one or more new contacts that I think may be useful in the future" with an average rating of "quite a bit" of help (mean = 4.2). General comments ranged from "I think all of you were extremely well organized" and "Great job! (and very timely)" to "Shorter! 4-6 hrs max" and "I would really like to see more industries involved in this process."

Integrated Assessment Outcomes

From our post-workshop survey (n = 22), we know that all of our outcomes from the integrated assessment received an average rating of at least "somewhat agree" on their value to participants (minimum mean value = 2.86; scale: strongly agree = 1, agree = 2, somewhat agree = 3, somewhat disagree = 4, disagree = 5, and strongly disagree = 6). The most valuable outcomes were "The working group has made a valuable contribution to addressing public awareness of DR-FCAs" and "The research team has provided valuable scientific information on DR-FCAs" with average ratings between "strongly agree" and "agree" (means of 1.75 and 1.85 respectively). The outcome on public awareness was directly related to the Outreach Working Group and the outcome on scientific information was directly related to the Food Web Working Group. Overall, participants agreed "the integrated assessment project has helped to address top priority issues for DR-FCAs" (mean = 2.2). We asked what were significant outcomes not listed in the survey where one participant listed the "coordination of FCA signage on US/CA sides of the river (just discussed at today's meeting)."

Not surprisingly, the more specific outcomes related to the Food Web Working Group were least valued with the lowest average ratings of "somewhat agree": "The working group has made a valuable contribution to the understanding of non-advisory fish contaminant levels in the Detroit River" and "The working group has made a valuable contribution to understanding the sources of contaminant in the basin that are high enough to translate into a DR-FCAs." Although the food web model can address these issues, the working group ran out of time to fully develop them. The working group was only somewhat successful in fully integrating stakeholders in the process of model development and implementation. While there was some integration in Workshop 2 and in a working group meeting, the modeling was not developed to point where it could be fully utilized and interactive with the participants. The questions and comments during Workshop 3 when the food web model was presented indicated a general distrust of the outputs by stakeholders.

We asked about the usefulness of our integrated assessment website (http://www.ciler.snre.umich.edu/fca/). Of those who participated in Workshop 3, 64% had visited our website at least 1-5 times and for some, 6-10 times. All participants saw themselves using the website in the future.

Finally, we asked if participants if they had made new connections since our first workshop and if so, about how many. All participants except 2 responded that they had made new connections with an average of 3.3 connections.

Changes in critical issues and knowledge

While some assessment may stop with surveys asking participants their opinions and values on workshop outcomes and to provide their own assessment on how they were changed by the process, we wanted to take our assessment a step further by taking a longitudinal measure of changes. Our pre-workshop survey (Time 1) and post-workshop (Time 2) survey contained the same four metrics so that we could assess changes in responses from Time 1 and Time 2.

Our response rates varied depending on how responses are calculated. For all three workshops, our overall population was 51 participants, where 15 participants attended more than 1 workshop. Only 9 of the 15 repeat participants attended both Workshops 1 and 3, where they had the opportunity to take the survey. Seven of the 9 completed the survey for both Time 1 and Time 2. Thus, we had a limited number of participants to measure individual participant change in knowledge across time. We had decent overall response rates where we captured 48% of all participants if we assume that our 51 participants responded in both Time 1 and Time 2 (n = 49 surveys for both Time 1 and Time 2). Of those 51 participants, 36 people represented our identified stakeholder organizations. In general, the remaining 15 people represented academia and did not attend more than 1 workshop. If we consider these 36 people 'stakeholder participants', the response rate is slightly higher at 54%. If we look at the responses relative to the number of people attending each individual workshop, response rates were very high where Workshop 1 had response rates of 91% (32 total participants) and 96% (25 stakeholder participants) and Workshop 3 had response rates of 84% (24 total participants) and 94% (18 total participants).

For our first analysis, we investigated whether the critical issues changed for workshop participants from Time 1 to Time 2. Participants were asked to rank the top 3 most critical and top 3 least critical issues from a list of 15 issues ("In your opinion, what are the top three issues that are the most and least critical for Detroit River stakeholders to unite around?", Question B1). The list was developed from the key informant interviews. We analyzed the data using a Wilcoxon Sign-Rank test to determine if the top critical issues had changed between Time 1 and Time 2. Both the most critical and the least critical showed no significant change ($p > 0.05$). The three most critical issues were 1. "Developing support to enable stakeholders to consistently monitor the river" (average of 18% of responses), 2. "Removal of existing contaminants in the sediments of the Detroit River" (average of 18% of responses), and 3. " Reducing the introduction of new contaminants by improving regulation and monitoring of point and non-point source contaminants" (average of 12% of responses). The three least critical issues were 1. "Identifying ‘hot issues’ that can be used to rally the public" (average of 14% of responses), 2. " Creating more achievable criteria for delisting the Detroit River as an Area of Concern" (average of 14% of responses), and "Creating a bi-national RAP (remedial action plan) process to address delisting the Detroit River as an Area of Concern" (average of 13% of responses).

For our second analysis, we assessed participant perceived knowledge in three areas about the Detroit River FCAs: (1) important issues, (2) the network of organizations, and (3) resource availability. For issues (1) and networks (2), participants rated how knowledgeable they felt they were on a series of questions related to each area using the following scale: "not at all" (1), "a little" (2), "somewhat" (3), "quite" (4), and "highly" (5). For issues (1), 7 statements focused on a participant’s perception of their level of knowledge on the issues that were identified as important in the on-going management of the Detroit River (Question B2). The alpha levels for this metric were very good (Time 1 = 0.88) to reasonable (Time 2 = 0.75). For networks (2), 5 statements focused on the broad network of organizations and agencies involved and invested in the issue of contamination and its associated impact on human health through the consumption of contaminated fish in the Detroit River watershed (Question B3). The alpha levels for this metric were very good (Time 1 = 0.89 and Time 2 = 0.82). Finally, for resource availability, 5 statements addressed the resources available within the broad network of organizations and agencies involved and invested in the issue of contamination and its associated impact on human health through the consumption of contaminated fish in the Detroit River watershed (Question C1). The scale for resources (3) was as follows: "strongly agree" (1), "agree" (2), "somewhat agree" (3), "somewhat disagree" (4), "disagree" (5), and "strongly disagree" (5). The alpha levels for this metric were very good (Time 1 = 0.91 and Time 2 = 0.91). We calculated the mean response across all statements within each area to measure a participant’s perceived knowledge.

To measure changes in perceived knowledge across our three areas, we conducted three levels of analysis. The first level included all of the participants to give us the highest number of observations ($n = 49$). The second level focused on our stakeholder participants, to check to see if there was a bias in the results with the inclusion of the non-stakeholder participants ($n = 39$). For these two levels, we did a simple ANOVA analysis (proc ANOVA SAS 9.1) with Time as the independent variable and mean knowledge as the dependant variable. Our third level focused on only those who responded both in Time 1 and Time 2. This third level had the lowest number of observations ($n = 14$), but allowed us to measure individual participant changes in knowledge; an analysis not that we could not accomplish with the first two levels. For this level, we conducted repeated-measures ANOVA where participants were our subjects (proc mixed SAS 9.1).

Overall, all three analysis were consist in their results. For participant perceived knowledge on issues, we found significant increases from Time 1 and Time 2 (level 1 $F_{1,48}$= 10.11 p = 0.0026; level 2 $F_{1,38}$ = 9.05 p = 0.0046; level 3 $F_{2,12}$ = 5.73 p = 0.0339). For level 1, the mean score was 2.7 at Time 1 and 3.7 at Time 2, indicating that participant perceived knowledge on issues in Workshop 3 was higher at quite knowledgeable compared to participant perceived knowledge on issues in Workshop 1 where participants averaged at somewhat knowledgeable. To support this finding, we found that individual participant perceived knowledge increased from Time 1 (mean = 2.6) to Time 2 (mean = 3.4).

For participant perceived knowledge of their network of organizations, we also had a significant increase from Time 1 and Time 2 across all levels (level 1 $F_{1,48}$= 13.81 p = 0.0005; level 2 $F_{1,38}$ = 9.05 p = 0.0046; level 3 $F_{2,12}$ = 13.05 p = 0.0036). For level 1, the mean score was 2.8 at Time 1 and 3.7 at Time 2,indicating that Workshop 3 participants perceived their knowledge of the network as quite knowledgeable as opposed to Workshop 1 participants who perceived their knowledge at somewhat knowledgeable. Again, our level 3 analysis supported this finding and estimated that individual perceived knowledge increased from Time 1 (mean = 2.9) to Time 2 (mean = 3.9).

We did not find a strong significant difference in perceived knowledge about resources within the network across our three levels of analysis. The level 1 analysis revealed borderline significance in participant perceived knowledge between Time 1 and Time 2 ($F_{1,48}$ = 4.03 p = 0.0503). Level 2 had a higher p-value indicating no significance ($F_{1,38}$ = 1.92 p = 0.1735) as did Level 3 ($F_{2,12}$ = 2.6 p = 0.1326).

In summary, our results indicated that participant perception of their knowledge about issues and their network changed over the course of our project. We had a more aware group of stakeholder participants and other participants who attended the third workshop regarding the issues and the network of organizations associated with the Detroit River FCAs than Workshop 1 participants. For some stakeholder participants, this awareness increased from Workshop 1 to Workshop 3. While we cannot directly attribute these results to our integrated assessment process, we achieved our goal of increased network awareness. Because of the small number of people who attended both the first and third workshops, we were unable to develop more sophisticated analytical models for understanding changes in perceived knowledge, such as the influence of close colleagues.

Stakeholder network analysis

Our analysis identified 4 subgroups in the Detroit River stakeholder network (Figure 1). These subgroups are comprised of organizations that have a high density of ties with each other. Ties between organizations were defined as (type 1) sharing information and data, (type 2) collaboration, and (type 3) professional relationships. The number of types ties weighted each tie (3 total) and were directional. For example, if organization A collaborated (2) and shared information and data (1) with organization B, it was analyzed as organization A chooses organization B with a weight of 2. The density of ties is defined as the proportion of the sum of the weights of the actual/realized ties to the maximum weights of potential ties (maximum weight =3), where every organization has the potential to have a tie with every other organization in the network. To identify subgroups, we used a clustering method and visualization method from the social sciences (Frank 1995, 1996; Krause et al. 2003). There was significant clustering ($p < 0.05$).

The subgroups can be defined by the country, in which the organization is located. Subgroups A and D are US organizations whereas subgroups B and C are Canadian organizations. These data support information obtained from the key informant interviews, which suggested that communication between US organizations and Canadian organizations was not strong. Two of the subgroups, A and B, also seemed to be largely comprised of representatives of organizations who have only recently begun to work on Detroit River issues. This finding would explain why the organizations in these subgroups are not directly a part of the main subgroups of C and D. Their positions in Figure 1 demonstrate their more satellite role in the stakeholder network.

Bridging ties are important to look at from a network perspective. These ties can be beneficial to subgroups because they allow access to information or resources that may not be available within their own subgroup. Subgroup D, the main US subgroup, has high density of interactions with all three of the other subgroups, indicating strong bridges.

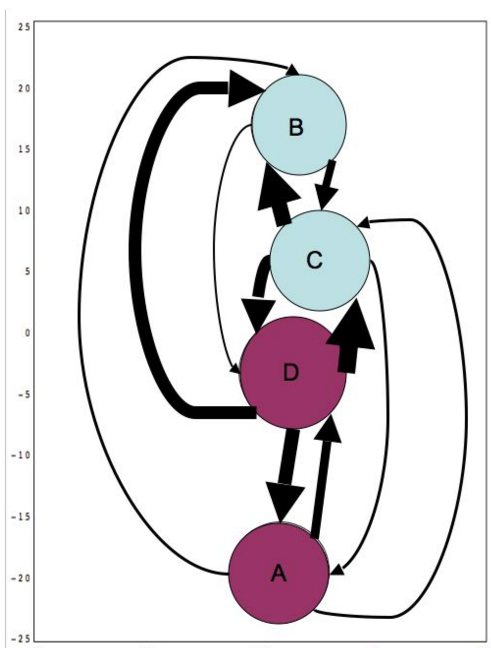


Figure 1. A sociogram of the subgroups identified by the network analysis of Detroit River stakeholders. The axes are two dimensions and units are based on the inverse of the density of ties between subgroups. Subgroup A and D are US stakeholder organizations. Subgroups B and C are Canadian stakeholder organizations. The size of arrows is proportional to the density of ties between subgroups.

At the stakeholder group level, survey respondents indicated that ties could be strengthened. Both Canadian and US organizations thought that ties could be strengthened between monitoring research and industry and economic organizations within their respective countries. Canadian organizations would like to see a stronger connection between end users and monitoring research in their country. From US organizations indicated that stronger ties between industry and economic groups and policy on FCA groups are needed in their country. That ties with industry and economic organizations needed to be strengthened in the US where an industry and economic organization plays such a central role is interesting.

Issues of greatest concern on the Detroit River were also identified. Representatives selected from 14 key issues brought forward during the key informant interviews. The Canadian organizations were most likely to select the following as their issues of greatest concern: 1. Reducing public fear of utilizing the Detroit River as a resource resulting from beneficial use impairments; 2. Securing the funds to ensure more consistent monitoring of the river; and 3. Reducing the introduction of new contaminants through improving regulation and monitoring of point and non point source contaminants. The US organizations were most likely to select the following issues: 1. Removing existing contaminants in the sediments of the Detroit River; 2. Reducing the introduction of new contaminants through improving regulation and monitoring of point and non point source contaminants; and 3. Within your country, increasing coordination among local, state/provincial, and federal government authorities in planning along the Detroit River.

Research thus far suggests that a strengthening of ties between the US and Canada may be beneficial for coordinating efforts on FCAs in the Detroit River. The stakeholder survey indicated that the density of ties between countries is one-third that of the density of ties within countries.

Working Group Success

Each working group had different outcomes with varying levels of success. We consider the Outreach Working Group as the most successful out of the four working groups that were formed in the second workshop. They set goals and reached those goals with outcomes that address the top question/issue identified in the first workshop, "How can we increase public awareness of FCAs?" These products should have a direct impact on those who consume fish from the Detroit River. But what were the key elements of this working group that allowed them to succeed in comparison to the other working groups?

This working group had the elements that have been identified for optimal capacity. We borrow these elements from Suarez-Balcazar et al. (2009), who developed a model of evaluating capacity building for community-based organizations. The first element is leadership. As it was mentioned in the development of the workshop process, we could not identify leaders to take on the issues within this network through our key informant interviews. This observation was supported by our survey results on the statement in Question C1 on resources knowledge was "I know who people look to for leadership in this network of stakeholders." For both the pre-survey and post-survey, this statement was the one where participants felt they were the least knowledgeable. However, this working group had a strong leader in Ms. Manente.

Ms. Manente demonstrated key capacity elements in a person. She was motivated and had the knowledge and skills about FCA outreach (Suarez-Balcazar et al. 2009). In the beginning of the integrated assessment process, she had recently finished up an outreach project in Saginaw Bay. She was looking for a new project for which she could apply the skills and knowledge she had gained through that experience. When contacted by our integrated assessment team to be involved, she saw her opportunity in the Detroit River. Her motivation was increased after she secured a small grant of $4,000 to work on outreach materials for the Detroit River, a grant for which the research team provided a letter support. What she did lack was a contextual awareness about the stakeholder network and the people who consume fish in the Detroit River. One key informant had indicated that a difficulty with working on FCA issues was the lack of involvement by the Michigan Department of Community Health (MDCH). Our stakeholder network supported this statement, where the MDCH was one of the organizations located in the US satellite subgroup (subgroup A). The integrated assessment provided this contextual awareness to her through the workshop series as well as through the environmental justice research conducted by the University of Michigan masters students (Appendix D).

The second element is a learning climate that "fosters open communication, critical self-evaluation, and new ideas" (Suarez-Balcazar et al. 2009). Drs. Kashian and Krause observed that Ms. Manente was an effective facilitator who encouraged working group members to contribute fully in the process of developing the outreach materials and provided some structure for discussion. Members developed the outreach materials and then reviewed them during meetings and over email through multiple iterations until they were satisfied. Drs. Kashian and Krause brought a suggestion made by a participant at the 2009 Michigan Sea Grant Integrated Assessment Workshop to the working group. The suggestion was for more public input. Drs. Kashian and Krause made this suggestion with some trepidation, as they were concerned that the outreach materials were almost finalized and public input would delay the process thus frustrating the working group members. However, the working group immediately embraced the suggestion and included the outreach materials at the Michigan Sea Grant booth during River Days and collected the comments made by the public on how to improve the outreach materials. These comments were shared to all working group members who then brainstormed on how to best to address those comments. Ultimately, this process produced more accessible language and graphics in the materials.

The third and fourth elements are resources and support. As mentioned earlier, Ms. Manente was able to secure funding for outreach efforts early in the process. During the process, it was evident that more could be accomplish if more funding was available. In response to this need, the integrated assessment provided a matched to the original funds. The stakeholder database from the integrated assessment was used to recruit members of the working group. Information from the environmental justice study was used to develop outreach materials as well as determine how they were to be distributed. One example is the inclusion of other locations for catching catfish in the Detroit area in the outreach materials, as the study revealed that people of color were taking home and eating catfish at a higher rate than white fishermen. The FCA recommends to not consuming catfish from the Detroit River. Members represented a diversity of stakeholder roles, which ensured resources and support. In addition to the education and outreach roles, members represented the roles of policy on FCAs, fish consumers, stewards, economic development, monitoring and research, and funders. The use of MeetingWizard, an Internet tool to organize meetings, proved to be highly effective with this group and likely improved attendance at working group meetings. Overall, this group fully utilized the resources and support available to them, which aided in their success.

The network diagram (Figure 1) provided insights into the availability of resources and support. As mentioned, the Michigan Department of Community Health was in the satellite subgroup A. They were not alone in this working group as four other members belonged to organizations in the satellite subgroup. In fact, 2/3rds of the organizations in subgroup A were involved in this working group. They teamed up with members that represented three organizations that were central organizations in US subgroup D. Thus, satellite members were granted access to resources and support available in subgroup D with such central organizations involved. They also were able to bring in new resources and support that members of D had limited access to, thus maximizing the resources and support available in the US network.

Although the working group on environmental justice did not materialize, the Outreach Working Group incorporated environmental justice into their products. Interestingly, we, the workshop organizers, were warned by key stakeholder representatives to not use the term "Environmental Justice" at our first workshop as it would polarize participants, thus preventing us from accomplishing our goals. By the end of the workshop series, the primary stakeholder outcomes was to directly address an important environmental justice issue. This outcome was providing outreach materials to shoreline fisherman that had little access to those materials previously. FCAs were only available on the Internet and were confusing. Materials made it easier to understand which fish to eat, how to prepare those fish, and why eating fish is important. They are also much more accessible with signs posted at key fishing places along with traditional printed materials. The working group included the term environmental justice in their presentation at the third workshop without fear of polarizing the group. This working group contributed greatly to contributing to capacity of the overall stakeholder network.

We learned lessons from our least successful working group, the Beneficial Use Impairment group. From our key informant interviews, Dr. Nowell developed an interesting model of stakeholder dynamics. She identified the tension between the FCAs and their use as a Beneficial Use Impairment. Essentially, FCAs are designed to protect human health. Thus, they will err on the side of caution in the direction of human well-being. They are revised based not only on information on the levels of contaminants in fish but also from studies on human health effects. Beneficial Use Impairments use them as an indicator of progress towards cleaning contaminants from the river sediments and water. From an ecological standpoint, the connection from sediments to human health is too tenuous for FCAs to be a realistic indicator for Beneficial Use Impairments. From a sociological standpoint, this model provided key insights into why there was potentially low initial capacity within the stakeholder network. However, it is clear from the responses to the survey question on critical issues that BUIs were the least critical issue throughout the integrated assessment. We could have perhaps developed activities for the stakeholder group so that they could reflect on this tension more explicitly. The capacity to work on this issue was not readily there and may have taken too much intervention to increase that capacity. Thus the question remains, how much should researchers influence the process versus how much should they facilitate and learn from the process?

Reflecting on this process from an innovation perspective can provide guidelines on how the stakeholder network can be successful in their goals in the future. Carlson and Wilmot (2006) outline 5 disciplines for innovation: (1) important customer/market needs; (2) value creation; (3) innovation champions; (4) innovation teams; and (5) organizational alignment. Our integrated assessment assisted with the customer needs identification, where customers are those who consume Detroit River fish, through several methods: key informant interviews of stakeholders, break-out groups in Workshops 1 and 3, and the University of Michigan customer surveys along the Detroit River. Documentation and discussion of needs provided strong support for better outreach materials as the primary need for customers. This need identification was continued through the next iteration in Workshop 3 and should continue to be an iterative process for the stakeholder network. As for value creation, the working group increased the value of the FCAs with two major innovations. First, they included the addition of signs to the traditional outreach materials of paper brochures and flyers. The posting of these signs at key shoreline fishing locations should allow for greater access to FCAs by shoreline fisherpeople than the traditional pamphlets or current website. Second, they employed simple visuals of the FCAs that did not require strong reading skills. Future working groups should discuss how they too can increase the value of the product they are creating to meet their focal customer need. We have already reviewed the third discipline of a strong innovation champion and the characteristics associated with that champion. Identification of a champion is perhaps the most challenging aspect for implementing innovation, particularly in a diffuse network of organizations. This challenge was exemplified during our last workshop breakout groups where each group had difficulty in identifying a champion. Because this innovation is occurring across organizations rather than within organizations, challenges arise with within organizational shifts. Since our workshop, we have learned that our champion, Ms. Manente, had duty reassignment in her position due to budget cuts, which will prevent her from continuing in her champion position. An emphasis is placed on the need for multidisciplinary teams for greater innovation. The diversity of roles in the working group certainly exemplified this discipline of innovation. Future working groups should keep role descriptions developed in Workshop 2 in mind to ensure they have multiple roles represented in their working group. Particularly, they should identify those roles the group consider key to the development and/or implementation of their product. Finally, the stakeholder network should continue with annual or biennial workshops. At these workshops, updated information should be exchanged. However, the stakeholders should also incorporate breakout sessions that focus on these four disciplines to create greater alignment on the important Detroit River FCA issues among the organizational network. Our integrated assessment has provided templates for guiding these breakout sessions. Incorporating more social science into workshops should increase the success of the stakeholder network in finding solutions to Detroit River FCA issues.

Bridging between Canada and US stakeholders

We had varying results with increasing the network capacity between US and Canada. While we held workshops in Windsor, we had poor participation by Canadian stakeholders throughout the process. We found that even with a Canadian co-investigator who was thoroughly embedded in the Canadian stakeholder network. Even with holding the second workshop in Canada, we consistently had little engagement from Canadian stakeholders. We were not effective in building capacity across the nations. The Detroit River is a narrow body of water where the ecology knows no political boundaries when it comes to contamination or human health effects. One newcomer to the network was effective in increasing communication across the border. Dr. Satyendra Bhasavar (Sport Fish Contaminant Monitoring Program, Ministry of the Environment, CA) was not in his position when we started the workshop series, but was fully engaged in the network starting with the second workshop. He has fostered good communication channels between his organization and the Michigan Department of Community Health. At the end of the third workshop, representatives from the Michigan Department of Natural Resources, Fisheries Division, had the goal of leading their subgroup along with Dr. Bhasavar to have better coordination between the two countries in fish collections for FCAs. Again, a stakeholder representative who was fairly new to their organization took a leadership role in the network. As mentioned above, a participant reported in their survey that an outcome was "coordination of FCA signage on US/CA sides of the river (just discussed at today's meeting)." These activities at the last workshop indicate that the communication gap may close in the future.

SUMMARY OF OUTCOMES

Workshop Development Outcome: A three part workshop series incorporating stakeholder engagement activities.

Workshop 1 "Detroit River Fish Consumption Guides: Navigating the Issues".
Goal: to develop greater stakeholder awareness of the organizational system surrounding FCAs in the Detroit River.
Stakeholder engagement activities: Activity (1) learn about other organizations who play a role in the Detroit River and educate others about the work of your organizations as it relates to the Detroit River; (2) reflection on FCA network; and (3) development of system maps and key questions/issues.

Workshop 2 "Fish Consumption Advisories in the Detroit River: A Canadian and US Partnering Opportunity".
Goals: (1) to develop working groups that help to address the top key questions identified in the last workshop and (2) to revise the stakeholder roles.
Stakeholder engagement activity: development of stakeholder role titles and definitions.

Workshop 3 "Fish Consumption Advisories in the Detroit River: Progress Towards a Solution".
Goals: (1) to provide an overview of the outcomes from this project (including the efforts of the stakeholder groups) in addressing key issues related to fish consumption advisories on the Detroit River; (2) to discuss the next priorities for FCAs in the Detroit River; and (3) to identify funding opportunities to support future high priority efforts.
Stakeholder engagement activities: (1) identification of key issues revisited and (2) development of working groups based on key issues that identified champions, diversity of roles, resources, and immediate next steps.

Workshop Implementation Outcomes by Workshop

Workshop 1:

1. A stakeholder consensus of the top five issues related to the causes and consequences of Fish Consumption Advisories in the Detroit River.
2. Network maps of the causes and consequences of Fish Consumption Advisories in the Detroit River, including the connections among the organizations who work on the causes and consequences.
3. An on-line description of available databases related to contaminants and human health effects in the Detroit River (http://ciler.snre.umich.edu/fca/data_sets.php).

Workshop 2:

1. The revision of stakeholder roles for greater awareness of stakeholder diversity in working groups.
2. The development of 4 working groups: Outreach, Food Web, Environmental Justice, and BUIs.
3. The establishment of a Google Groups website for FCAs in the Detroit River.

Outreach Working Group: The development and production of new outreach materials.

1. Brochure: "Eat Safe Fish in the Detroit Area: A guide to buying and catching fish that are healthy for you and your family"
2. Flier: "Best Spots for Catfish in the Detroit Area"
3. Sign: "Eating Fish from the Detroit River"

Food Web Working Group:

1. A risk analysis of PCB body burdens in fish, including those not included in the advisories.
2. A spatial integration of water and sediment inputs for predicting PCB body burdens in fish.

Workshop 3: The development of three working groups to continue work beyond the project end: Public Outreach, Fish Monitoring Coordination, and Contaminant and Pollution Prevention.

Assessment Outcomes

Workshop 1 Evaluation: Participants found Workshop 1 “quite” useful overall where the most helpful impact was “Developed one or more new contacts that I think may be useful in the future”.

Integrated Assessment Outcomes: The most valuable outcomes to participants were addressing public awareness of DR-FCAs (80% agreed or strongly agreed) and providing valuable scientific information on DR-FCAs (86% agreed or strongly agreed). Overall, participants agreed "the integrated assessment project has helped to address top priority issues for DR-FCAs".

Outcomes that were the least valued were the understanding of non-advisory fish contaminant levels in the Detroit River and of the sources of contaminant in the basin that are high enough to translate into a DR-FCAs.

Of those who participated in Workshop 3, 64% had visited our website at least 1-5 times and for some, 6-10 times. All participants saw themselves using the website in the future.

All participants except 2 responded that they had made new network connections with an average of 3.3 connections.

Changes in critical issues and knowledge:

Issue alignment: Participant most critical and least critical issues stayed the same over the course of our project.

Knowledge: We achieved our goal of increased network awareness. Our group of stakeholder participants and other participants who attended the third workshop were more aware of the issues and the network of organizations associated with the Detroit River FCAs than those participants of workshop 1. For the subset of stakeholder participants we could measure a change in perceived knowledge, which increased from Workshop 1 to Workshop 3.

Network Capacity: We developed three surveys to assess network capacity: stakeholder network, pre-workshop survey, and post-workshop survey.

In the stakeholder network, we assessed that:

- Higher knowledge of issues and network of organizations indicates higher capacity to work on goals.
- Working groups can learn from the outreach working group: effective leadership by a champion, effective learning climate that created increase value of FCAs, diversity of roles in the group, and effective use of resources and support.
- The outreach working group champion demonstrated high capacity with motivation, knowledge, and skills.
- The weak connections in the network bridge between Canada and the United States proved to be the biggest challenge. Some progress in strengthening these connections towards the end of the project indicates that this capacity may increase in the future.

References

Carlson, C.R. and W.W. Wilmot. 2006. *Innovation: The Five Disciplines for Creating What Customers Want.* New York, Crown Business.

Conrad, C.T. and T. Daoust. 2008. Community-based monitoring frameworks: increasing the effectiveness of environmental stewardship. *Environmental Management*. 41:358-366.

Frank, K. 1995. Identifying cohesive subgroups. Social Networks. 17:27-56.

Frank, K. 1996. Mapping interactions within and between cohesive subgroups. *Social Networks*. 18:93-119.

Krause, A.E., K.A. Frank, D.M. Mason, R.E. Ulanowicz, and W.W. Taylor. 2003. Compartments revealed in food-web structure. *Nature*. 426:282-285.

Suarez-Balcazar, Y., T. Taylor-Ritzler, E. Garcia-Iriarte, C. Keys, L. Kinney, H. Rush-Ross, M. Restrepo-Toro, and G. Curtin. 2009. Evaluation capacity building: a cultural and contextual framework. *In* Balcazer, Suarez-Balcazar, Taylor, and Keys, eds. *Race, Culture, and Disability: Rehabilitation Science and Practice.* Jones and Bartlett, Boston, Ma. pp. 307-324.

van Kerkhoff, L. and L. Lebel. 2006. Linking knowledge and action for sustainable development. *Annual Review in Environmental Resources*. 31:445-77.

APPENDIX 2.0: Detroit River Key Informant Interview Guide

Detroit River Key Informant
Interview Guide

Introduction to Phone Interview

My name is _____ and I'm calling from {North Carolina State University/University of Toledo) to do the interview we scheduled with you concerning fish consumption advisories in the Detroit River. Before we begin, I wanted to just briefly review the information in the informed consent you signed. As you read, for these interviews, we are talking with several individuals such as yourself who have been identified as key informants with valuable knowledge about the key issues involved in addressing the drivers of fish consumption advisories in the Detroit River. Through this interview, we would particularly like to learn from you how members in the (stakeholder group) community are thinking about the issue of fish consumption advisories.

As was stated in your informed consent form, all information you share with me will remain confidential—only myself and the other members of the research team will have access to identifiable data. The information you provide will help to inform the design of a series of workshops which will convene Detroit River stakeholders to engage in an integrated assessment of the causes and consequences of fish consumption advisories starting in October 2007

{if consented}

In order to make sure my notes are as accurate as possible, the interview will be audio taped however, if at any point you would like me to turn the recorder off, just let me know.

Do you have any questions before we get started?

To start with, can you tell me about how your organization/agency is currently thinking about the issue of fish consumption advisories? • What do you think really needs to happen to address this issue? • What do you think is the critical driver of fish consumption advisories?
PROBES: What specific priorities do your agency hold related to this issue? What role do you see it playing? Why has this become a priority? **note – probe whether focused on source of contaminants, how to clean up existing contaminants, how to manage public health concerns related to fish consumption
To what extent to you feel the priorities you just described are shared among the other organizations/agencies representing (stakeholder group)? If not – what differences exist?
What other factors may separate people within the watershed region around this issue? • Are there key differences related to how people think about this issue? What are these? Who holds what beliefs?
Are there key differences in philosophy between organizations and agencies related to this issue? o If so, what are these?
How would you characterize your organization/agency's philosophy concerning this issue?

Is your organization/agency working with any other stakeholders on this issue? In what ways?

To what extent do you think the Detroit River community as a whole – all the various organizations, community groups, agencies invested in this issue are effectively coordinating their efforts to address issues of fish contaminants? What do you see that makes you think this?
To what extent do you think the most important stakeholders have the capacity to organize around addressing this issue? If yes - What does this capacity look like? If no – What is missing? What capacities are needed?
To what extent is a lack of relationships among stakeholders a barrier to addressing fish consumption advisories? - if yes – what relationships are lacking? What are the implications of this?
When you think about effective relationships between stakeholders in this context – what do you think about? What do relationships need to look like? - What qualities of relationships are particularly important for addressing this issue?
Are there other things not mentioned that gets in the way of organizations, agencies and groups working together more effectively?
Other things that you think its important for us to consider as we move forward designing a process for faciliting stakeholders to come together to better address the causes and consequences of fish consumption advisories?

APPENDIX 2.1: Detroit River Stakeholder Survey

North Carolina State University is a land-grant university and a constituent institution of The University of North Carolina

Department of Pubic Administration

NC STATE UNIVERSITY

October 18, 2007

Dear XXXXX,

Your organization has been identified as an important and invested stakeholder concerning issues that directly relate to contaminants and/or human health concerns in the Detroit River. We hope that you have received our invitation to attend the first workshop of a series entitled ***Detroit River Contaminants and Human Health Effects: Navigating the Issues***. Members from our researcher team are from the University of Michigan, University of Toledo, North Carolina State University, and University of Windsor.

A research member has recently contacted you or someone who works with you in your organization and you were identified as the key person for taking a survey in preparation for this workshop. Thank you very much for agreeing to participate in the enclosed survey. We have anticipated some questions you may have about this survey and have tried to answer them below:

How do I participate?
Simply fill out the enclosed survey and return it directly to North Carolina State University in the provided postage-paid envelope **BY OCTOBER 31st**. If you have any questions about this study, please feel free to contact me at (919) 513-1768.

Why should I participate?
The goal of this survey is to provide information that both your organization/agency and other organizations can use in order to better understand how the current stakeholder system is structured and what resources and capacities exist within it. Our objective is to create a picture of the current stakeholder system of the Detroit River, including the interactions among stakeholders groups, to aid in discussions aimed at building awareness among stakeholders of the system they work within when tackling issues and to identify new opportunities for strengthening connections. Findings of the survey will be shared with stakeholders during our first workshop on Nov. 13th.

How do I know the information I provide won't come back to haunt me?
You will provide the information directly to the researcher team and they will be the only ones who have access to that information. Your identity as the representative of your organization or agency is **confidential**. Further, the information you provide about your organization will also be kept confidential and will be presented only in aggregated form. All organizations and agencies will be categorized into one of ten categories such that multiple organizations and agencies will comprise any one stakeholder group category. The ten categories will be created based on each organization's self-assignment into one of five categories (community end users, regulatory compliance, monitoring research, industrial development, and policy on fish

consumption advisories) and one of two countries (US or Canada). Presentation and reporting of this data will be in the aggregated form by category level; specific organizations and individuals will not be identified.

Thank you in advance for your time and participation.

Sincerely,

Branda Nowell, PhD -Branda_nowell@ncsu.edu

DETROIT RIVER STAKEHOLDER SURVEY

Thank you for taking time to fill out the Detroit River Stakeholder survey. This brief survey is being conducted as part of an integrated assessment of the issue of water contamination in the Detroit River leading to beneficial use impairments such as fish consumption advisories. The goal of this project will be to convene stakeholders to identify the causes and consequences of these beneficial use impairments and opportunities for improved management of this issue. **Even if you or your organization is not very active concerning this issue, you represent the perspective of an important stakeholder group.** The goal of this survey is to understand the current social network that exists among and between stakeholder groups invested in the Detroit River. This survey should take you approximately 20 minutes to complete.

Instructions:

In this survey, you will be asked to provide information about your organization or agency. **If you are the representative of a unit, program, or department that is nested within a larger organization or agency, please answer the questions as they relate to your unit, program, or department.** Once you have completed the survey, please return it to Branda Nowell at North Carolina State University in the postage paid envelop provided.

Informed Consent

PRINCIPAL INVESTIGATORS

Branda Nowell, PhD, Department of Public Administration, Campus Box 8102, North Carolina State University, Raleigh, NC 27695 (919-513-1768)

PURPOSE

This research is a part of an integrated assessment designed to address the causes and consequences of fish consumption advisories in the Detroit River carried out by an interdisciplinary team of researchers from the University of Toledo, North Carolina State University, and University of Michigan.

DESCRIPTION OF PROCEDURES

We are surveying you to help us understand stakeholder networks surrounding the issue of fish consumption advisories in the Detroit River. The applied goal of this study is to provide information that your organization/agency as well as other organizations can use to understand how the current management system is structured and what resources and capacities exist within it during the Detroit River participatory integrated assessment workshop series beginning in November, 2007. Our objective is to create a map profiling the current management system of the Detroit River, including the interactions among stakeholders groups to aid in discussions for setting goals related to fish consumption advisories for important fish species in the Detroit River. This map will not reveal the networks of any one organization or agency but rather display the extent and types of interaction that occurs among and between different stakeholder groups (e.g., end-user community groups, monitoring and research organizations/agencies, etc) who are involved or invested in the Detroit River on both the US and Canadian side. We are NOT evaluating the performance of any of those involved in use of the results.

The academic goal of this study is to pilot this approach as a tool for supporting watershed management networks and to identify what kinds of information yielded from this study prove most useful to stakeholders.

We anticipate that participating in this survey will take no longer than 30 minutes.

CONFIDENTIALITY

Participating in this study is voluntary, whether you choose to participate or not will remain confidential, and your privacy will be protected to the maximum extent allowable by law. The data you provide will be stored on password protected computers. Your identity as the representative of your organization or agency in this study will be kept confidential. Further, the information you provide about your organization will also be kept confidential and will be presented only in aggregated form based on the stakeholder group and country within which you identify your organization to belong. All organizations and agencies will be categorized into one of 10 categories such that multiple organizations and agencies will comprise any one stakeholder group category. The 10 categories will be created based on each organizations' self-assignment into one of five categories (community end users, regulatory, research and monitoring, industrial development, and fish consumption policy) and one of two counties (US or Canada). All data will be aggregated to this category level.

VOLUNTARY PARTICIPATION

You may choose not to participate at all, or you may refuse to answer certain questions or discontinue your participation at any time without penalty or loss of benefits. Your answers will be kept confidential. That is, your identity will be known only to members of our research team.

Informed Consent

RISKS

The risks associated with participation in this study are minimal. The data will be presented in a way that the social network of your organization or agency is strictly confidential. The only foreseeable risk is that the resulting networks could be viewed by someone in a way that they feel shines a negative light on the stakeholder group to which your organization or agency belongs.

BENEFITS

Participating in this study can directly benefit your organization or agency and others working within the Detroit River watershed. Understanding the network of organizations and agencies working within the watershed helps us to answer questions such as: What are the institutional resources that exist within this system of stakeholders? To what extent are the networks in place to take maximum advantage of those resources? Where are the needs or opportunities for collaboration or information sharing within this system? To what extent are the networks in place to support that? Discussion around these questions can create the opportunity for your organization/agency and others to gain a greater appreciation for current areas of capacity and help to identify new opportunities for coordination and collaboration.

CONTACT INFORMATION

If you have questions at any time about the study or the procedures, you may contact the researcher Branda Nowell, in the Department of Public Administration, Campus Box 8102, North Carolina State University, Raleigh, NC 27695 {919-513-1768} If you feel you have not been treated according to the descriptions in this form, or your rights as a participant in research have been violated during the course of this project, you may contact Dr. David Kaber, Chair of the NCSU IRB for the Use of Human Subjects in

Research Committee, Box 7514, NCSU Campus (919/515-3086) or Mr. Matthew Ronning, Assistant Vice Chancellor, Research Administration, Box 7514, NCSU Campus (919/513-2148).

By completing and returning this survey, you are indicating that you have read the above information and consent to participate

Please Tell Us About Yourself and Your Organization

Please state the title of the position you currently hold:

How many years have you worked for your current organization or agency?

How many years have you been in your current position?

How many years have you worked in or around the Detroit River?

At what level is your position within your organization or agency? *Choose only one of the following*
□ Director/head administrator
□ Middle-level administrator/supervisor/coordinator
□ Project/program staff

Regarding Your Organization

Below is a description of stakeholder groups who make up the overall system of stakeholders interested and/or involved in the management of the Detroit River. Please indicate which stakeholder group description best fits your organization or agency.
Choose only one of the following

□ **Industrial and Economic Development:** Private and non-profit groups and government agencies that have a vested interest in the industrial and economic development of the Detroit River and its adjacent land or are industrial property owners along the Detroit River.

□ **Regulatory Compliance:** Government agencies who set contaminant policy or regulate the input of contaminants in the Detroit River, such as through enforcement or permits. This includes oversight monitoring, particularly for non-point sources. Permitees collect their own data to demonstrate compliance.

□ **Monitoring Research:** University groups or government agencies who collect data on the ecological system in the Detroit River for research and/or academic purposes or collect fish for setting trigger levels.

□ **Policy on Fish Consumption Advisories:** Government agencies who are involved in planning and information gathering to carry policy out on setting the trigger levels for fish contaminant advisories in the Detroit River, including the distribution of information to those at risk.

□ **Community End Users:** non-profit and private community groups who are involved in conservation, sports fishing, or human health risks related to the Detroit River.

□ **Other (please describe):**

Section B: Industrial & Economic Development Stakeholders

Your Organization's Network

Below is a list of Industrial & Economic Development stakeholders interested or involved in the management of the Detroit River. For each organization below, please indicate whether your organization's relationship with that agency is characterized in any of the following three ways **(check all that apply for each organization).**

(Note: answers are confidential and will be reported back in aggregate)

	My organization **has received data or**	My organization **has collaborated with** (e.g., worked	There are **one or more professional relationships** that

	information from this organization / agency at least once over the past 12 months	together on joint projects) this organization at least once during the past 12 months	link my organization to the members of this organization such that we would feel comfortable going to them to ask for assistance and/or their organization's support on a project
BASF			
Brighton Beach Power			
Canadian Environmental Law Association			
City of Detroit-Dept of Water and Sewer			
Council of Great Lakes Industry			
Detroit Edison/DTE Energy			
Detroit Port Authority			
FORD			
US Steel			

Section C: Regulatory Compliance Stakeholders

Your Organization's Network

Below is a list of Regulatory Compliance stakeholders interested or involved in the management of the Detroit River. For each organization below, please indicate whether your organization's relationship with that agency is characterized in any of the following three ways **(check all that apply for each organization).**

	My organization **has received data or information from this organization / agency** at least once over the past 12 months	My organization **has collaborated with** (e.g., worked together on joint projects) this organization at least once during the past 12 months	There are **one or more professional relationships** that link my organization to the members of this organization such that we would feel comfortable going to them to ask for assistance and/or their organization's support on a project

City of Detroit-Department of Environmental Affairs			
City of Windsor-Env Services, Poll Control			
Environment Canada-Rest. Prog. Div			
Environment Canada-Ontario Water Quality Monitoring (Regulatory Compliance)			
MDEQ-Water Bureau			
MDEQ-Office of the Great Lakes			
MDEQ-Southeast Michigan District Office			
Wayne County-Dept of Environment			

Section D: Monitoring Research Stakeholders

Your Organization's Network

Below is a list of Monitoring Research stakeholders interested or involved in the management of the Detroit River. For each organization below, please indicate whether your organization's relationship with that agency is characterized in any of the following three ways **(check all that apply for each organization).**

	My organization **has received data or information from this organization / agency** at least once over the past 12 months	My organization **has collaborated with** (e.g., worked together on joint projects) this organization at least once during the past 12 months	There are **one or more professional relationships** that link my organization to the members of this organization such that we would feel comfortable going to them to ask for assistance and/or their organization's support on a project
Environment Canada-Nat'l Water Research Institute			(
Environment Canada-Wildlife Service	(	(	(
MDNR-Fisheries Division	(	(	(

OMOE-Sport Fish & Biomonitoring Unit	(	(	(
OMNR-Lake Erie Basin	(	(	(
SEMCOG	(	(	(
University of Windsor-Great Lakes Institute for Env Research	(	(	(
US EPA-Office of Research and Development (Grosse Ile)	(	(	
USFWS-Detroit River International Wildlife Refuge			(
USGS-Great Lakes Science Center	(	(	(

Section E: Policy on Fish Consumption Advisories Stakeholders

Your Organization's Network

Below is a list of Monitoring Research stakeholders interested or involved in the management of the Detroit River. For each organization below, please indicate whether your organization's relationship with that agency is characterized in any of the following three ways (check all that apply for each organization).

	My organization has received data or information from this organization / agency at least once over the past 12 months	My organization has collaborated with (e.g., worked together on joint projects) this organization at least once during the past 12 months	There are one or more professional relationships that link my organization to the members of this organization such that we would feel comfortable going to them to ask for assistance and/or their organization's support on a project
City of Detroit-Dept of Health			
Great Lakes Commission			
Health Canada-Chemical Health Hazard Assessment			
International Joint Commission			

MDCH-Div of Env Health			
MDCH-Division of Env & Occup Epidemiology			
US EPA-Great Lakes National Program Office			
Fisheries and Oceans Canada-Great Lakes Policy & Economics			
Wayne County-Department of Public Health			
Provincial Parliament-MPP Windsor West			
Office of Ed Clemente, State Rep. Dist. 014			

	My organization **has received data or information from this organization / agency** at least once over the past 12 months	My organization **has collaborated with** (e.g., worked together on joint projects) this organization at least once during the past 12 months	There are **one or more professional relationships** that link my organization to the members of this organization such that we would feel comfortable going to them to ask for assistance and/or their organization's support on a project
Office of Bettie Scott, State Rep. Dist. 003		(	(
Office of Barb Farrah, State Rep. Dist. 013	(	(	(
Office of Marsha Cheeks, State Rep. Dist. 006	(	(	(
Office of Kathleen Law, State Rep. Dist. 023	(	(	(
Office of Steve Tobocman, State Rep. Dist. 012	(	(	(
Office of Coleman Young II, State Rep. Dist. 004	(	(	(
Office of Ray Basham, State Sen. Dist. 08	(	(	(
Office of Irma Clark-Coleman, State Sen. Dist.	(	(	(

03			
Office of Hansen Clarke, State Sen. Dist. 01	(	(	(
Office of Bruce Patterson, State Sen. Dist. 07	(	(	(
Office of Martha Scott, State Sen. Dist. 02	(	(	(
Office of Carolyn Kilpatrick, US House of Reps – Dist. 13	(	(	(
Office of John Conyers, US House of Reps-Dist. 14	(	(	(
Office of John Dingell, US House of Reps-Dist. 15	(	(	(
Office of US Senator Carl Levin	(	(	(
Office of US Senator Debbie Stabenow	(	(	(

Section F: Community End User Stakeholders

Your Organization's Network

Below is a list of Community End User stakeholders interested or involved in the management of the Detroit River. For each organization below, please indicate whether your organization's relationship with that agency is characterized in any of the following three ways **(check all that apply for each organization).**

	My organization **has received data or information from this organization / agency** at least once over the past 12 months	My organization **has collaborated with** (e.g., worked together on joint projects) this organization at least once during the past 12 months	There are **one or more professional relationships** that link my organization to the members of this organization such that we would feel comfortable going to them to ask for assistance and/or their organization's support on a project
Canadian Detroit Riverkeeper		(	(
Citizens Environment Alliance	(	(	(
City of Detroit-Dept of Rec.	(	(	(
City of Trenton-Dept of Parks and Rec.	(	(	(

Detroit Area Steelheaders	(	(	(
Detroit River Canadian Cleanup Committee	(	(	(
Canadian Detroit River Public Advisory Council	(	(	(
Detroit Riverfront Conservancy	(	(	(
Detroiters Working for Env Justice	(	(	(
Essex Region Conservation Authority	(	(	(
Friends of the Detroit River	(	(	(
MDEQ-Env Sci and Services	(	(	(
MI Sea Grant-Urban SE District	(	(	(
Michigan Food Policy Council	(	(	(
US Detroit River Public Advisory Council	(	(	(
National Wildlife Federation-Ann Arbor	(	(	(
Parks Ontario-Canadian Heritage River Sys.	(	(	(
Town of La Salle-Dept of Culture & Rec.		(	(
Racial & Ethnic Approaches to Comm. Health	(	(	(

Organizational network (cont'd.)

In general, to what extent do you feel the interests, obligations, and constraints of your organization or agency are understood by the representatives of the following stakeholder groups who work within the Detroit River? Please circle one

	Not at all	A little	Somewhat	Quite a bit	Completely	Don't know
Industrial & Economic Development Stakeholders	1	2	3	4	5	□
Regulatory Compliance Stakeholders	1	2	3	4	5	□
Monitoring Research Stakeholders	1	2	3	4	5	□
Policy on Fish Consumption Advisories Stakeholders	1	2	3	4	5	□
Community End User Stakeholders	1	2	3	4	5	□

Issues

Below is a list of management issues related to the management of water contamination in the Detroit River and/or associated policies and practices concerning fish consumption advisories.

From the list of issues below, **identify UP TO THREE** that are of greatest concern to you and your organization.
Check at most 3 answers

□ Developing a more consistent public health message between the US and Canadian fish consumption advisories
□ Standardizing measurement protocols to allow for better comparability of datasets and findings related to the fish consumption advisory
□ Increasing public trust/confidence in the legitimacy of the fish consumption advisories
□ Improving the readability of the fish consumption advisory reports
□ Securing the funds to ensure more consistent monitoring of the river
□ Improving the ability of the fish consumption advisory system to adequately reach those populations most impacted by PCB or mercury contamination in fish
□ Within your country, increasing coordination among local, state/provincial, and federal government authorities in planning along the Detroit River
□ Identifying 'hot issues' that can be used to rally the public
□ Increasing empirical clarity about the human consequences of PCB and mercury to inform fish consumption advisory policy
□ Creating a bi-national RAP (remedial action plan) process to address delisting the Detroit River as an Area of Concern
□ Creating a more achievable criteria for delisting the Detroit River as an Area of Concern
□ Reducing public fear of utilizing the Detroit river as a resource resulting from beneficial use impairments
□ Reducing the introduction of new contaminants through improving regulation and monitoring of point and non point source contaminants
□ Removing existing contaminants in the sediments of the Detroit River
□ Other (please describe):

Thank You for Completing This Survey!

Please return this survey to Branda Nowell at North Carolina State University in the postage paid envelope provided.

APPENDIX 2.2: Pre Workshop Survey

Detroit River Contaminants and Human Health Effects: Navigating the Issues

PRE WORKSHOP SURVEY

<u>Instructions:</u>

In this survey, you will be asked to provide information about your organization or agency. **If you are the representative of a unit, program, or department that is nested within a larger organization or agency, please answer the questions as they relate to your unit, program, or department.**

A. BACKGROUND

1. What year were you born? ___________

2. Are you (circle one): Male Female

3. What best describes your racial/ethnic background? (circle one)

African American /Black	Asian /Pacific Islander	Hispanic /Latino	White /Caucasian	Native American

Other: _____________

4. What is the highest degree you have received (circle one)
   a. Did not graduate from high school
   b. GED or high school diploma
   c. Associate's degree
   d. Bachelor's degree
   e. Master's degree
   f. Ph.D., MD, or JD
   g. Other? ______________________

5) How many years have you worked for the organization or agency you currently work for?

_____

6) How many years have you been in your current position? ______

7) How many years have you worked in & around issues associated with the Detroit River ? ________

B. KEY ISSUES FOR THE DETROIT RIVER

In a previous survey, you may have been asked about the issues of greatest concern *to your organization or agency*. Now, we'd like to know what you think are the overall most and least critical issues for the Detroit River community.

B1. In your opinion, what are the top issues that are the most and least critical for Detroit River stakeholders to unite around? Please mark (X) up to three for each column.

MOST CRITICAL (check up to 3)		**LEAST CRITICAL (check up to 3)**
☐	**a. Developing a more consistent public health message between the US and Canadian fish consumption advisories**	☐
☐	**b. Standardizing measurement protocols for contaminant levels in fish to allow for better comparability of datasets and findings between the two countries**	☐
☐	**c. Increasing public trust/confidence in fish consumption advisories**	☐
☐	**d. Improving the readability of the fish consumption advisory reports**	☐
☐	**e. Developing support to enable stakeholders to consistently monitor the river**	☐

☐	**f. Improving the ability of the fish consumption advisory system to adequately reach those populations most impacted by the consumption of contaminated fish**	☐
☐	**g. Increasing regional coordination in planning within your country across jurisdictional and political boundaries along the Detroit River**	☐
☐	**h. Increasing bi-national coordination in planning along the Detroit River**	☐
☐	**i. Creating a bi-national RAP (remedial action plan) process to address delisting the Detroit River as an Area of Concern**	☐
☐	**j. Identifying 'hot issues' that can be used to rally the public**	☐
☐	**k. Increasing the empirical clarity about the human health consequences of PCB and mercury contamination to inform fish consumption advisory policy**	☐
☐	**l. Creating more achievable criteria for delisting the Detroit River as an Area of Concern**	☐
☐	**m. Reducing public fear of utilizing the Detroit River as a resource**	☐
☐	**n. Reducing the introduction of new contaminants by improving regulation and monitoring of point and non-point source contaminants**	☐
☐	**o. Removal of existing contaminants in the sediments of the Detroit River**	☐

B2. There are a number of issues that have been identified as important in the on-going management of the Detroit River. This section asks you to assess your own level of knowledge concerning some of these issues.

***As they relate to the Detroit River*, how knowledgeable do you feel you are about:**

Mark (X) one box for each item.

	Not at all	A little	Some what	Quite	Highly
a. The current sources of PCB and mercury contamination that lead to the need for fish consumption advisories	☐	☐	☐	☐	☐
b. The extent to which and ways in which consumption of contaminated fish from the Detroit River impacts human health	☐	☐	☐	☐	☐
c. What it would take to eliminate the need for fish consumption advisories	☐	☐	☐	☐	☐
d. The impacts water and sediment contamination has on the river ecology	☐	☐	☐	☐	☐
e. How fish consumption advisories are set in your country (USA or Canada)	☐	☐	☐	☐	☐
f. How fish consumption advisories are set in the country across the river from you (USA or Canada)	☐	☐	☐	☐	☐
g. How fish consumption advisory policies relate to – and impact – remedial action planning in the Detroit River	☐	☐	☐	☐	☐

B3. Working within the Detroit River watershed, there is a broad network of organizations and agencies involved and invested in the issue of contamination and its associated impact on human health through the consumption of contaminated fish. This section asks you to assess your own level of knowledge concerning this network

How knowledgeable do you feel you are about: *Mark (X) one box for each item*

	Not at all	A little	Some what	Quite	Highly
a. Who the organizations and agencies concerned about contamination and its human health effects in the Detroit River	☐	☐	☐	☐	☐
b. The different roles and responsibilities of the organizations and agencies responsible for managing and creating policies around contamination and its human health effects in the Detroit River	☐	☐	☐	☐	☐
c. The constraints of the organizations and agencies responsible for managing and creating policies around contamination and its human health effects in the Detroit River	☐	☐	☐	☐	☐
d. How my organization's role fits into the broader system for managing fish consumption advisories	☐	☐	☐	☐	☐
e. How the actions and decisions of my organization affect the work of other organizations in the Detroit River	☐	☐	☐	☐	☐

B4. Please indicate your level of agreement or disagreement with the following statements.
Mark (X) one box for each item

	Strongly Agree	Agree	Some what Agree	Some what Disagree	Disagree	Strongly Disagree
a. The Great Lakes Water Quality Agreement is effective for addressing issues related to contaminants and its human health effects in the Detroit River	☐	☐	☐	☐	☐	☐

b. The process of the Remedial Action Plan for the Areas of Concern is effective for addressing issues related to contaminants and its human health effects in the Detroit River	☐	☐	☐	☐	☐	☐

C. RESOURCES AND NEEDS OF STAKEHOLDERS

C1. Working within the Detroit River watershed, there is a broad network of organizations and agencies involved and invested in the issue of contamination and its associated impact on human health through the consumption of contaminated fish. This next section asks you to assess the extent to which you feel you have sufficient knowledge about and relationships with other stakeholders to work effectively within this network

Please indicate your level of agreement or disagreement with the following statements.
Mark (X) one box for each item

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
a. I know who has information that is relevant to my work within this network of stakeholders	☐	☐	☐	☐	☐	☐
b. I know who has the datasets that are relevant to my work within this network of stakeholders	☐	☐	☐	☐	☐	☐
c. I have sufficient relationships such that I could go to people within this network of stakeholders	☐	☐	☐	☐	☐	☐
d. I know who people look to for leadership in this network of stakeholders	☐	☐	☐	☐	☐	☐
e. For the issues I face in my job, I know who to go to within this network of stakeholders	☐	☐	☐	☐	☐	☐

C2. Please rank in order of priority 1-3, what you feel are the most important needs (e.g. information, communication, tools, methods, or research needs) to address issues related to fish consumption advisories on the Detroit River

1.

2.

3.

C3. Does the organization you are representing today collect data?
Mark (X) one box

☐ No

☐ Yes

If you marked Yes above, please mark (X) the *any* of the following that apply:

☐ My organization has data concerning the food web of the Detroit River (e.g., fish, benthic invertebrates, plankton, etc.)

☐ My organization has data concerning water chemistry or PCBs or mercury for water released into the Detroit River, water in the Detroit River, or chemistry of sediments from the Detroit River

☐ My organization has data concerning PCBs and mercury in fish collected from the Detroit River

C4. Who are the *primary* "customers" of the "services" your organization provides?
Mark (X) one box

☐ Public citizens or citizen organizations
☐ Private industry or development organizations
☐ Government agencies

If you check Government agencies above and your organization is also a government agency, then are the primary recipients:
Mark (X) one box
☐ Equal government agencies (e.g., local government agency to local government agency)
☐ Higher government agencies (e.g., local government agency to state government agency)

D. YOUR COLLEAGUES

The following section asks about the extent to which other workshop participants here today are part of *your professional social network. Please refer to the number roster provided in responding to these questions*. NOTE: your answers will be held strictly confidential!

D1. Please circle the numbers that correspond to any person on the roster whom you consider to be a close professional colleague. *For these people only,* indicate the frequency with which you interact with each of them. Mark as many or as few people as apply.

Roster number	Frequency of interaction: Once or twice a year	Monthly	Weekly or more
1	☐	☐	☐
2	☐	☐	☐
3	☐	☐	☐
4	☐	☐	☐
5	☐	☐	☐
6	☐	☐	☐
7	☐	☐	☐
8	☐	☐	☐
9	☐	☐	☐
10	☐	☐	☐
11	☐	☐	☐
12	☐	☐	☐
13	☐	☐	☐
14	☐	☐	☐
15	☐	☐	☐
16	☐	☐	☐
17	☐	☐	☐
18	☐	☐	☐
19	☐	☐	☐
20	☐	☐	☐
21	☐	☐	☐
22	☐	☐	☐
23	☐	☐	☐
24	☐	☐	☐
25	☐	☐	☐
26	☐	☐	☐
27	☐	☐	☐
28	☐	☐	☐
29	☐	☐	☐
30	☐	☐	☐
31	☐	☐	☐
32	☐	☐	☐

Continued on Next Page

D2. Please circle the number that corresponds to any person on the roster who has provided you with information and/or data related to contaminants, its human health effects, and/or consumption advisories in the Detroit River *in the past 12 months*. *For those people only,* please indicate the frequency of those types of interactions with each of them.

Roster number	Frequency of interaction: Once or twice a year	Monthly or more
1	☐	☐
2	☐	☐
3	☐	☐
4	☐	☐
5	☐	☐
6	☐	☐
7	☐	☐
8	☐	☐
9	☐	☐
10	☐	☐
11	☐	☐
12	☐	☐
13	☐	☐
14	☐	☐
15	☐	☐
16	☐	☐
17	☐	☐
18	☐	☐
19	☐	☐
20	☐	☐
21	☐	☐
22	☐	☐
23	☐	☐
24	☐	☐
25	☐	☐
26	☐	☐
27	☐	☐
28	☐	☐
29	☐	☐
30	☐	☐
31	☐	☐
32	☐	☐

Continued on Next Page

D1. CONTINUED
Please circle the numbers that correspond to any person on the roster whom you consider to be <u>a close professional colleague</u>. *For these people only,* indicate the frequency with which you interact with each of them. Mark as many or as few people as apply.

Roster number	Frequency of interaction: Once or twice a year	Monthly	Weekly or more
33	☐	☐	☐
34	☐	☐	☐
35	☐	☐	☐
36	☐	☐	☐
37	☐	☐	☐
38	☐	☐	☐
39	☐	☐	☐
40	☐	☐	☐

D2. CONTINUED
Please circle the number that corresponds to any person on the roster who has <u>provided you with information and/or data related to contaminants, its human health effects, and/or consumption advisories</u> in the Detroit River *in the past 12 months. For those people only,* please indicate the frequency of those types of interactions with each of them.

Roster number	Frequency of interaction: Once or twice a year	Monthly or more
33		
34	☐	☐
35	☐	☐
36	☐	☐
37	☐	☐
38	☐	☐
39	☐	☐
40	☐	☐

APPENDIX 2.3: Workshop Evaluation and Feedback

WORKSHOP EVALUATION AND FEEDBACK

HOW USEFUL WAS TODAY'S WORKSHOP?					
	Not at all	A little	Some what	Quite	Very
Overall, how useful did you find today's workshop to be?	1	2	3	4	5
What did you find most useful?					

WORKSHOP IMPACTS Below is a list of possible impacts. Please rate on a scale of 1-5 the extent to which you feel participation in today's workshop has impacted you in the following ways:					
Participation in this workshop has helped me to:	Not at all	A little	Some what	Quite a bit	A lot
Develop one or more new contacts that I think may be useful in the future	1	2	3	4	5
Identify a new opportunity for getting information or resources	1	2	3	4	5
Identify one or more new possibilities for future collaboration	1	2	3	4	5
Become more aware of key issues related to water contaminants and their impacts on human health	1	2	3	4	5
Become more knowledgeable about how issues of water contamination and their impacts on human health are managed	1	2	3	4	5
Gain new insights into how the work of my organization or group fits within the larger network of Detroit River stakeholders	1	2	3	4	5

Become more knowledgeable about the roles, priorities, and constraints of other stakeholders	1	2	3	4	5
Gain new insights that will aid me in working within this network of stakeholders to get something accomplished	1	2	3	4	5

1. How would you rate the location of this workshop? please circle:

   1 2 3 4 5

   Inadequate Adequate

Comments:

2. Do you have any suggestions for other program locations?

3. Were there any topics that you wanted to discuss but were unable to?

   yes / no

   If so, please explain.

4. Please provide any additional comments or feedback that might be useful in helping us to design future workshops.

APPENDIX 2.4: Post Workshop Survey

Detroit River Fish Consumption Advisory Integrated Assessment
POST WORKSHOP SURVEY

Instructions:

In this survey, you will be asked to provide information about your organization or agency. **If you are the representative of a unit, program, or department that is nested within a larger organization or agency, please answer the questions as they relate to your unit, program, or department.**

B. BACKGROUND

1. What year were you born? __________

2. Are you (circle one): Male Female

3. What best describes your racial/ethnic background? (circle one)

African American /Black	Asian /Pacific Islander	Hispanic /Latino	White /Caucasian	Native American

Other: ____________

4. What is the highest degree you have received (circle one)

h. Did not graduate from high school

i. GED or high school diploma

j. Associate's degree

k. Bachelor's degree

l. Master's degree

m. Ph.D., MD, or JD

n. Other? ____________________

5) How many years have you worked for the organization or agency you currently work for?____

6) How many years have you been in your current position? ______

7) How many years have you worked in & around issues associated with the Detroit River? ____

B. KEY ISSUES FOR THE DETROIT RIVER

In a previous survey, you may have been asked about the issues of greatest concern to your organization or agency. Now, we'd like to know what you think are the *overall most and least critical issues for the* **Detroit River community** to address.

B1. In your opinion, what are the top issues that are the most and least critical for Detroit River stakeholders to unite around? Please mark (X) up to three for each column.

MOST CRITICAL (check up to 3)		**LEAST** CRITICAL (check up to 3)
☐	p. Developing a more consistent public health message between the US and Canadian fish consumption advisories	☐
☐	q. Standardizing measurement protocols for contaminant levels in fish to allow for better comparability of datasets and findings between the two countries	☐
☐	r. Increasing public trust/confidence in fish consumption advisories	☐
☐	s. Improving the readability of the fish consumption advisory reports	☐
☐	t. Developing support to enable stakeholders to consistently monitor the river	☐
☐	u. Improving the ability of the fish consumption advisory system to adequately reach those populations most impacted by the consumption of contaminated fish	☐
☐	v. Increasing regional coordination in planning within your country across jurisdictional and political boundaries along the Detroit River	☐
☐	w. Increasing bi-national coordination in planning along the Detroit River	☐
☐	x. Creating a bi-national RAP (remedial action plan) process to address delisting the Detroit River as an Area of Concern	☐
☐	y. Identifying 'hot issues' that can be used to rally the public	☐
☐	z. Increasing the empirical clarity about the human health consequences of PCB and mercury contamination to inform fish consumption	☐

advisory policy

☐	aa. Creating more achievable criteria for delisting the Detroit River as an Area of Concern	☐
☐	bb. Reducing public fear of utilizing the Detroit River as a resource	☐
☐	cc. Reducing the introduction of new contaminants by improving regulation and monitoring of point and non-point source contaminants	☐
☐	dd. Removal of existing contaminants in the sediments of the Detroit River	☐

B2. There are a number of issues that have been identified as important in the on-going management of the Detroit River. This section asks you to assess your own level of knowledge concerning some of these issues.

***As they relate to the Detroit River*, how knowledgeable do you feel you are about:**
Mark (X) one box for each item.

	Not at all	A little	Some what	Quite	Highly
h. The current sources of PCB and mercury contamination that lead to the need for fish consumption advisories	☐	☐	☐	☐	☐
i. The extent to which and ways in which consumption of contaminated fish from the Detroit River impacts human health	☐	☐	☐	☐	☐
j. What it would take to eliminate the need for fish consumption advisories	☐	☐	☐	☐	☐
k. The impacts water and sediment contamination have on the river ecology	☐	☐	☐	☐	☐
l. How fish consumption advisories are set in your country (USA or Canada)	☐	☐	☐	☐	☐
m. How fish consumption advisories are set in the country across the	☐	☐	☐	☐	☐

river from you (USA or Canada)					
n. How fish consumption advisory policies relate to – and impact – remedial action planning in the Detroit River	☐	☐	☐	☐	☐

B3. Working within the Detroit River watershed, there is a broad network of organizations and agencies involved and invested in the issue of contamination and its associated impact on human health through the consumption of contaminated fish. This section asks you to assess your own level of knowledge concerning this network

How knowledgeable do you feel you are about: *Mark (X) one box for each item*

	Not at all	A little	Some what	Quite	Highly
f. Who are the organizations and agencies concerned about contamination and its human health effects in the Detroit River	☐	☐	☐	☐	☐
g. The different roles and responsibilities of the organizations and agencies responsible for managing and creating policies around contamination and its human health effects in the Detroit River	☐	☐	☐	☐	☐
h. The constraints of the organizations and agencies responsible for managing and creating policies around contamination and its human health effects in the Detroit River	☐	☐	☐	☐	☐
i. How my organization's role fits into the broader system for managing fish consumption advisories	☐	☐	☐	☐	☐
j. How the actions and decisions of my organization affect the work of other organizations in the Detroit River	☐	☐	☐	☐	☐

C. RESOURCES AND NEEDS OF STAKEHOLDERS

C1. Working within the Detroit River watershed, there is a broad network of organizations and agencies involved and invested in the issue of contamination and its associated impact on human health through the consumption of contaminated fish. This next section asks you to assess the extent to which you feel you have sufficient knowledge about and relationships with other stakeholders to work effectively within this network

Please indicate your level of agreement or disagreement with the following statements.
Mark (X) one box for each item

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
f. I know who has information that is relevant to my work within this network of stakeholders	☐	☐	☐	☐	☐	☐
g. I know who has the datasets that are relevant to my work within this network of stakeholders	☐	☐	☐	☐	☐	☐
h. I have sufficient relationships such that I could go to people within this network of stakeholders	☐	☐	☐	☐	☐	☐
i. I know who people look to for leadership in this network of stakeholders	☐	☐	☐	☐	☐	☐
j. For the issues I face in my job, I know who to go to within this network of stakeholders	☐	☐	☐	☐	☐	☐

D. YOUR COLLEAGUES

The following section asks about the extent to which other workshop participants here today are part of *your professional social network. Please refer to the number roster provided in responding to these questions.* NOTE: your answers will be held strictly confidential!

D. YOUR COLLEAGUES

The following section asks about the extent to which other workshop participants here today are part of *your professional social network. Please refer to the number roster provided in responding to these questions.* NOTE: your answers will be held strictly confidential!

D1. Please circle the numbers that correspond to any person on the roster whom you consider to be a close professional colleague. *For these people only,* indicate the frequency with which you interact with each of them. Mark as many or as few people as apply.

Roster number	Frequency of interaction: Once or twice a year	Monthly	Weekly or more
1	☐	☐	☐
2	☐	☐	☐
3	☐	☐	☐
4	☐	☐	☐
5	☐	☐	☐
6	☐	☐	☐
7	☐	☐	☐
8	☐	☐	☐
9	☐	☐	☐
10	☐	☐	☐
11	☐	☐	☐
12	☐	☐	☐
13	☐	☐	☐
14	☐	☐	☐
15	☐	☐	☐
16	☐	☐	☐
17	☐	☐	☐
18	☐	☐	☐
19	☐	☐	☐
20	☐	☐	☐
21	☐	☐	☐
22	☐	☐	☐
23	☐	☐	☐
24	☐	☐	☐
25	☐	☐	☐
26	☐	☐	☐
27	☐	☐	☐
28	☐	☐	☐
29	☐	☐	☐
30	☐	☐	☐
31	☐	☐	☐
32	☐	☐	☐

Continued on Next Page

D2. Please circle the number that corresponds to any person on the roster who has provided you with information and/or data related to contaminants, its human health effects, and/or consumption advisories in the Detroit River *in the past 12 months. For those people only,* please indicate the frequency of those types of interactions with each of them.

Roster number	Frequency of interaction: Once or twice a year	Monthly or more
1	☐	☐
2	☐	☐
3	☐	☐
4	☐	☐
5	☐	☐
6	☐	☐
7	☐	☐
8	☐	☐
9	☐	☐
10	☐	☐
11	☐	☐
12	☐	☐
13	☐	☐
14	☐	☐
15	☐	☐
16	☐	☐
17	☐	☐
18	☐	☐
19	☐	☐
20	☐	☐
21	☐	☐
22	☐	☐
23	☐	☐
24	☐	☐
25	☐	☐
26	☐	☐
27	☐	☐
28	☐	☐
29	☐	☐
30	☐	☐
31	☐	☐
32	☐	☐

Continued on Next Page

D1. CONTINUED
Please circle the numbers that correspond to any person on the roster whom you consider to be <u>a close professional colleague</u>. *For these people only,* indicate the frequency with which you interact with each of them. Mark as many or as few people as apply.

Roster number	Frequency of interaction: Once or twice a year	Monthly	Weekly or more
33	☐	☐	☐
34	☐	☐	☐
35	☐	☐	☐
36	☐	☐	☐
37	☐	☐	☐
38	☐	☐	☐
39	☐	☐	☐
40	☐	☐	☐

D2. CONTINUED
Please circle the number that corresponds to any person on the roster who has <u>provided you with information and/or data related to contaminants, its human health effects, and/or consumption advisories</u> in the Detroit River *in the past 12 months. For those people only,* please indicate the frequency of those types of interactions with each of them.

Roster number	Frequency of interaction: Once or twice a year	Monthly or more
33		
34	☐	☐
35	☐	☐
36	☐	☐
37	☐	☐
38	☐	☐
39	☐	☐
40	☐	☐

E. OUTCOMES OF INTEGRATED ASSESSMENT

E1. Please indicate your level of agreement or disagreement with the following statements regarding the Integrated Assessment of Detroit River Fish Consumption Advisories (DR-FCAs).

Mark (X) one box for each item

	Strongly Agree	Agree	Somewhat Agree	Somewhat Disagree	Disagree	Strongly Disagree
c. The research team has provided valuable scientific information on DR-FCAs.	☐	☐	☐	☐	☐	☐
d. The working group has made a valuable contribution to addressing public awareness of DR-FCAs.	☐	☐	☐	☐	☐	☐
e. The working group has made a valuable contribution to the understanding of non-advisory fish contaminant levels in the Detroit River.	☐	☐	☐	☐	☐	☐
f. The working group has made a valuable contribution to understanding the sources of contaminant in the basin that are high enough to translate into a DR-FCAs.	☐	☐	☐	☐	☐	☐
g. The website associated with the integrated assessment project (http://ciler.snre.umich.edu/fca/index.php) is a valuable resource on DR-FCAs.	☐	☐	☐	☐	☐	☐
h. Overall, I feel that the integrated assessment project has helped to address top priority issues for DR-FCAs.	☐	☐	☐	☐	☐	☐

E2. Please list any outcomes from the Integrated Assessment efforts that were NOT covered in today's presentations:

E3. Please circle your response to the following questions about the website related to the Integrated Assessment http://ciler.snre.umich.edu/fca/.

Have you visited our website? YES NO

If so, approximately how many times have you visited it?

1-5 times 6-10 times 11-25 times More than 25 times

Do you see yourself using it in the future? YES NO

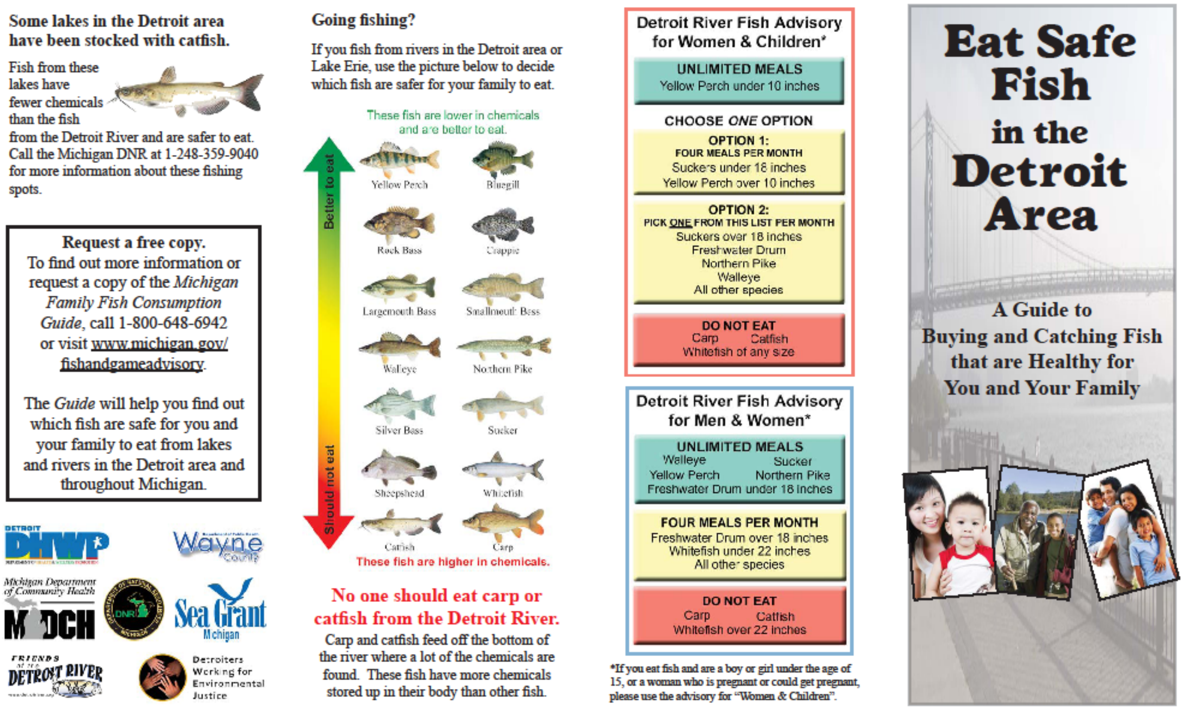
E4. Have you made new connections with people in association with the Detroit River fish consumption advisories since Workshop 1?

YES NO

If yes, how many would you say were a result of participating in activities related to the Integrated Assessment?

NONE 1 2 3 4 5+

APPENDIX 2.5: Tri-Fold Brochure "Eat Safe Fish in the Deroit Area"



Some lakes in the Detroit area have been stocked with catfish.

Fish from these lakes have fewer chemicals than the fish from the Detroit River and are safer to eat. Call the Michigan DNR at 1-248-359-9040 for more information about these fishing spots.

Request a free copy.
To find out more information or request a copy of the *Michigan Family Fish Consumption Guide*, call 1-800-648-6942 or visit www.michigan.gov/fishandgameadvisory.

The *Guide* will help you find out which fish are safe for you and your family to eat from lakes and rivers in the Detroit area and throughout Michigan.

Going fishing?

If you fish from rivers in the Detroit area or Lake Erie, use the picture below to decide which fish are safer for your family to eat.

No one should eat carp or catfish from the Detroit River.
Carp and catfish feed off the bottom of the river where a lot of the chemicals are found. These fish have more chemicals stored up in their body than other fish.

Detroit River Fish Advisory for Women & Children*

UNLIMITED MEALS
Yellow Perch under 10 inches

CHOOSE *ONE* OPTION

OPTION 1:
FOUR MEALS PER MONTH
Suckers under 18 inches
Yellow Perch over 10 inches

OPTION 2:
PICK <u>ONE</u> FROM THIS LIST PER MONTH
Suckers over 18 inches
Freshwater Drum
Northern Pike
Walleye
All other species

DO NOT EAT
Carp Catfish
Whitefish of any size

Detroit River Fish Advisory for Men & Women*

UNLIMITED MEALS
Walleye Sucker
Yellow Perch Northern Pike
Freshwater Drum under 18 inches

FOUR MEALS PER MONTH
Freshwater Drum over 18 inches
Whitefish under 22 inches
All other species

DO NOT EAT
Carp Catfish
Whitefish over 22 inches

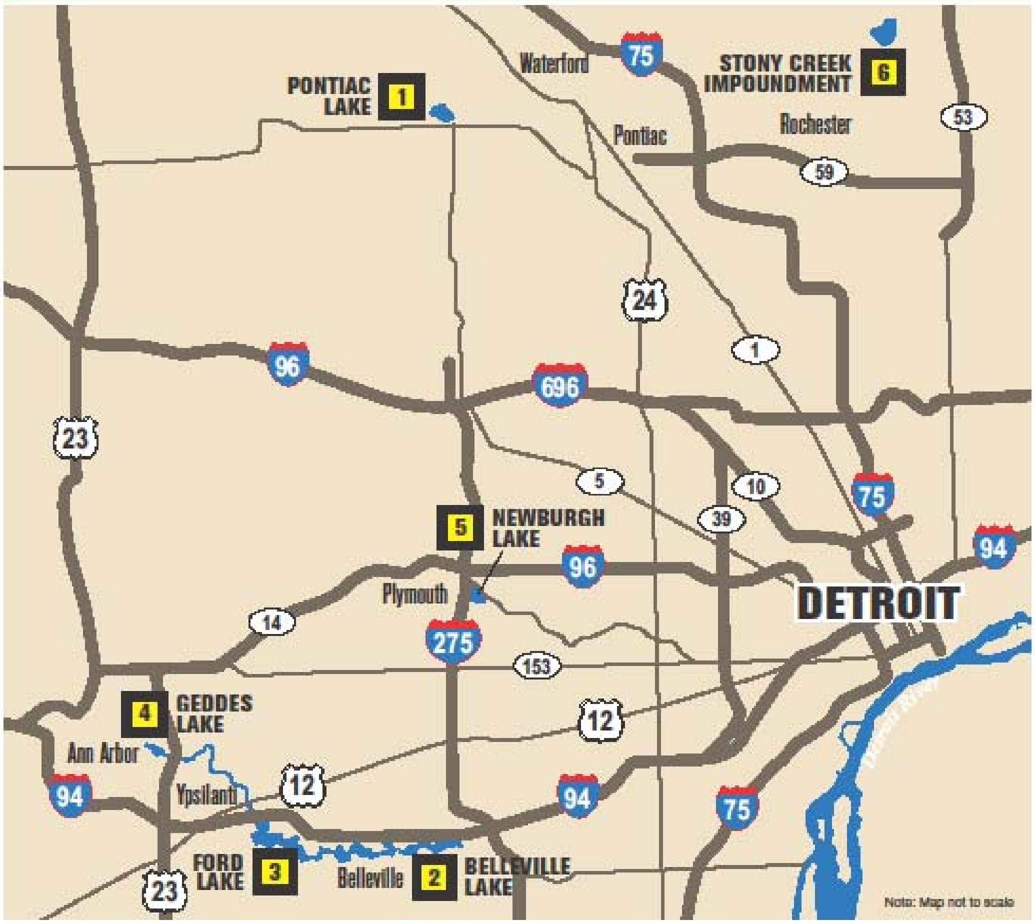
*If you eat fish and are a boy or girl under the age of 15, or a woman who is pregnant or could get pregnant, please use the advisory for "Women & Children".

Eat Safe Fish in the Detroit Area

A Guide to Buying and Catching Fish that are Healthy for You and Your Family

APPENDIX 2.6: Distribution flier "Best spots to catch Catfish in the Detroit area"

Best Spots for Catfish in the Detroit Area



For a free copy of the Michigan Family Fish Consumption Guide,
call the Michigan Department of Community Health at:

1-800-648-6942

or visit: www.michigan.gov/fishandgameadvisory

These lakes in southeast Michigan have been stocked with channel catfish

The catfish in these lakes are a healthier choice than the catfish in the Detroit River. Check the Michigan Family Fish Consumption Guide for advice on eating catfish from these lakes.

1. PONTIAC LAKE, OAKLAND COUNTY

Access: Pontiac Lake State Recreation Area, Williams Lake Rd., north of M-59, four miles west of Pontiac. Boat launch and fishing piers in Recreation Area. State park sticker required.

Additional Information: Excellent catfish population with 2007 survey showing many fish in the 18-24 inch size range. Good walleye, bluegill and largemouth bass as well.

Contact: Pontiac Lake State Recreation Area at 248-666-1020; or MDNR Southfield Service Center Fish Division at 248-359-9040.

2. BELLEVILLE LAKE, WAYNE COUNTY

Access: Two public boat access sites: Huron River Drive one mile west of Haggerty Rd.; and Rawsonville Rd. half mile south of I-94. Shore fishing at both access sites and fishing pier near dam on east end of lake.

Additional Information: Good catfish population with many larger fish reported by anglers. Latest DNR survey found many catfish in 18-24 inch range with fish up to and over 30 inches caught. Good walleye, smallmouth bass and crappie.

Contact: South Street Tackle Store in Belleville at 734-697-0990; or MDNR Southfield Service Center Fish Division at 248-359-9040.

3. FORD LAKE, WASHTENAW COUNTY

Access: Ypsilanti Township Park with boat access site and shore fishing at east end of lake off Huron River Dr. Other local parks provide some shore fishing as well.

Additional Information: DNR 2006 survey caught over 600 catfish averaging 22 inches with fish up to 30 inches. Also good walleye, smallmouth bass, black crappie and some yellow perch.

Contact: Ypsilanti Township Recreation Department at 734-544-3800; or MDNR Southfield Service Center Fish Division at 248-359-9040.

4. GEDDES LAKE, WASHTENAW COUNTY

Access: City of Ann Arbor boat launch off Geddes Rd. west of US-23. Shore fishing in Gallup Park off Fuller Rd. west of Huron Parkway and along paved path on south side of lake.

Additional Information: DNR 2008 survey showed good numbers of catfish averaging 22 inches with many in the 20-25 inch range. Also largemouth bass, northern pike and bluegill.

Contact: Ann Arbor Department of Parks and Recreation at 734-994-2780; or MDNR Southfield Service Center Fish Division at 248-359-9040.

5. NEWBURGH LAKE, WAYNE COUNTY

Access: Two fishing piers off Hines Drive on north side of lake. Shore fishing along most of north shore. Paddleboat and row boat rental available. Canoe or carry-in boat access at central parking and pier location.

Additional Information: DNR 2005 survey found fair numbers of catfish up to 25 inches. Largemouth bass, bluegill and northern pike also present. The previous "no consumption" advisory for all fish has been removed by Michigan Department of Community Health.

Contact: Wayne County Division of Parks at 734-261-2025; or MDNR Southfield Service Center Fish Division at 248-359-9040.

6. STONY CREEK IMPOUNDMENT, MACOMB COUNTY

Access: Stony Creek Metropark provides public boat launch and shore fishing around much of the lake. Speed limit of 10 mph on lake. Metropark sticker required for park entry.

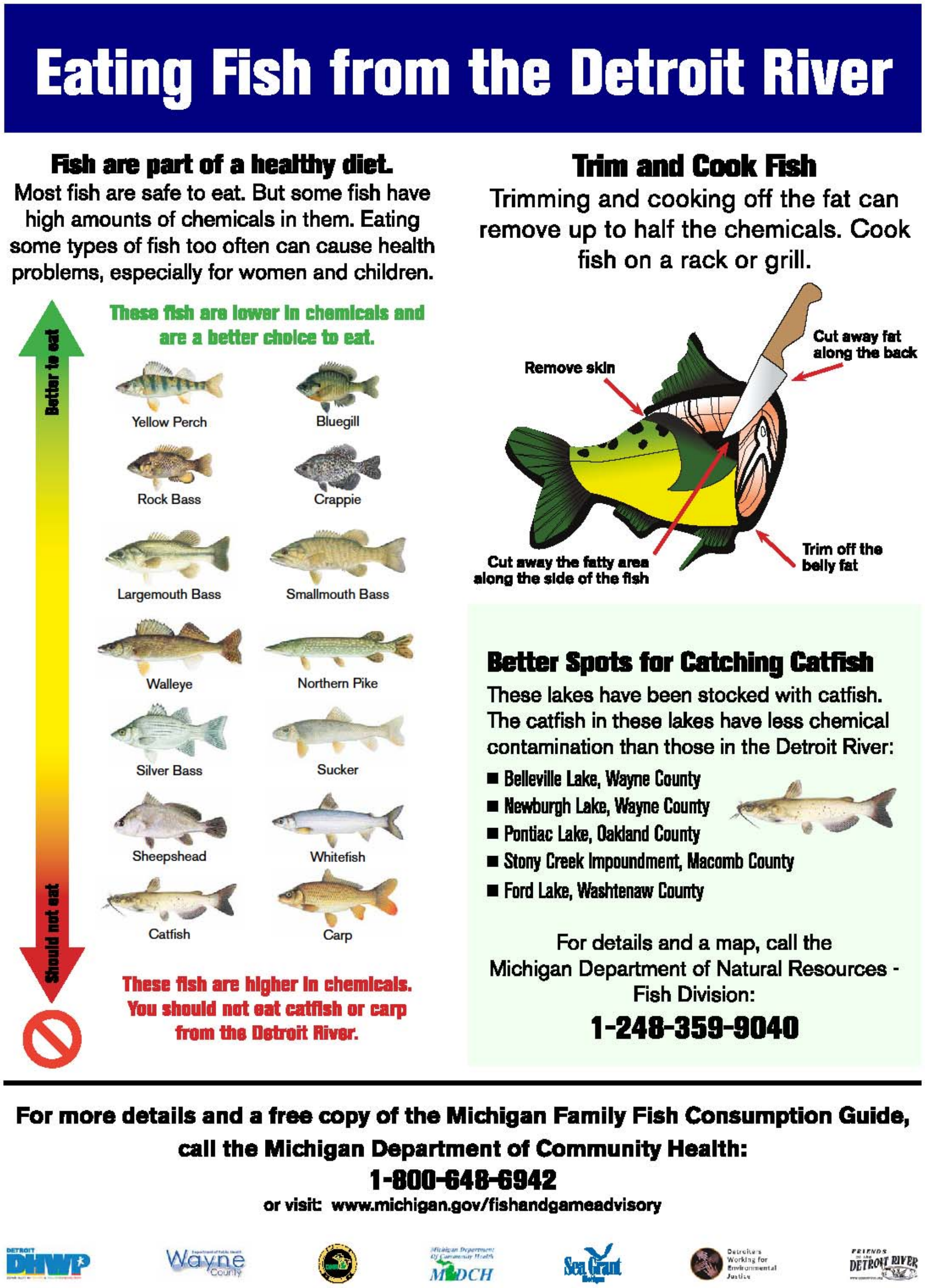
Additional Information: Last DNR survey found a fair population of catfish averaging 16 inches and up to 26 inches. Good walleye, largemouth bass and some large crappie also present.

Contact: Stony Creek Metropark at 586-781-4242; or MDNR Southfield Service Center Fish Division at 248-359-9040.

For more information on fishing these lakes, call the Michigan Department of Natural Resources (MDNR) at:

1-248-359-9040

APPENDIX 2.7: Signs to be posted along Detroit River in April 2010



CHAPTER 3:

FISH CONSUMPTION ADVISORIES: A REVIEW OF STATE-LEVEL APPROACHES

Abstract

In 2000, the US Environmental Protection Agency (USEPA) issued its most recent national guidelines for establishing fish consumption advisories (FCAs). While most states have adopted these recommendations, an assessment of current state practices indicates important inter-state variances in FCA protocols for polychlorinated biphenyls (PCBs). Some states, for example, use USEPA reference dose estimates for calculating non-cancer health risks, while other states still rely on US Food and Drug Administration action levels. The latter endpoint is no longer considered appropriate for setting recreational consumptions advisories. In comparison to other states, most of the Great Lakes states are consistent in their approach to FCAs and follow a 1993 regional protocol. Since this time, however, the literature about human health risks associated with PCBs has improved and analytical techniques for identifying congener-specific PCBs have advanced. These changes have occurred in the context of mostly declining state budgets that support fish contaminant monitoring program and outreach efforts. Some states have recently revisited their consumption advisory process, focusing on the following issues: 1) honing local consumption advice to adequately protect populations at most risk of PCB effects, either because they are more susceptible or because they consume more fish; 2) evaluating the latest science regarding PCBs, specifically with respect to non-cancer health effects; and 3) where appropriate, working with other states to assess interstate variations in fish advisory approaches when managing shared water resources. These efforts have direct relevance to Michigan's FCA process, as they can help support any efforts the state may undertake to update and improve it FCA process related to PCBs and to enhance their public outreach efforts by targeting communication materials to those most in need of specific consumption advice.

Introduction

Consumption advisories for recreational fish caught in US waters continue to be a major issue for local and state governments. As of 2006, 48 states have fish consumption advisories in place along with the District of Columbia, the U.S. territories of American Samoa and Guam, and 5 Indian tribes (U.S. EPA 2007). This has translated into 3,852 consumption advisories for recreational fish by the end of 2006. This number has been increasing over the years for a variety of reasons, including improved monitoring and surveillance for contaminants along with advances in the understanding of human health risks associated with existing and emerging contaminants of concern.

The current process for issuing fish consumption advisories related to PCBs comes largely from guidelines issued by the U.S. Environmental Protection Agency in 2000. Although the majority of states have adopted these guidelines, there are important variances that define individual states efforts. The Great Lakes states are differentiated from other states by their effort in the early 1990s to develop a uniform protocol for establishing fish consumption advisories across the different states. The protocol developed from this effort continue to guide FCAs in these states, despite recent advances in the science of PCB effects in humans, declining state revenue for FCA monitoring and outreach, and changes in best practices for analyzing PCBs and associated congeners.

Federal role in fish consumption advisories

In the United States, the Environmental Protection Agency (USEPA) is responsible for assessing human health risks associated with the consumption of contaminated recreational fish. The USEPA's mandate in this area comes from the language of the 1972 Federal Water Pollution Control Act, now known as the Clean Water Act, with a stated primary objective to "restore and maintain the chemical, physical, and biological integrity of the Nation's waters." 33 U.S.C.§1251(a). A specific goal of this effort is to assure that all U.S. waters have adequate water quality that "provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water." This goal has been interpreted by the USEPA both as requiring the survival of fish in US waters as well as providing for fish that can be safely consumed from the waters (USEPA 2000, 2003).

The national criteria for contaminants in fish are promulgated through the Criteria and Standards Division of USEPA's Office of Water Regulation and Standards. Under Section 304(a) of the CWA, the USEPA is required to establish standards for the amounts of contaminants such as PCB that can be consumed by people without adverse health effects.

Over the years, the USEPA has worked to improve the way in which it assists state in implementing fish monitoring and consumption guidelines. One of the biggest changes occurred in the late 1980s, after the American Fisheries Society, at the request of the USEPA, completed a survey of state fish and shellfish consumption advisory practices. Surveys and responses were solicited from a range of state health departments, fisheries agencies, and water quality/environmental departments in all 50 states plus the District of Columbia (Cunningham et al. 1990). The results indicated that monitoring and risk assessment procedures implemented by states varied widely. States also identified specific requests for USEPA and other federal agencies including that they:

1) Provide a consistent approach for state agencies to use in assessing health risks from the consumption of contaminated fish;
2) Develop guidance on sample collection procedures;
3) Develop or endorse uniform, cost-effective analytical methods for quantifying contaminants;
4) Establish a quality assurance program that includes the use of certified reference materials for chemical analyses (Cunningham et al. 1990).

The USEPA responded to this feedback by forming a working group to develop guidelines for using the most cost-effective and scientifically-sound methods for sampling and analyzing fish and shellfish tissue. This effort resulted in the publication of a series of guidelines to help states in developing, issuing, and communicating consumption advisories. In addition, the USEPA developed a national database of state-issued consumption advisories, known as the National Listing of Fish and Wildlife Advisories.

Since then, the USEPA has made at least two other important recommendations related to fish consumption advisories. The first of these occurred in 1995 when the USEPA[1] issued a supplementary advisory for PCB-contaminated fish targeted at women of reproductive age. This was in response to increased concern regarding the effects of PCBs on developing fetuses. The second major change came in 2007, when the USEPA and FDA specified that FDA Action Levels should no longer be used to issue fish consumption advisories. These action levels have been established for chemicals found in commercial products of food (fish, shellfish, etc.), but are not intended as cutoffs for issuing advisories for sport fish.

In developing its guidelines for states, the USEPA has used a risk-based approach for estimating health risks associated with PCBs. In this case, the USEPA has estimated a reference dose (RfD), which represents an estimate of a daily exposure to humans that is likely to be without appreciable risks of negative health effects over the course of a lifetime (USEPA 2004). The RfD explicitly includes uncertainty factors that can span several orders of magnitude and is conservative enough to apply to sensitive subgroups.

State-level approaches to issuing FCAs

An important characteristic of the CWA is its vision that states and the federal government form partnerships to improve the quality of the nation's water. As such fish consumption advisories and fish tissue monitoring programs constitute an important way in which state's can periodically assess the condition of their waters, as required by Section 305(b) reports of the CWA and in listing impaired water bodies under Section 202(d) of the CWA.

States are responsible for implementing a fish contaminant monitoring and testing program, including collecting fish samples, issuing FCAs when needed, and communicating to the public regarding FCAs. Individual states can set their own criteria and decide which where and when to sample.

States usually issue 5 different types of advisories: 1) A statewide no consumption advisory due to health risks for all populations; 2) a statewide no consumption advisory for sensitive subpopulations only; 3) an advisory that is specific to a given water body for a given populations; 4) an advisory that is specific to a given water body for all populations; and 5) a commercial fishing ban.

The Great Lakes States approach to FCAs

Great Lakes Uniform Protocol

In the Great Lakes region, work on a more uniform interstate approach to issuing FCAs began in the early 1990s. The Great Lakes Sport Fish Advisory Task Force ("Task Force") was made up of representatives from health and environmental or natural resource agencies from all eight of the Great Lakes states (i.e., Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin). The Task Force was charged with developing a uniform

[1] This recommendation was issued in conjunction with the Agency for Toxic Substances and Disease Registry (ATSDR).

approach and protocol for issuing FCAs in these states (see Anderson et al. 1993). Although not all states have adopted the protocol in its entirety, the resulting guidelines have been important in improving interstate consistency in FCAs.

Under the guidelines of the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory ("Protocol"), most species collected for advisory purposes are scale- and skin-on fillets. The fillets are specified to include "all flesh from the back of the head to the tail, from the top of the back down to and including the belly flap area… [A]l fins, the tail, head, viscera, and major bones" should be removed. The primary exceptions to this are bullheads, channel catfish, flathead catfish, and burbot fillets, all of which should be skinned. The Protocol also cites a preference for the use of individual fillets for chemical analysis; however, if states opt to use composite samples, the guidelines are to use fish of a similar size, with the smallest fish being at least 90% as long as the largest fish.

Although the Protocol does not give specific preference to any PCB analytical method, it does give a minimum detection goal for PCBs of 0.5 mg/kg. It also specifies guidelines for 5 meal frequencies: unlimited, 1 meal per week, 1 meal per month, 6 meals per year, and do not eat.

In terms of human health risks, the Protocol used a weight-of-evidence approach to designate a Health Protective Value (HPV) concentration of 0.05 μg total PCBs/kg/day. The HPV was developed in consideration of both cancer and reproductive and neurodevelopmental risks. Using the assumptions provided below, this leads to an ingestion rate of 0.22 mg per week of total PCBs in raw fish as the upper risk limit to trigger an "eat no more than once per week" advisory. Total PCB ingestion rates that range between 0.22 to 1.0 mg per week in raw fish would trigger an "eat no more than one meal for month" advisory (Table 1).

Table 1. PCB concentrations in fish that trigger consumption advisories for fish, as outlined in the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory (Anderson et al. 1993).

Group	**PCB conc. (ppm)†**
Unrestricted consumption	0 – 0.5
1 meal/week	0.06 – 0.2
1 meal/month	0.21 – 1.0
6 meals/year	1.1 – 1.9
No consumption	> 1.9

†In parts-per-million (mg/kg) wet weight and for raw skin-on fish fillets.

In order to translate raw fish PCB levels to human health risks, the Protocol uses several assumptions that are generally consistent with USEPA recommendations. These include assuming an average meal size of 227 g (or one-half pound) of uncooked fish, a weight of 70 kg for an adult consumer, and a 70-year lifetime duration of exposure.

Finally, the Protocol recommends that states consider both state-wide and site specific consumption advisories, depending on the circumstances. In terms of the latter, site-specific advisories allow agencies the ability to highlight waterbodies that might house fish with either higher or lower contaminant loads, thereby tailoring health recommendations. In most cases, this is the model followed by most Great Lakes' states.

Michigan

In the state of Michigan, three different agencies collaborate in the FCA process: The Department of Natural Resources (MDNR) is responsible for collecting the fish, the Department of Environmental Quality (MDEQ) is responsible for running the PCB analysis, and the Department of Community Health (MDCH) is responsible for issuing and publishing advisories. In general, Michigan follows the guidelines of the Great Lakes Uniform Protocol. To monitor contaminant loads in fish, the MDNR collects fish every 2-5 years from specified bodies of water. They generally aim to collect 10 fish for each species monitored, including species of bottom-feeders and top predators. Although the MDCH prefers to have a data set of at least 10 fish samples before either establishing or modifying an advisory, occasionally best professional judgment must be used in evaluating smaller data sets.

PCB concentrations are analyzed for individual fish and are not composited. FCAs are then based on an evaluation of the relationship between contaminant concentrations and trigger levels across the range of fish collected usually by employing a linear regression analysis to predict concentrations at lengths not collected. When linear regression cannot be used[2], MDCH will use either median concentrations or the percentage of samples exceeding the trigger level, in order to establish an advisory (see Bohr and Zbytowski 2009 for details).

When issuing consumption advisories for the general public, MDCH uses the FDA's 2.0 ppm action level. When concentrations in more than 10% of the samples from a fish species exceed the trigger level, the MDCH advises the general population to eat no more than 1 meal per week. When PCB concentrations in more than 50% of the samples exceed the trigger level, the MDCH advises the general population against eating any of these fish from a given water body.

Since 1998, the MDCH has been issuing separate advisories for women of child-bearing age and children less than 15 years old.

[2] Although linear regression is the preferred approach, alternative methods are sometimes required either because the underlying assumptions of the statistical model are not met or the regression does not produce a statistically significant line.

Additional details about consumption advisories issued by MDCH and others states are provided in Table 2.

Table 2. Summary information for PCB consumption advisories for U.S. states. Some states are not listed, as there was not adequate information about their advisory process. Those states with an N/A do not issue advisories related to PCBs.

State	Non-cancer risk source	Exposure durations (yrs)	Cooking loss (%)	Sensitive subpop	Use TEQs for PCBs
Alaska	N/A				
Arizona	N/A				
Arkansas	FDA	70	50	Yes	Yes
California	EPA RfD	30	0	Yes	?
Colorado	N/A				
Connecticut	GL HPV	70	50	Yes	?
Delaware	EPA RfD	30	0	Yes	Yes
Florida	EPA RfD	--	0	Yes	Yes
Georgia	EPA RfD	30	0	Yes	?
Hawaii	N/A				
Idaho	N/A				
Illinois	GL HPV	70	50	Yes	No
Indiana	GL HPV	70	50	Yes	
Iowa	GL HPV & EPA RfD	70	0	Yes	No
Kansas	EPA RfD	70	0	No	Yes
Maine	EPA RfD	70	0	Yes	Yes
Maryland	EPA RfD	30	30	Yes	
Massachusetts	½ FDA action level	70	0	Yes	
Michigan	GL HPV and FDA	70	50	Yes	
New Hampshire	EPA RfD	70	0	Yes	
New Jersey	EPA RfD	70	0	Yes	
New Mexico	N/A		0	No	Yes
North Carolina	EPA RfD	70	50	Yes	
North Dakota	N/A				
Ohio	GL HPV	30	50	No	No
Oklahoma	N/A				
Oregon	EPA RfD	70	50	Yes	Yes
Pennsylvania	GL HPV	--	50	No	No
Rhode Island	FDA		0	Yes	
South Carolina	EPA RfD		50	Yes	No
South Dakota	EPA RfD	70	50		No
Tennessee	FDA	--	0	No	Yes
Virginia	EPA RfD	30	0	Yes	
Washington	EPA RfD	30	0	Yes	Yes
Wisconsin	GL HPV	70	50	No	No

Illinois

Fish consumption advisories in Illinois are issued by the Illinois Fish Contaminant Monitoring Program (IFCMP), which consists of staff from the Illinois Emergency Management Agency, the

Illinois Environmental Protection Agency, and the Departments of Agriculture, Natural Resources, and Public Health. IFCMP has been analyzing fish from Illinois water bodies since 1974.

As part of the IFCMP, fish samples are collected at river basin stations and analyzed for 14 different chemical contaminants. These samples are collected each year from approximately 50 stations through Illinois' rivers and streams. In order for Illinois to issue a consumption advisory, samples must be collected two years in a row to add, change, or remove a consumption advisory from the published list.

Indiana

The state of Indiana follows the Protocol's guidelines for major assumptions regarding PCB consumption and human health effects. Indiana issues advisories when contaminant levels in fish fillets exceed the HPV of 0.05 μg per kilogram of bodyweight per day over the course of a lifetime. To accommodate variations in body weight as they related to meal size, Indiana recommends that consumers subtract or add one ounce of fish for every 20 pounds of body weight in order to scale proportionally to the consumption rate advice (IDEM 2006). In addition, Indiana follows the 50% contaminant reduction assumption per the Protocol, but also uses a 35% reduction factor for samples that are analyzed as skin-off fillets (such as catfish).

The Indiana Interagency Fish Consumption Advisory Workgroup is responsible for deciding on consumption advisories. This workgroup consists of participants from the Indiana Department of Environmental Management, the Indiana State Department of Health (ISDH) and the Indiana Department of Natural Resources. This working group has been responsible for assessing consumption advisories in the state since the early 1970s. The Consumption Advisory booklet is issued annually through the Indiana State Department of Health.

Minnesota

Three different agencies oversee Minnesota's FCA process: the Minnesota Pollution Control Agency (MPCA), the Department of Natural Resources (MDNR), and the Department of Health (MDH). The MPCA is responsible for developing state water standards and monitoring water quality, while the MDNR enforces fishing regulations and assists with analyzing fish for contaminants. The MDH develops guidelines for safe fish consumption and publishes state-wide and site-specific advisories for both the general population and sensitive subpopulations (children and women of child-bearing age).

Minnesota also provides advice on consumption amounts. The state also relies on the Protocol's average body weight for issuing the advisory, the state's advisory suggests reducing for amount for those lighter than 70 kg (or 150 lbs) or increasing for those who weigh more.

New York

In New York State, FCAs are based on contaminant information gathered by the Department of Environmental Conservation (NYDEC). In most years, NYDEC collects fish from water bodies around the state. The agencies sampling approach focuses on water bodies with known or suspected contamination, water bodies susceptible to mercury contamination, popular fishing waters and waters where trends in fish contamination are being monitored. After the contaminant data are analyzed, the New York Department of Health (NYDOH) reviews the contaminant results for fish and game to determine if an advisory should be issued or revised for a given water body or fish or game species. When reviewing the data, NYDOH compares testing data to federal marketplace standards (when available) for a contaminant and considers other factors such as potential human exposures and health risks; location, type and number of samples. For sensitive groups, NYDOH issues "do not eat" advisories for entire water bodies when fish are sampled with contaminant levels of concern[3].

Ohio

The state of Ohio adopted the Protocol's guidelines for issuing FCAs in 1994. Consistent with the Protocol's approach, Ohio uses five consumption advisory categories and issues both statewide and water-body specific advisories. The advisory process is handled by the Ohio Environmental Protection Agency, Division of Surface Water (ODSW), and the Ohio Department of Health (ODH). The ODSW is responsible for calculating the fish consumption risk assessment while the ODH is responsible for releasing this information to the public.

Beginning in January 2003, all fish consumption advisory calculations for all jurisdictional waters use the Protocol's HPV of 0.22 mg Total PCBs in raw fish for "eat no more than one meal per week upper limit."

In 2007, Ohio modified its fish consumption advisory calculations. Prior to this date, Ohio relied on the FDA's PCB action level of 2.0 ppm when calculating contaminant concentrations exceeded this level[4]. Ohio made this change given FDA's position on the inappropriateness of action levels for recreational fish.

Ohio uses fillet composite samples of most sport fish and analyzes them as scaled, skin-on samples (although per the Protocol, catfish and bullhead composite fillets are analyzed with skin off). Fat is not trimmed and the percent lipid is analyzed and reported for all fish tissue samples. All fillet composites are based on samples from 2-5 fish of the same species, with the smallest fish in the composite being within 10% of the total length of the largest fish in the sample.

Pennsylvania

The state of Pennsylvania has been monitoring contaminant levels in fish since 1979. The process became formalized in the mid-1980s, when three separate state agencies signed an agreement to participate in the state advisory process. A fourth agency, the Department of

---

[3] The impetus for this more conservative approach assumes that if sampled fish have a given level of body burden of PCBs, methylmercury, etc., that other fish in the water are likely also affected.

[4] At this time, ODH made a second change to its FCA process for mercury, by adopting the April 2006 Mercury Addendum to the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory, which added a "two meals per week" category to those originally proposed in the Protocol, but only for mercury.

Agriculture (PADOA), was later added to the program. Today, the Department of Environmental Protection (PADEP), the Department of Health (PADOH), the Pennsylvania Fish and Boat Commission (PFBC) and the PADOA participate in a two-tiered system for advisory decisions and issuance. A Fish Consumption Advisory Policy Workgroup oversees the program and makes management decisions, with activities coordinated through the Governors Policy Office. There is also a Fish Consumption Advisory Technical Workgroup, which coordinates the routine program activities through sampling site identification and provides recommendations to the policy workgroup for advisory issuance or removal.

For FCAs related to PCBs, Pennsylvania follows the Uniform Protocol's trigger levels and consumption rate categories. For its advisory process, Pennsylvania normally collects 10 scaled, skin-on fillets from a composite of 5 individuals of the target species (although channel catfish and bullhead samples are skinless fillets). Fish used in the composite samples are of the same approximate size, with the smallest being at least 75% of the length of the largest.

Once contaminant levels in fish have been assessed, DEP staff evaluates the data in advance of a meeting of the Interagency Fish Consumption Advisory Technical Work Group. The data are compared with trigger levels to assess the need for an advisory for particular water bodies or water segments. Once advisories are set, the official advisory is sent to the PFBC to be included in fishing regulations booklets for the next calendar year. Public press releases are then issued in late Fall to inform the public of these advisories.

In contrast to other states, Pennsylvania does not issue separate advisories for sensitive subpopulations. The state has, however, issued a general statewide advisory for recreationally caught sport fish – advising all of the population to eat no more than one half-pound meal per week of sport fish taken from the state's waterways.

Wisconsin

The state of Wisconsin uses a complex fish consumption advisory system for waters containing PCBs. The advisories vary by species and size and have four severity levels, ranging from ''eat no more than one meal a week'' to ''do not eat.'' In general, Wisconsin has several statewide advisories for inland lakes.

Non-Great Lakes States

California

The state of California has recently changed its method for evaluating human health risks associated with consumption of contaminated fish, and has identified two different goals with respect to fish consumption advice. The first are fish contaminant goals (FCGs), which are estimates of contaminant levels in fish that pose no significant health risk to individuals consuming sport fish at a standard consumption rate of eight ounces per week (32 g/day), prior to cooking, over a lifetime. These FCGs were developed by the Office of Environmental Health Hazard Assessment (OEHHA) to assist other agencies, which want to use fish tissue contamination as one end goal in developing pollution mitigation or elimination. OEHHA developed these goals in order to prevent consumers from being exposed to more than the daily RfD for non-carcinogens or to a risk level greater than 1×10^{-6} for carcinogens (i.e., not more than one additional cancer case in a population of 1,000,000 people consuming fish at the given consumption rate over a lifetime).

The OEHHA has also developed advisory tissue levels (ATLs), which are exposure levels that are meant to pose no significant individual health risks but balanced with an explicit recognition that fish consumption confers health benefits. OEHHA has calculated ATLs using the same general formulas as those used to calculate FCGs, with some adjustments to incorporate the benefits of fish consumption. This is accomplished by decreasing (or offsetting) the mortality and/or cancer risk(s) associated with eating contaminated fish. For ATLs, OEHHA provides consumption advice that prevents consumers from being exposed to more than the average daily reference dose for non-carcinogens or to a risk level greater than 1×10^{-4} for carcinogens (not more than one additional cancer case in a population of 10,000 people consuming fish at the given consumption rate over a lifetime).

The non-cancer and cancer critical values used to evaluate PCBs in fish for the development of consumption guidelines will be 2×10^{-5} mg/kg-day and 2.0 (mg/kg-day)$^{-1}$, respectively.

In developing these guidelines, OEHHA makes many standard assumptions regarding fish consumption including an average adult weight of 70 kg and a fish serving size of 8 oz per week (32 g/day)[5]. The OEHHA also assumed an exposure duration averaging time of 30 years over a 70 year lifespan (based on the 95th percentile of U.S. residence time). Also, for the FCGs, contaminant loss through cooking is assumed to be 30% (based on Anderson et al. 1993; Zabik et al. 1996; Santerre 2000 and others). Finally, OEHHA has developed these advisories for fish consumed with skin-off; however, site-specific data from sites including the San Francisco Bay indicate that a considerable number of fishers cook and consume their fish with the skin on (SFEI 2000[6]). OEHHA has indicated that this may affect how they issue future advisories, as the agency may consider using skin-on fillet data in issuing their advisories.

Washington

In Washington State, the Department of Health (WADOH) is responsible for overseeing fish consumption advisories. In evaluating risks, WADOH assesses fish consumption rates for anglers, tribal members, additional high-consuming populations, and other citizens. To do this, the agency tries to use both the mean and 90th (or 95th) percentile population-specific consumption rates. In addition, for those sites in which fish have body burdens of more than one chemical, WADOH will calculate meal limits based on exposure to more than one chemical to

[5] In the California OEHHA report, the more recent average US weight for females is 75 kg and for males is 87 kg (see Ogden et al. 2004), which is higher than when the original 70 kg average weight was introduced. In terms of serving sizes, the Institute of Medicine and American Hearth Association considers one serving of fish to be 3 oz and that National Health and Nutrition Examination Study indicate that those who eat fish consume approximately 3 oz/day. Although CA considered changing this, responses from focus groups interviewed by the CA Dept Public Health indicate that sport fishers typically consume larger portion size than the general public.

[6] In a study of San Francisco Bay anglers, it was found that up to 30% of fishers (predominately African Americans and Asians) were consuming their fish with the skin on.

account for additive toxicological effects (Selecky et al. 2006). For non-cancer risks, WADOH calculates the estimated dose for each contaminant and compares this to USEPA's oral reference dose. A hazard quotient approach[7] is then used to determine when consumption of a specified population may be exceeding levels protective of human health.

The fish consumption advisory process in the state of Washington has recently updated their FCA process to more specifically account for the consumption habits of sustenance consumers, primarily tribal consumers. Thus the WA Department of Ecology now considers fish consumption rates for Native American tribal populations and other high exposure groups when "developing site-specific cleanup levels under the MTCA and the Sediment Management Standards (SMS) rules."

Of potential interest: USEPA exposure guidance materials include exposure parameters based on tribal exposure scenarios. The USEPA Exposure Factor Handbook recommends, for tribal exposure scenarios, an average ingestion rate of 70 g/day and a 95th percentile ingestion rate of 170 g/day. 5 For children, the USEPA Child-Specific Exposure Factors Handbook identifies weighted average (21 g/day), 90th percentile (60 g/day) and 95th percentile (78 g/day) values, respectively, for the tribal exposure scenario.

Other Regional FCA Management Efforts

Upper Mississippi River management

States that border the upper Mississippi River (UMR) basin are also working on ways to standardize resource management in the river, including better coordination on FCAs. Similar to the Great Lakes region prior to the adoption of the Protocol, the UMR consists of different states that monitor different fish species using a range of different techniques to assess human health risks. This has resulted in interstate variations in FCAs for similar segments of the river and has led to public confusion regarding guidelines for safe fish consumption along the river.

Interstate Workgroup for Atlantic Coastal Advisories

In 2000, a working group was formed to evaluate variations in state protocols for issuing PCB FCAs for recreationally caught striped bass and bluefish (see Eastern Coastal Advisory Workgroup 2008). This effort brought together 13 states with striped bass and bluefish fisheries and evaluated the potential health risks associated with PCB in these two species and assessed the potential for a coordinated health advisory process. To this end, four subgroups assessed the state of the science in the following areas: 1) data on PCB concentrations in striped bass and bluefish along the Atlantic coast; 2) biology and ecology of Atlantic coast striped bass and bluefish; 3) recent toxicological information on the health effects of PCBs; and 4) consumption advisory methods and protocols for bluefish and striped bass for all of the Atlantic coastal states.

[7] The equation for this relationship is: Hazard quotient = Estimated dose (mg/kg - day)/RfD (mg/kg - day)

Canadian Approach to FCAs – Province of Ontario[8]

The province of Ontario issues FCAs biennially[9]. The Ministry of Natural Resources and the Ministry of the Environment collect the fish, which are analyzed for a range of contaminants by a Ministry of the Environment Lab. The results from this contaminant analysis are then used to develop the advisory tables for the FCA guide. The advisories are based on health protection guidelines that have been developed by the Food Directorate of Health Canada. Since 2005, FCAs have been provided separately for the general population and for sensitive population of women of child-bearing age and children under 15.

The consumption advice is based on the assumptions of an average meal size of 227 grams (8 oz) and an average adult weight of 70 kg (154 lbs). Contaminant samples are taken from skinless and boneless dorsal fillets. When possible, the FCAs are based on 10 or more fish with a range of lengths and weights from each species of interest.

The sampling schedule for sites is as follows: areas with elevated contaminant levels or where contaminant levels have changed significantly are sampled ever one to three years; areas that show no signs of substantial changes in contaminant levels, but are frequented by anglers, are retested every 5 years; and all other areas, which are usually remote locations, are retested approximately every 10-15 years.

For PCBs, Food Directorate of Health Canada has 2 guidelines, one based on total PCBs present in a sample and the other based on a select few PCBs with toxicological properties similar to dioxins. The ministry derives two sets of consumption restriction values from Health Canada's two guidelines for PCBs and adopts the lower value. Thus, consumption restrictions for total PCBs begin at 0.105 ppm with complete restriction advised for levels above 0.211 ppm for sensitive population and 0.844 ppm for the general population.

There are 12 forms of PCBs that are "dioxin-like" PCBs and possess toxicological properties similar to toxic forms of dioxins. THe Ontario Ministry of the Environment monitors the 12 dioxin-like PCBs in sport fish. These are then multiplied by an equivalency factor to convert it to a number referred to as a toxic equivalent, which represents its toxicity relative to the most toxic form, 2,3,7,8-TCDD. Consumption restrictions for sport fish begin at levels of 2.7 ppt, with a total restriction advised for levels above 5.4 and 21.6 ppt for toxicity equivalents TCDD for the sensitive and general population, respectively.

In 2007-2008 guide, there was a change in toxic equivalency factors for dioxins, based on recommendations of an expert panel of the WHO. Toxicity of dioxin-like-compounds were found to be less than originally estimated for some of the compounds, with the results that overall dioxin toxicity in fish is approximately 20% less than previously estimated.

---

[8] Additional information on the Ontario Province approach for setting FCAs is further covered in Appendix D: Environmental Justice and Fish Consumption Advisories on the Detroit River Area of Concern (Kalkirtz et al. 2008).

[9] In years in which the advisory is not normally published, major changes in consumption advice are made public by the Ministry of the Environment through the Public Information Centre (and on the Ministry website, and via media notices).

Summary and Conclusions

As is demonstrated in the above section, states use a variety of methods in establishing FCAs within their jurisdictional waters. In most cases, the overall methodology for PCBs has become more uniform, since the USEPA issued specific guidelines in 2000. Some of the most important areas of inter-state variability are how states address sensitive subpopulations and the tissue trigger level used in considering human health endpoints. Of equal importance to the FCA process in Michigan, are the differences in how the Canadian province of Ontario issues these advisories. These differences, in particular, may have tangible effects for human health and may affect the perception of the safety of fish consumption on the different sides of the international border.

Summary of the Great Lakes States

Prior the USEPA guidelines, the Great Lakes states had already completed their own initiative to streamline, standardize, and coordinate states approaches to FCAs for PCBs. This document, the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory, was a hallmark effort at coordinating regional efforts related to contaminated fish. Importantly, the Protocol adopted a Health Protective Value for PCBs of 0.05 μg/kg/day. This value is now used in some capacity by all of the Great Lakes' states in setting their advisories, and has even been adopted by other states.

While most of the Great Lakes' states closely follow the Protocol's advice for advisories, there are some important variations. These variations are highlighted primarily because they can provide important insight into current FCA protocols. One of the most important variances concerns how advisories address sensitive subpopulations. The majority of Great Lakes' states have modified their consumption advice for women of childbearing age and children under the age of 15. For these groups, most of the states issue meal advice based on a more conservative effect level (in this case, the HPV). Another approach is that adopted by the state of New York, which advises that "infants, children under the age of 15 and women of childbearing age" not eat any fish from specific waterbodies listed in the advisory. Finally, the state of Pennsylvania does not target consumption advice towards sensitive subgroups, but instead have issued a statewide general meal advice for all populations (do not eat more than one meal per week of recreationally caught fish from the state's waterways).

State-to-State Comparisons

Since the Protocol was finished in 1993, several other states have looked at similar coordination efforts for FCAs. One important and recent example comes from the coastal Atlantic states. This working group (the Eastern Coastal Advisory Workgroup) evaluated several issues related to PCB-driven fish consumption advisories. Two of these have potentially important implications for Michigan's FCA process. The first is that the workgroup found that most Atlantic states (although not all) felt that for striped bass and bluefish "new evidence regarding neurodevelopmental effects in children are compelling enough to recommend no consumption for sensitive populations.[10]" This recommendation came from a sub-workgroup's assessment of

[10] The workgroup based their conclusions on the Oswego study (Stewart et al. 2000), in which the concentrations

more recent longitudinal prospective epidemiological studies that were published in the past 20 years (since 1988).

Of note, this workgroup reached the following conclusion regarding the state of science of PCB toxicity:

> The current toxicological bases for developing advisories based on PCBs consist of FDA's tolerance for commercial fish, USEPA's Reference Dose, ATSDR's Minimum Risk Level, or the Great Lakes Health Protection Value. All these values are outdated and do not take into account the effects observed in the several longitudinal prospective epidemiological studies published in the last 20 years[11].

Another finding of note concerns dioxin-like PCBs. The workgroup found that two states (Delaware and Maine) now explicitly recognize that some PCBs congeners act as dioxin-like compounds (referred to as coplanar PCBs or dioxin-like PCBs). In this method, dioxin-like PCBs are subtracted from total PCBs and, using a TEF scheme based on the World Health Organization's 2005 guidelines, combined with dioxin measurements to develop risk based decision criteria.

In addition to these trends, other states are investigating additional ways to improve their FCA process. One general trend is that states are looking more closely at their high risk subgroups and tailoring risk messages to work to decrease exposure in these consumers. The state of Alaska, for example, is using human biomonitoring of Inuit groups in order to optimize fish consumption advice (Arnold et al. 2005). By assessing existing body burdens in these high risk groups, risk assessors can better gauge the potential health risks versus benefits of consuming certain fish species.

---

found to cause deleterious effects in children are close to the body burdens of PCBs in the U.S. population, indicating there is little remaining margin of safety for women who may become pregnant.

[11] Eastern Coastal Working Group, 2008, page 168.

References

Anderson, H.A., J.F. Amrhein, P. Shubat, J. Hesse, . 1993. Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory. Great Lakes Fish Advisory Task Force. Protocol Drafting Committee.

Arnold, SM, Lynn, TV, Verbrugge, LA, and Middaugh JP. 2005. Human biomonitoring to optimize fish consumption advice: Reducing uncertainty when evaluating benefits and risks. American Journal of Public Health 95(3): 393- 397.

Bohr, J. and J. Zbytowski. 2009. Michigan Fish Contaminant Monitoring Program Report: 2008 Annual Report. MDEQ-WB Report #MI/DEQ/WB-09/044.

Cunningham, PA, JM McCarthy, and D Zeitlin. 1990. Results of the 1989 Census of State Fish Consumption Advisory Programs. U.S. Environmental Protection Agency, Office of Water Regulations and Standards, Washington DC.

DEP. Fish Tissue Sampling and Assessment Protocol. Pennsylvania Department of Environmental Protection.

Eastern Coastal Advisory Workgroup. 2008. Report of the Interstate Workgroup on Evaluating Atlantic Costal Advisories for Recreationally Caught Striped Bass and Bluefish Based on PCBs. October 1, 2008.

IDEM. 2006. IDEM's Surface Water Quality Assessment Program. Fish Consumption Risk Assessment. Indiana Department of Environmental Management, Office of Water Quality. Fact Sheet A-024-OWQ-A-BS-06-0-R2, Rev. September 2006.

Klasing and Broadburg 2008. Development of fish contaminant goals and advisory tissue levels for common contaminants in California sport fish: Chlordane, DDTs, dieldrin, methylmercury, PCBs, selenium, and toxaphene. California Office of Health Hazard Assessment (OEHHA).

Santerre, C.R.. 2000. Chlordane and toxaphene residues following cooking of treated channel catfish fillets. Journal of Food Protection 63:763-767.

Selecky, MC, J. Hardy, and G. Palcisko. 2006. Human Health Evaluation of Contaminants in Puget Sound Fish. October 2006. Washington Department of Health, Division of Environmental Health. Publication # - 334 – 104.

SFEI. 2000. San Francisco Bay Seafood Consumption Study. San Francisco Estuary Institute, Richmond, CA.

Stewart P, Reihman J, Lonky E, Darvill T, Pagano J. 2000. Prenatal PCB exposure and neonatal behavioral assessment scale (NBAS) performance. Neurotoxicology and Teratology Jan-Feb 22:21-9

U.S. EPA. 1997. Exposure Factors Handbook. Washington: US. Environmental Protection Agency, Office of Research and Development, 1997

U.S. EPA. 2000. Guidance for Assessing Chemical Data for Use in Fish Advisories, Volume 2, Risk Assessment and Fish Consumption Limits. EPA 823-13-00-008. U.S. EPA Office of Water. Washington, D.C.

U.S. EPA. 2003. Guidance for 2004 Assessment, Listing and Reporting Requirements Pursuant to Sections 303(d) and 305(b) of the Clean Water Act. TMDL-01-03. U.S. EPA. Washington, DC.

U.S. EPA (U.S. Environmental Protection Agency). 2007. EPA Fact Sheet: 2005/2006 National Listing of Fish Advisories. Available: http://www.epa.gov/waterscience/fish/advisories/2006/tech.pdf [accessed 26 July 2007].

Zabik, ME, Booren, A, Zabik, MJ, Welch, R, Humphrey, H. 1996. Pesticide residues, PCBs, and PAHs in baked, charbroiled, salt boiled and smoked Great Lakes lake trout. Food Chemistry 55:231-239.Table 1. PCB concentrations in fish that trigger consumption advisories for fish, as outlined in the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory (Anderson et al. 1993).

CHAPTER 4:

ASSESSING UNCERTAINTY IN FISH CONSUMPTION ADVISORY DATA FOR THE DETROIT RIVER: APPLICATION OF A PROBABILISTIC APPROACH

Abstract

The fish consumption advisory process is characterized by several sources of uncertainty: managers and regulators must combine the best available science on human health effects with information on contaminant concentration in recreational fish and risk factors of a general public to decide when and how to issue an advisory. Because several of the parameters associated with this process are unknown or not fully resolved, there are many ways in which uncertainty propagates through the process. To better assess the nature of uncertainty in the data used to develop consumption advisories, we reviewed relevant literature and developed a probabilistic model to assess the potential impact of uncertainty in key parameters related to these advisories. Available information for polychlorinated biphenyls (PCBs) in fish indicates high variability in some fish populations, including cases of sex-based differences in contaminant levels. PCB levels were also found to vary seasonally in some fish species, indicating a potential need for more consistent field sampling protocols. Available data on human consumption rates suggest that certain subpopulations of the general public vary in both the quantity of sport fish they consume and the way in which they prepare their meals. These variations in consumption habits, in particular, may serve to increase the chance that some individuals are exposed to concentrations exceeding human health endpoints. A simple probabilistic Monte Carlo model was developed to evaluate the effect of data uncertainty on potential human consumption rates. The results of the simulations indicate that variations in fish PCB concentrations and the ingestion rate of contaminated fish strongly affect the estimated chronic daily intake for PCBs. The main implications of these results for Detroit River fish consumption advisories are 1) to improve the rigor of sampling effort for fish used to derive consumption advisories (both in terms of temporal consistency and quantity of samples), 2) to improve information about the consumption habits of high risk groups in the Detroit River, and 3) to target outreach efforts to those populations with the greatest level of risk and exposure – namely minority subsistence fisherpersons, women of childbearing age, and children under the age of 15. These outreach efforts should be developed in the context of the well-known health benefits of eating fish, which are known to be a good source of protein and omega-3 fatty acids.

Introduction

Fish consumption advisories (FCAs), like all risk-based decision processes; rely on the best available science to develop guidelines to protect the health of a diverse population. In general, the consumption advisory process addresses uncertainty by using conservative estimates for risk factors, primarily in the estimation of human health risks. As with other risk-based management decisions, uncertainty is a key, but sometimes overlooked, part of the process. These uncertainties are inherent to many elements of FCAs, including the estimation of no-adverseobservable effect levels, the derivation of reference doses, assumptions regarding the characteristics of the exposed population, and knowledge about variability in exposure rates.

Many of the uncertainties associated with the human health effects of PCBs are addressed through the application of safety factors. These factors are used to counterbalance a lack of information about contaminant effects in humans, since most dose-response data on health risks are derived from non-primate animals. The US Environmental Protection Agency, for example, uses both uncertainty factors and modifying factors to protect human health given a range of unknowns in how the data are derived (US EPA 2000). These factors vary depending on the type of available toxicity studies: for example, a 10-fold uncertainty factor is often used when only subchronic studies (versus chronic exposure studies) are available. Modifying factors, in contrast, are used to cover a wider range of circumstances, including differences in the absorption rates between study species and humans or differences in species-specific tolerances to a given chemical.

There are additional sources of uncertainty that extend beyond human health that are important to consumption advisories. These include the limited size range of fish from which advisories are based, the limited information on variability in PCB concentrations in the actual field populations, seasonal differences in fish contaminant levels, and potential differences between concentrations in raw fish versus consumed fish (subject to freezing and cooking).

An important component of this integrated assessment was to better characterize the range of uncertainties associated with the consumption advisory process. There were two main objectives associated with this original part of the effort:

1) To evaluate current trigger-levels used in issuing fish consumption advisories;

2) To assess options for a toxicologically-defensible and more probabilistic approach for these advisories including assessing whether toxicity equivalency factors (TEFs) improve the consumption advisory process.

As part of the integrated assessment framework used in this study, we focused on the type of uncertainty associated with consumption advisories for PCB. This review assesses the use of these trigger levels and the state of science regarding probabilistic approaches that may be applied in issuing FCAs. In doing so, it draws from other sections of this final report.

Tissue Trigger Analysis

Use of tissue trigger levels in Michigan

Fish consumption advisories are usually issued when contaminant levels in fish exceed a certain threshold (i.e., the tissue trigger level). In the Great Lakes region, most states use advice contained in the Protocol for a Uniform Great Lakes Sport Consumption Advisory (i.e., Protocol; Anderson et al. 1993). This protocol applied a weight-of-evidence approach to identify a health protection value (HPV) for sensitive subpopulations of 0.05 μg total PCBs/kg/day. Using a range of assumptions regarding cooking methods, consumption rates, and exposure duration, the HPV was then used to derive consumption guidelines based on the measured wet weight of PCBs in fish tissue. These ranges are provided in Table 1.

The Michigan Department of Community Health (MDCH) establishes, modifies, and removes sport fish consumption advisories. Currently the state uses the HPV for sensitive subgroups, as prescribed in the Protocol. In contrast, the concentrations used in issuing advisories for the general public derive from the US Food and Drug Administration's action level for PCBs of 2.0 ppm (mg/kg).[12] In terms of the latter, when concentrations in more than 10% of the samples from a particular length of a given fish species exceed 2.0 ppm, MDCH advises the general public to eat no more than 1 meal per week. When concentrations in 50% of more of the samples fish of a given length range exceed this value, MDCH advises the general public against eating any of the fish from that location.

Both advisories are based on fish collected from various locations throughout the state. In most cases, fish length and associated consumption advice are based on sampling results from at least 10 individuals of a given species.

Table 1. PCB concentrations in fish that trigger consumption advisories for fish, as outlined in the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory (Anderson et al. 1993).

Group	**PCB conc. (ppm)†**
Unrestricted consumption	0 – 0.5
1 meal/week	0.06 – 0.2
1 meal/month	0.21 – 1.0
6 meals/year	1.1 – 1.9
No consumption	> 1.9

†In parts-per-million (mg/kg) wet weight and for raw skin-on fish fillets.

Based on fish collected throughout state waters in 2008, total PCB concentrations for women and children[13] exceeded a tissue trigger level in 41% of samples (n=275) and for 88% of all locations (n=17). For the general public, total PCB concentrations were greater than or equal to the trigger level in 0.4% of the samples (n=275) and for 6% (n=17) of the locations.

Sampling intensity for FCA monitoring

Each year, the Michigan Department of Natural Resources (MDNR) collects fish from water bodies throughout the state. In 2007, MDNR collected samples of 361 fish collected from 30 locations, in 2006, they collected 150 fish from 12 locations, and in 2003 they collected 4 fish from 1 location. For the state, a total of 15 species of fish were analyzed as edible portion

[12] Although Michigan still relies on US FDA action levels in issuing consumption advisories for the general public, both the US FDA and the US EPA now advise states against this practice.

[13] In the state of Michigan, women and children under the age of 15 are considered sensitive subpopulations, and consequently a lower tissue trigger level is used to better insure protection of health.

samples for issuing the 2008 report[14].

In the Detroit River, the most recent fish collections were in 2004, in which 8 individuals of carp and 10 individuals each of freshwater drum, redhorse sucker, and yellow perch were collected by the MDNR for analysis. The PCB concentrations in these fish (based on congeners) were used in developing the advisories for this site in this and subsequent years.

Given the limited ability to collect and analyze a wider range of fish, there are many important uncertainties inherent to the FCA process including a limited size range of fish from which to issue the FCAs and unknown variability in contaminant concentration in the actual fish population.

Key assumptions in FCA models

There are several assumptions that are integral to the advisory process including an assessment of contaminant concentrations associated with human health effects, an assessment of exposure potential (including fish consumption rate, frequency of exposure, duration of exposure, and consumer body weight), and an assessment of contamination level in the fish population of interest.

In terms of human health effects, the USEPA uses a risk-based approach to estimate effect-level contaminant concentrations. The USEPA does this by calculating a reference dose (RfD), which is an estimate of a daily exposure that is likely to be without appreciable risk of deleterious effects during a lifetime (USEPA 2000). The RfD is calculated by determining a no-observed-adverse-effect level (NOAEL) or a lowest-observed-adverse-effect level (LOAEL) from the published literature. Depending on the availability of the studies, safety factors are then applied to take into account a range of uncertainties, including extrapolations from non-human models to humans, from data gaps and other factors. These safety factors can range from 1 to 10,000. For PCBs, the EPA uses for example an RFD of 0.00002 mg/kg/day for Aroclor 1254, the most commonly cited reference compound in establishing PCB FCAs.

In terms of the exposure assessment, the US EPA recommends assuming an average consumption rate of 227 grams (or 8 ounces) per day, an exposure duration of 30 years, and a generic consumer body weight of 70 kilograms (about 154 pounds).

For the consumption rate, it should be noted that people are assumed to eat fish in direct proportion to their body weight. The fish consumption advisories established using these meal consumption limits assume that the portion size of fish is proportional to a person's body weight. So, for instance, a child weighing 24-32 kilograms (51-70 pounds) is advised to eat an 85 gram (3 ounce) portion of fish at a meal; however, this relationship is not always linear, and children often consume food at a higher proportional rate than adults. Thus the RfD is the same for children and adults, although children are known to consume more food on a per weight basis.

Toxic equivalency factors

[14] Samples for the edible portion sampling program in Michigan are targeted toward sites of known or suspected contamination, sites popular with sport anglers, and sites with public access.

Some PCBs have a planar conformation and activate the aryl hydrocarbon (Ah) receptor. These PCBs are thought to share a common mode of toxic action with 2,3,7,8-tetrachlorodibenzo-p-dioxin (2,3,7,8,-TCDD). The toxicity of coplanar PCBs is converted into TCDD equivalents by using a toxicity equivalency quotient that is based on an assumption of a common mode of action (van den Berg et al. 1998). For coplanar PCBs, the cancer risk is estimated by multiplying total PCB TEQs from fish consumption by a TCDD cancer slope factor[15]. This approach, however, does not account for the toxicity of some of the more abundant coplanar congeners.

In 2008, Michigan began measuring and calculating the concentrations of dioxin-like PCB congeners in fish samples. Total 2,3,7,8-TCDD TEQs are calculated using the 2005 World Health Organization's factors (Van den Berg et al. 2006). The concentrations of individual dioxin, dibenzofuran, and dioxin-like PCB congeners in a fish sample are then multiplied by a toxic equivalency factor and the resulting products summed to calculate a 2,3,7,8-TCDD TEQ concentration. Any individual congener concentration that is less than the detection level were assigned a value of 0 for the purpose of calculating the dioxin TEQ. To be consistent with past calculations, the dioxin-like PCBs are not included in the calculation of TEQ for the whole fish trend samples.

Methods

Standard deviation estimates of PCB variability in freshwater fish

A literature review was conducted to evaluate the potential range in PCB concentrations in freshwater fish and to assess the drivers of these variations. Keyword searches using "fish and PCB" and "fish and tissue and PCB" and "fish and tissue and PCB and analytical." Additional details about the methods and results of this literature review are detailed in an earlier portion of the report. Resulting publications were then reviewed for relevance to this effort. After appropriate publications were identified, the data related to variations in PCB concentrations in populations of fish were used to derive the distributions for the Monte Carlo analysis.

Monte Carlo model for fish PCBs

In order to assess the potential impact of variation in contaminant concentrations in fish on consumption risks associated with PCBs, an equation for chronic daily intake was employed. This is based on the chronic daily intake as specified in the USEPA's Risk Assessment Guidance for Superfund sites. It helps establish the potential full range and variability in exposure of a given population and has been used to assess the variability in human health risks associated with consumption of contaminated fish (see Harris and Jones 2006). Chronic daily intake of PCBs can be expressed as:

$$CDI = C \times IR \times FI \times ED \times EF/BW \times AT$$

where CDI is in mg/kg d, C is the concentration of PCB in tissue (mg/kg), IR is the ingestion rate (kg/d or kg/meal), FI is the fraction ingested from the contaminated source, ED is the exposure

[15] AhR activation by environmental chemicals such as dioxin are known to cause immune, reproductive, and neurotoxicity; more recent data now also implicate AhR activation in cancer progression.

duration (yr), EF is the exposure frequency (d/yr or meals/yr), BW is the body weight (kg) and AT is the averaging time (d).

A Monte Carlo simulation was developed using a range of parameter estimates. The simulations were run with point estimates (as are currently used for the FCA process) and using a Monte Carlo sampling approach. In terms of the latter, Crystal Ball was linked with an Excel™ database to allow for variations in PCB concentrations in fish tissue (and several other parameters, as deemed necessary).

For sport fish tissue concentrations, we used lognormal distributions of measured PCB concentrations in walleye and carp collected from the Detroit River. The PCB concentration data were fit to a lognormal distribution, based on a best fit of some of the existing data sets, and is consistent with observations from other studies (e.g., see Rypel et al. 2007). We separated out data on Aroclor from that on PCB congeners and ran the analysis separately for these two analytical scenarios. A continuous uniform distribution model was used for ingestion rate, exposure duration, exposure frequency, and averaging time. Finally, for body weight, a normal distribution was assumed.

PCB distributions in fish

Significant sex-based differences in fillet PCB concentrations have been found for channel catfish (*Ictalurus punctatus*), largemouth bass (*Micropterus salmoides*) and spotted bass (*Micropterus punctulatus*: Rypel et al. 2007). In contrast, there were no such differences for striped bass (*Morone saxatilus*), black crappie (*Pomoxis nigromaculatus*) and freshwater drum (*Aplodinotus grunniens*). This may have implications when analyzing fillet samples for FCA advisories; however, Rypel et al. 2007 note that the sexual differences reported in their study should not be considered universal and that variations in ecosystems may be an important driver of sexual differences in PCB bioaccumulation.

Results

Monte Carlo model for fish PCBs

The statistics of PCB concentrations in fish collected from the Detroit River are given in Tables 2 and 3. The two species used in the Monte Carlo model simulation were common carp (*Cyprinus carpio*) and walleye (*Sander vitreus*), both of which are currently included in the Detroit River FCAs. Data are given for concentrations of both total PCBs (Table 2) and total Aroclors (Table 3). The former is the current analytical technique used in the monitoring program, while the latter is the older method for measuring PCB concentrations. As can be seen in Table 2, data for total PCBs is limited, and based on only 8 fillet samples for carp and 6 fillet samples for walleye. The mean total PCB concentrations in carp are substantially higher than for walleye (2.956 ppm versus 0.7710 ppm, respectively). Carp demonstrate considerable variability in this small sample set, with a minimum concentration of 1.263 ppm wet weight and a maximum concentration of 6.754 ppm wet weight. Total PCB concentrations in walleye have a minimum concentration of 0.2840 ppm and a maximum concentration of 1.381 ppm.

Table 2. Total PCB concentrations (i.e., sum of the individual congeners) in the Detroit River, for edible portion fillet sampling

Species	No. of samples	Length Min	Max	Total PCBs (wet weight; ppm) Mean	Median	Min	Max	S.D.
Carp	8	46.2	67.8	2.956	2.340	1.263	6.754	1.951
Freshwater drum	10	38.2	51.2	0.4139	0.4250	0.0590	0.8890	0.2510
Walleye	6	53	67.3	0.7710	0.7650	0.2840	1.381	0.3860

Table 3. Total aroclor concentrations in the Detroit River, for edible portion fillet sampling

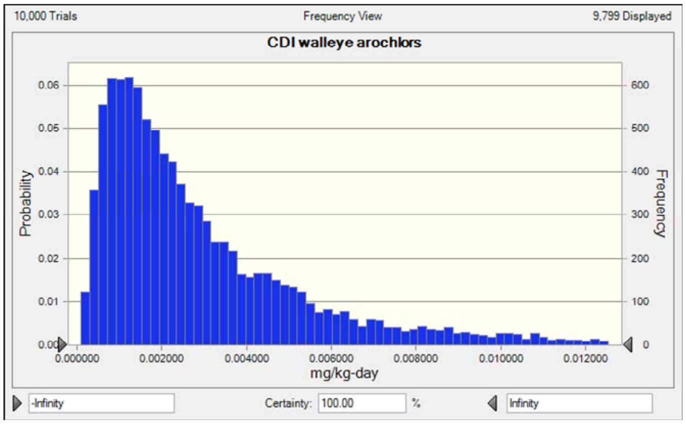
Species	No. of samples	Length Min	Max	Total PCBs (wet weight; ppm) Mean	Median	Min	Max	S.D.
Carp	40	42	69	6.273	4.110	0.7000	25.60	6.411
Walleye	30	40	66	0.4250	0.3340	0.0860	2.570	0.4470

In contrast to total PCB concentrations, fish from the Detroit River were analyzed for total Aroclor concentrations over a longer time period and therefore provide a larger sample size. The mean total aroclor concentration for carp was 6.273 ppm wet weight, with a range of 0.700 ppm to 25.60 ppm. For walleye, the mean total aroclor concentration was 0.425 ppm wet weight, with a range of 0.086 ppm to 2.570 ppm (Table 3).

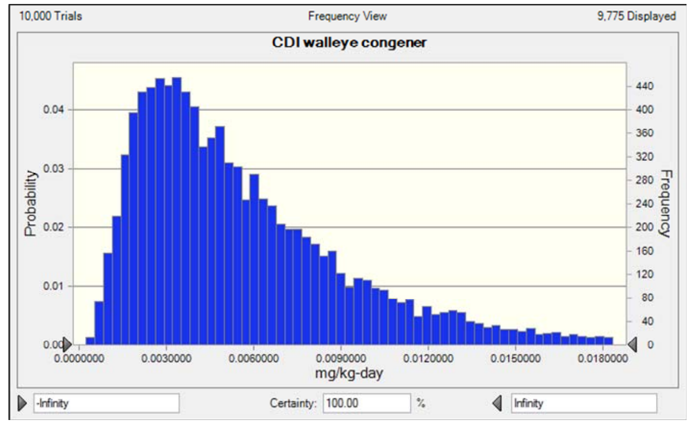
The parameters used for the Monte Carlo simulations are provided in Table 4. The resulting statistics related to the CDI are given in Table 5. These statistics are based on 10,000 simulations (i.e., using the chronic daily intake equation and sampling independently 10,000 times from the probability distributions for all parameters). Because of the larger datasets for aroclors, the software program (Crystal Ball) was able to fit a lognormal distribution curve to the existing dataset; however, for total PCBs, only the mean and standard deviation were used for fish concentration given the limited number of data points.

Using the CDI for walleye based on total aroclor concentrations, the mean forecast value was 0.003173 mg/kg-day compared to a point estimate of 0.001378 mg/kg-day. The range for the forecast value was 0.000103 mg/kg-day to 0.06283 mg/kg-day. The distribution curve for the forecast CDI is given in Figure 1a. In comparison, the forecast mean CDI value for walleye based on total PCB congeners was 0.0059017 mg/kg-day compared to a point estimate of 0.002500 mg/kg-day. The range for this scenario was 0.0003612 mg/kg-day to 0.04996 mg/kg-day. The distribution curve for the forecast CDI is given in Figure 1b.

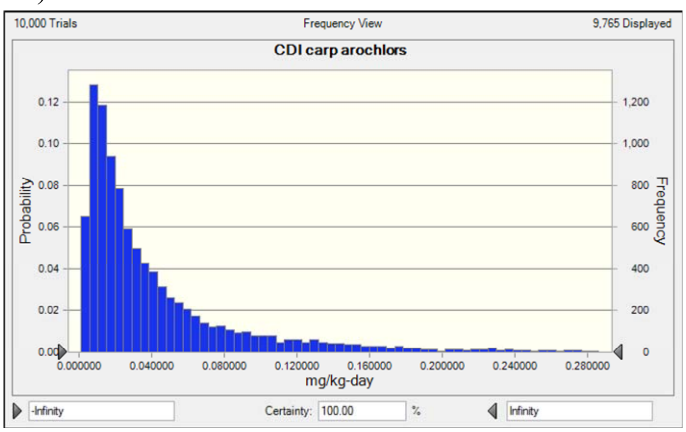
a)



b)



c)



d)

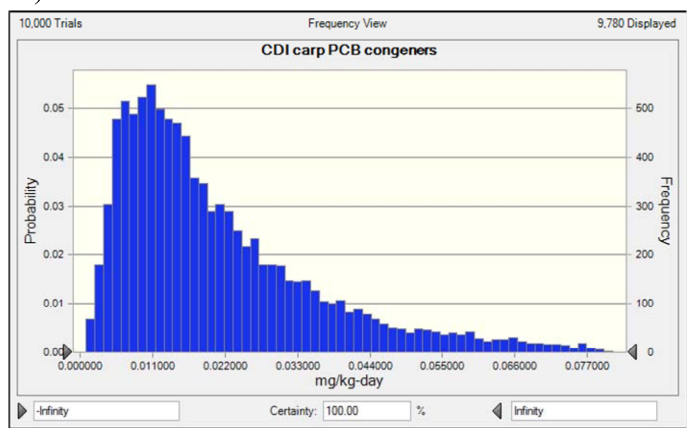


Figure 1. a) CDI walleye aroclors; b) CDI walleye congeners; c) CDI carp aroclors; and d) CDI carp congeners.

For carp, the forecast CDI value based on total aroclors was 0.05160 mg/kg-day compared to a point estimate of 0.02211 mg/kg-day. The range for the forecast value was 0.0009960 mg/kg-day to 1.495 mg/kg-day and the distribution curve for the CDI forecasts is given in Figure 1c. In comparison, for total PCB congeners in carp, the forecast CDI was 0.02278 mg/kg-day compared to a point estimate of 0.009586 mg/kg-day. The range for the former (forecast value) was 0.0009190 mg/kg-day to 0.3087 mg/kg-day. The distribution curve for this scenario is provided in Figure 1d.

Table 4. Parameters used for the chronic daily intake equation used in the Monte Carlo simulations related to fish consumption advisories in the Detroit River.

Parameter	**Value**	**Unit**	**Comments**
Mean fish concentration (C)	See Table 3	mg/kg	For Aroclors, from MNDR database
Mean fish concentration (C)	See Table 2	mg/kg	For PCB congeners, from MDNR database
Ingestion Rate (IR)	0.200-0.800	kg/day	EPA default is 0.227 kg/day; new Louisiana protocol ranges from 0.2 to 1.65 kg/day
Exposure frequency (EF)	365	days/year	Assumes daily exposure (as opposed to bolus dosing)
Exposure duration (ED)	30 to 70	years	USEPA 2000
Body weight (BW)	70	kg	Adult mean weight
Averaging time (AT)	10,950	days	30 years, but up to 70 (25,550 days)
Reference dose (RfD)	2×10^{-5}	mg/kg-day	USEPA IRIS (for Aroclor 1254)

Data from a sensitivity analysis for each model scenario were also compiled and are presented in Table 6. For all of the different model scenarios (in which all parameters were selected from a range of potential parameters), the fish tissue concentration had the largest effect on model outcome (i.e., the forecast value was most influenced by the variability in this parameter). The influence of fish tissue concentration ranged from 78.4% for the CDI estimate for carp based on aroclors to 44.6% for the CDI estimate for walleye based on total PCB congeners. The simulations were also sensitive to the ingestion rate, particularly for the total PCB congener analysis for both walleye and carp.

Table 5. Statistics associated with different simulations of the chronic daily intake (CDI) using probability distributions for 5 of the equation parameters (see Table 4).

Parameter	**Forecast value**	**Point estimate**
CDI – walleye Aroclors		
Mean	0.003173 mg/kg-day	0.001378 mg/kg-day
Median	0.002174 mg/kg-day	
Standard deviation	0.003339	
Minimum	0.0001030 mg/kg-day	
Maximum	0.06283 mg/kg-day	
CDI walleye congener		
Mean	0.005902 mg/kg-day	0.0025 mg/kg-day
Median	0.004754 mg/kg-day	
Standard deviation	0.004372	
Minimum	0.0003612 mg/kg-day	
Maximum	0.04996 mg/kg-day	
CDI – carp Aroclors		
Mean	0.05160 mg/kg-day	0.02212 mg/kg-day
Median	0.02527 mg/kg-day	
Standard deviation	0.08374	
Minimum	0.0009960 mg/kg-day	
Maximum	1.495 mg/kg-day	
CDI – carp congener		
Mean	0.02278 mg/kg-day	0.009586 mg/kg-day
Median	0.01667 mg/kg-day	
Standard deviation	0.02073	
Minimum	0.0009190 mg/kg-day	
Maximum	0.3087 mg/kg-day	

Table 6. Sensitivity analysis of parameters used in developing equations for chronic daily intake (CDI). Separate simulations were run based on Aroclor concentrations in fish and PCB congeners concentrations.

Simulation	**Fish tissue conc**	**Ingestion rate**	**Exposure duration**	**Averaging time**	**Body weight**
CDI walleye aroclors	63.7%	18.9%	8.6%	-7.4%	-1.5%
CDI walleye congeners	44.6%	30%	12.6%	-12.1%	0.7%
CDI carp aroclors	78.4%	11.3%	-4.9%	4.2%	-1.2%
CDI carp congeners	56.4%	21.7%	-10.3%	9.5%	-2.1%

Summary and Conclusions

Monte Carlo model for fish PCBs

There are several potential benefits to using a probabilistic approach when issuing FCAs. For example, because only a limited number of fish are sampled from a given population in monitoring for contaminant concentrations, a probability approach can allow managers to better integrate data variability when estimating tissue trigger levels. The utility of this approach was demonstrated in a study by Harris and Jones (2008), which found that a Monte Carlo simulation model produced a consistently lower risk estimate for consumption hazards to anglers than a default or point estimate models because it drew from an entire distribution of each assumption variable. The key to maintaining this advantage, however, is to ensure that the parameters used in the model are well defined.

The Monte Carlo model developed for this application highlights the potential importance of variability in fish tissue concentrations in its impact on the CDI. For all of the forecast simulations, the use of probability distributions for this and the other parameters both increased the mean forecast value of PCB concentrations and added a considerable amount of variation to the range in the CDI. The forecast distributions were skewed, with the greatest probability of CDI values falling towards the lower end of the spectrum; however, there is the potential to have individuals with high exposure, depending on the given scenario configuration.

Importantly, the sensitivity analysis indicates that for this simulation model, fish tissue concentration and ingestion rate strongly influence the values of the forecast. Future efforts to improve the predictive value of FCAs in the Detroit River would likely need to improve the certainty of these two parameters, by better defining the average and range in these values.

Although the initial intent of the literature meta-analysis was to identify a potential range in variability in PCBs in freshwater fish populations (see Table 7), the utility of these data are limited. Most studies indicate that variability in concentrations of PCB in fish are somewhat site specific and can be influenced by the ecology of fish in the area and by other factors such as sex and the time of year in which the fish are sampled. The large variability in the actual field data from the Detroit River suggest that additional sampling of fish from this site could greatly improve our understanding of the level of risk posed to fish consumers from this site.

One of the other key parameters to the advisory process that remains poorly defined is the actual consumption rate for subsistence fisherpeople, especially minority groups. When the original Uniform Protocol guideline was developed, the main sensitive subgroup that was targeted was women of childbearing age and children/infants. This was driven largely by the particular sensitivity of these groups to the toxicity of PCBs. Since this time, however, it has become increasingly recognized that there are other subgroups that may be at higher risk to PCB effects due to their consumption habits. For example, several more recent studies have found a relationship between race and fish consumption, with African Americans and Asians consuming significantly more fish and larger portion sizes than their Caucasian counterparts (Burger et al. 1999; Harris and Jones 2008). This has important implications both when issuing advice for those portions of both the sensitive subpopulations and the general population who may be minorities with a higher consumption rate of contaminated fish.

Finally, this study initially set out to evaluate the utility of TEQs in improving the FCA process. Since the study was initiated, the state of Michigan added dioxin-like PCBs to its advisories for dioxin. This approach is consistent with the trend in other states and is supported by the World Health Organization. Thus, the limited review of the literature on this topic indicates that the use of TEQs to Michigan's advisory is supported by the most recent science on the topic.

References

Anderson, H.A., J.F. Amrhein, P. Shubat, J. Hesse. 1993. Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory. Great Lakes Fish Advisory Task Force. Protocol Drafting Committee.

Burger, J., W.L. Stephens Jr., C.S. Boring, M. Kuklinski, J.W. Gibbons, M. Gochfeld. 1999. Factor in exposure assessment: ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River. Risk Analysis 19:427-438.

Carlson, D.L. and D.L. Swackhamer. 2006. Results from the US Great Lakes fish monitoring program and effects of lake processes on bioaccumulative contaminant concentrations. J. Great Lakes Res

Carlson, D. L., and D. L. Swackhamer. 2006. Results from the US Great Lakes fish monitoring program and effects of lake processes on bioaccumulative contaminant concentrations. *J Great Lakes Res* 32: 370-385.

Harris, S.A., and J.L. Jones. 2008. Fish consumption and PCB-associated health risks in recreational fishermen on the James River, Virginia. Environmental Research 107:254-263.

Madenjian, C.P., D.J. Jude, R.R. Rediske, J.P. O'Keefe, G.E. Noguchi. 2009. Gender difference in walleye PCB concentrations persists following remedial dredging. Journal of Great Lakes Research 35:347-352.

MDEQ 2009. Michigan Fish Contaminant Monitoring Program. MI/DEQ/WB-09/044. 2008 Annual Report.

Rypel, A.L., R.H. Findlay, J.B. Mitchell, and D.R. Bayne. 2007. Variations in PCB concentrations between genders of six warmwater fish species in Lake Logan Martin, Alabama, USA. Chemosphere 68:1707-1715.

US EPA (United States Environmental Protection Agency). 2000. Guidance for Assessing Chemical Contaminant Data for Use in Fish Advisories Volume 2: Risk Assessment and Fish Consumption Limits, Third edition. United States Environmental Protection Agency, Office of Water.

Van den Berg, M., L. Birnbaum, A.T.C. Bosveld, B. Brunstrlim and 20 other co-authors. 1998. Toxic equivalency factors (TEFs) for PCBs, PCDDs, PCDFs, for humans and wildlife. Environmental Health Perspectives 106: 775-792.

Van den Berg, M., L.S. Birnbaum, M. Denison, M. DeVito, W. Farland, M. Feeley, H. Fiedler, H. Hakansson, A. Hanberg, L. Haws, M. Rose, S. Safe, D. Schrenk, C. Tohyama, A. Tritscher, J. Tuomisto, M. Tysklind, N. Walker, and R.E. Peterson. 2006. The 2005 World Health Organization reevaluation of human and mammalian toxic equivalency factors for dioxins and dioxin-like compounds. Toxicological Sciences 93:223-241.

CHAPTER 5:

DETROIT RIVER FISH CONSUMPTION HAZARD ASSESSMENT MODEL: A PROBABILISTIC BIOACCUMULATION MODEL TO PREDICT PCB EXPOSURES IN SPORT FISH TO APPLY HAZARD AND RISK ASSESSMENTS FOR FISH CONSUMPTION ADVISORIES IN THE DETROIT RIVER

Abstract

The Detroit River Fish Consumption Hazard Assessment model was developed and parameterized to address three of five central questions formulated by the stakeholder workshops developed to identify What are the causes, consequences and correctives of fish contamination in the Detroit River AOC that cause health consumption advisories? The major stakeholder questions addressed by modelling activities included the following: 1) Do fish collected for contaminant analysis represent the population of fish accurately?; 2) What are contaminant levels of fish not included in the advisory that are consumed from the Detroit River?; and 3) Where are the sources of contaminant in the basin that are high enough to translate into a fish consumption advisories? Since the majority of fish consumption advice in the Detroit River are issued as a result of PCB contamination in edible fish flesh, the modeling efforts focused on this class of compounds over the modelling period from 1998-2008.

Examination of both empirical data on fish contamination and interpretation of model output led to several conclusions and recommendations pertaining to each stakeholder question. Information gaps were apparent in the number of fish species and number of replicate fish available to answer question #1 based strictly on empirical evidence from existing sport fish monitoring programs. This led to recommendations about target collections that should be initiated by Michigan Department of Environmental Quality and Ontario Ministry of Environment to provide a minimum of empirical data to support the generation of fish consumption advice information for all sport species that are regularly consumed from the Detroit River. To address question #2, model simulations were performed to predict contaminant concentrations in fish species consumed in the Detroit River but not covered by existing fish advice in the two international jurisdictions. Model predicted fish contamination and model inferred potential fish consumption advice were subsequently generated for these species and reported within this chapter.

To address question #3, model simulations were analyzed to assess the relative contribution of water and sediment contamination to fish contamination and to determine if removal of contaminants from these environmental media would reduce the number and intensity of fish advice information provided. A main conclusion was that upstream sources of PCBs to the Detroit River are sufficiently high to generate fish consumption advice associated with the least restrictive advice information triggers for many species of fish. In other words, even under a scenario of virtual elimination of PCBs from the Detroit River, upstream sources of contaminated water will still contribute to the presence of fish advice information unless these upstream sources are also remediated. Alternatively, highly contaminated sediments, particularly within the U.S. portions of the Detroit River, appear to be responsible for the most stringent

types of advice information given, e.g. Do Not Eat advice information issued for carp and channel catfish. Additional research efforts to develop and link a more comprehensive sediment clean-up model with the Detroit River Fish Consumption Hazard Assessment model would be useful to further delineate the scale and types of sediment clean-up activities necessary to achieve reductions in fish advice information issued within the Detroit River.

Executive Summary

As part of the project, What are the causes, consequences and correctives of fish contamination in the Detroit River AOC that cause health consumption advisories?, the Detroit River Fish Consumption Hazard Assessment model was formulated to support priority questions identified by the stakeholder consultation process conducted through a series of workshops. Through the stakeholder process, a set of five priority questions emerged through which the project was aimed at making progress. The top priority questions and issues identified in Workshop 1 by stakeholders were:

1) How can we increase public awareness of fish consumption advisories?
2) Do fish collected for contaminant analysis represent the population of fish accurately?
3) What are contaminant levels of fish not included in the advisory that are consumed from the Detroit River?
4) Where are the sources of contaminants in the basin that are high enough to translate into a fish consumption advisory?
5) Are we appropriately measuring emerging contaminants?

Of the above priority issues, questions 2, 3 and 4 were identified as being capable of being addressed using a food web bioaccumulation model. A model was therefore parameterized and inputs compiled in order to address each question and to provide recommendations and advice to participating stakeholders for communication at the final project workshop, held at the Belle Island Nature Zoo, Detroit MI, Jan 12, 2010. The conclusions and key findings from modelling activities relating to the stakeholder generated questions above are summarized below.

Stakeholder Question 2) Do fish collected for contaminant analysis represent the population of fish accurately?

The modelling group examined this question by performing an analysis of available data for empirical sport fish contaminants and to characterize expected frequency distributions of PCB concentrations in different sport fish species in six pre-defined modelling zones encompassing the boundary waters of the Detroit River. The empirical data had gaps in the availability of PCB concentrations in several frequently consumed sport fish species from the U.S. side and for fewer numbers of species on the Canadian side of the Detroit River. Of the 20 sport fish species considered in the Detroit River Fish Consumption Hazard Assessment model, 13 species had empirical data available on PCB concentrations in edible fish flesh from the Detroit River during the period of 1998-2008 that met minimum replicate targets (at least 10 fish/species). However, the availability of replicate numbers of fish and fish species data sampled from different regions of the Detroit River was found to be highly uneven.

In the U.S. boundary waters, Michigan Department of Environmental Quality (MDEQ) data were available for only 5 species of sport fish at two sampling locations. *It is recommended that additional fish sampling and contaminant analysis be performed on the Michigan side of the Detroit River to capture a minimum of n=10 fish per species of the following sport fish: black crappie, bluegill sunfish, brown bullhead, channel catfish, gar pike, gizzard shad, largemouth bass, muskellunge, northern pike, rock bass, smallmouth bass, white bass and white perch.* The Ontario jurisdiction had more extensive contaminant data for a more diverse number of species. To complete an empirical data base on all model sport fish species commonly consumed in the Detroit River it *is recommended that supplemental information by Ontario Ministry of the Environment (OMOE) be generated to capture and analyse a minimum of n=10 of the following species: black crappie, bluegill sunfish, brown bullhead, northern pike, sucker and smallmouth bass from Ontario waters of the Detroit River.*

Another issue identified within the context of Stakeholder Question 2 was the need to subdivide the Detroit River into different advisory jurisdictions. Ontario divides the Detroit River into an upstream and downstream boundary and establishes separate fish advisory information for each river section. Michigan provides a single set of advice information for the entire U.S. side of the Detroit River. The Detroit River Fish Consumption Hazard Assessment model considered 6 river regions encompassing upstream, midstream and downstream sections of the river within each international jurisdiction. Both the empirical data and hazard assessment model utilized in this project confirmed that differences exist between fish contamination in fish collected from U.S. waters compared to Canadian jurisdictions of the Detroit River. *This confirms the need for separate evaluation and fish advisory information by international jurisdiction.* Neither model or empirical observations on PCB concentrations in sport fish indicated major differences in PCB concentrations in sport fish between different river reaches within a given international jurisdiction. This result confirms the Michigan policy of adopting a single set of fish consumption advisories for all U.S. waters of the Detroit River. A further recommendation is that *OMOE consider adopting a single set of advice information for all Canadian waters encompassed by the Detroit River.*

Stakeholder Question 3) What are contaminant levels of fish not included in the advisory that are consumed from the Detroit River?

The Detroit River Fish Consumption Hazard Assessment model was used to predict PCB concentrations in 18 sport fish species in U.S. and Canadian waters. In general, model predicted fish advisories in the U.S. jurisdiction tended to be more conservative (i.e. recommend more restrictive advice information) for sport fish than current advice information issued by Michigan. These differences arise from a combination of model error, fish movements/feeding ecology, statistical methods used to define central tendency measures of fish contamination and limitations in the empirical database to describe the actual distribution of contamination in a given fish species. For the U.S. jurisdiction, no sport fish advice information was available for the following species: bluegill sunfish, brown bullhead, channel catfish, gar pike, gizzard shad, largemouth bass, mudkellunge, rock bass, smallmouth bass, white bass and white perch. *Model predicted fish consumption advice for species not included in U.S. fish consumption advisories by Michigan were predicted to range from 1 meal/week (bluegill, brown bullhead, largemouth* *bass, northern pike), 1 meal/mo (gizzard shad, largemouth bass, rock bass, smallmouth bass), 6 meal/year (gar pike, white bass, white perch) and no consumption (channel catfish).*

For the Canadian jurisdiction, sport fish advice information was not available for bluegill, brown bullhead, gar pike, gizzard shad, muskellunge, sucker and smallmouth bass. *Model predicted Ontario advisories for these species ranged from no advisories necessary (bluegill, brown bullhead, gizzard shad, muskellunge and sucker), limited meals (smallmouth bass) and no consumption for sensitive sub populations (gar pike).* In general, model predicted fish consumption advisories in the Canadian jurisdiction were less conservative (i.e. less restricted) than the most restrictive advice information advisories issued by Ontario. This may be related to the size adjusted advisory algorithms used by OMOE that are not considered by the Detroit River Fish Consumption Hazard Assessment model, fish movements occurring between international jurisdictions and outside the area of concern and also due to the fact that issued fish advisories in both jurisdiction consider additional contaminants other than PCBs, e.g. mercury and dioxins and furans. Additional model simulations considering fish movements within the Detroit River and the implications of such movements to fish consumption advice are provided in Chapter 6.

Model Stakeholder Question 4) Where are the sources of contaminants in the basin that are high enough to translate into a fish consumption advisory?

The upper Canadian food web modelling zone had the lowest PCB concentrations in its water and sediments. The levels of PCBs in environmental media found within this zone were found to be similar to background contamination present in Lake St. Clair (Raeside et al 2009). For the upper Canadian zone, PCBs in water contributed an average of 60.3% of the bioaccumulated residues in the different species of sport fish. Given that water quality in this region of the river is strongly influenced by upstream contributions, *this suggests that contaminated water, originating from Lake St. Clair, will contribute to PCB bioaccumulation in fish that will warrant fish advice information even under a virtual PCB elimination scenario for Canadian waters of the Detroit River.* Thus, complete removal of PCBs from sediments in this zone would be predicted to reduce the number of advisories issued by Ontario by only 1 species but would also decrease the restrictiveness of advice issued for white bass, common carp and channel catfish.

The model predicted PCB concentrations in Canadian sport fish were always predicted to be lower than Ontario's most restrictive advice trigger of 'No consumption' for the general public. Yet present sport fish advisories by Ontario include 'No consumption' advice information for the general public for three species: common carp, channel catfish and white bass. These same species, along with gar pike and white perch, were predicted to exceed the Ontario 'No consumption' advice triggers in all three U.S. modelling zones. Common carp and channel cat were also predicted to exceed the Michigan 'No consumption' advice trigger for the general public. *This suggests that the most restrictive advice information currently being issued in Ontario waters for common carp, channel catfish and white bass can be attributed to fish movements that involve spatially integrated exposures outside of the modelling zone.* For the upper Canadian model zones, the issuing of 'No consumption' advice information for channel catfish and common carp would appear to be a result of fish exposures to contaminated sediments occurring on the U.S. side of the Detroit River.

For the U.S. side of the Detroit River, all three zones had similar zone wide sediment contamination, whereas PCBs in water increased from upstream to downstream sections of the river. PCB concentrations in waters of the upper U.S. zone were well above those measured in upper Canadian Detroit River waters and in Lake St. Clair suggesting that in-stream sources of PCBs have contributed to degraded water quality. Despite notable spatial trends in water quality on the U.S. side of the river, a primary conclusion of the Detroit River Fish Consumption Hazard Assessment Model was that contaminated sediments in the U.S. zones were the most important driver of bioaccumulated PCB residues in fish, contributing to an average of 73.3±16.1% of total bioaccumulated residues across different species. *These results provide a strong rationale for the continued management focus on remediation of contaminated sediments within the U.S. side of the Detroit River.*

In order to achieve sediment clean-up results that translate into reductions in number and intensities of fish advice information, mass balance assessments and river-wide surveys of water and sediment quality must be performed to demonstrate the effect that smaller scale clean-up activities have on zone-wide mean PCB concentrations in sediments. With its focus on predicting PCB residues in sport fish, the Detroit River Fish Consumption Hazard assessment in its current format lacks the spatial resolution necessary to provide recommendations on areas of priority for sediment remediation. *It is therefore recommended that a sediment clean-up sub-model be developed that can be linked with the Detroit River Fish Consumption Hazard Assessment models to aid as a decision support tool for sediment remediation.* The sediment clean-up model should be able to provide high resolution sediment contamination maps, contaminant mass balances and be able to translate how specific sediment dredging and clean-up activities influence zone wide average contaminant concentrations. The summarized data can then serve as inputs to the fish consumption hazard assessment model to determine anticipated effects of specific sediment dredging and clean-up activities.

Introduction

The Detroit River Fish Consumption Hazard Assessment Model was a tool initially developed and utilized as part of the Detroit River Modelling and Management Framework to evaluate the contamination in the Detroit River and its potential to contribute to sport fish advisories issued for the system (GLIER 2002). The model, commissioned through the Detroit River Canadian Cleanup Committee, was originally applied to predict the likelihood of fish achieving PCB concentrations that exceed the trigger levels used to establish fish consumption advice information in the two State/Provincial jurisdictions encompassed by the Detroit River.

In the above application, the length and width of the Detroit River was subdivided into 11 food web model zones and the food web bioaccumulation model was run independently for each zone. This permitted establishment of zone specific hazard assessments for fish consumption advisories due to PCBs and to evaluate areas that contribute to the most stringent advice information in the river. Although the above hazard assessment entailed simplistic assumptions, i.e. all food web components, including sport fish species, were assumed to live their entire lives within the boundaries of each model zone, the model was able to demonstrate that only certain regions of the Detroit River had sufficient contamination to generate highly restrictive advice information (e.g. consumption advice of the nature: do not eat). Furthermore, contaminated sediments, particularly those in the lower U.S. portion of the Detroit River, were considered to be the strongest drivers of highly restrictive advice information. Alternatively, the model also indicated that the least restrictive advice information (i.e. advice to indicate allowable consumption of 1 meal per week) would likely be generated as a consequence of degraded water quality coming from upstream of the Detroit River. In other words, no amount of remediation within the Detroit River itself would completely eliminate fish consumption advisories from the system. However, removal of contaminated sediments from the most contaminated regions of the Detroit River would be predicted to lessen the severity of restriction advice information issued.

While the above simulations had already made progress towards identifying one of the priority issues/questions outlined by the stakeholder consultation, additional revision of the model was necessary in order to address other priority issues raised by the stakeholders. Specifically, priority questions 2 and 3, required more comprehensive model output than could be provided by the deterministic framework used in initial hazard assessments. As such, the Detroit River Hazard Assessment Model was revised into a probabilistic model in order to provide predictions of not only mean sport fish tissue concentrations of PCBs, but also to predict the frequency distributions of PCB concentrations in a given sport fish species on the basis of uncertainty in model inputs (water and sediment contamination).

Finally, the original Detroit River Hazard Assessment simulations were conducted almost a decade ago. Since the time of the original simulations, changes to state-of-the-art food web bioaccumulation model algorithms had been published (Arnot and Gobas 2004). In addition, the Ontario government revised its fish consumption advisory triggers for PCBs invalidating the past hazard assessment for the Canadian portion of the river (OMOE 2005). Finally, the project compiled additional data on model inputs including extended mussel biomonitoring data that became available after 2001 as well as extended the validation data set to include the much larger sport fish contaminant data bases used by Michigan and Ontario to establish their fish consumption advice information.

In order to update both the Detroit River Hazard Assessment model as well as consider new data as well as advisory trigger information, the following steps were taken as part of the modelling sub-project:

1) Update the food web bioaccumulation model algorithms to the latest published model formulation. Since the original publication of the Morison et al. model (1995, 1997), PCB food web bioaccumulation models have underwent a series of iterative changes. The Detroit River Fish Consumption Hazard Assessment Model was therefore updated to reflect the newest published model formulation as described in Arnot and Gobas (2004). In addition to the above, the model was formulated to run as a probabilistic model rather than as a deterministic model as was performed in the original 2001 hazard assessments. The probabilistic model used Monte Carlo simulations to predict not only the mean concentration in sport fish species but also to provide a distribution of sport fish PCB concentrations for each species based on variability and error in model input terms.

2) Develop an up-to-date database of model inputs (water and sediment PCB concentrations) for the Detroit River. Since the time of the original hazard assessments, additional data on PCB concentrations in water and sediments became available. These additional data were compiled into a data base, evaluated for temporal changes with time and compiled to provide estimates of zone specific mean and standard deviations of critical model inputs necessary for running the Detroit River Fish Consumption Hazard Assessment Model.

3) Develop a comprehensive database on sport fish PCB contamination in the Detroit River in order to evaluate model performance. The original hazard assessment model was validated using a limited food web data set compiled by the Great Lakes Institute for Environmental Research, University of Windsor. In this project, additional data from the sport fish contaminant monitoring programs were collected between the period of 1998-2008 to establish a much more rigorous data set on which to evaluate model performance. Model evaluation was then conducted by comparing zone specific and species specific predictions of PCB concentrations in dorsal muscle of sport fish with the empirical data base.

4) Utilize the model to predict concentrations and likely frequency distribution of contaminant levels in sport fish which are consumed by the public but for which no advisory information are currently in place. This application of the model was developed to specifically address stakeholder issue # 3: What are contaminant levels of fish not included in the advisory that are consumed from the Detroit River?

5) Utilize the empirical data base on model inputs and the model to predict which zones of the Detroit River were contributing to the most restrictive types of fish advice information. Model simulations were also performed to determine the relative importance of PCBs in water and sediments as contributors to fish bioaccumulation potentials and to make remediation priority suggestions about how to reduce the number and restrictiveness of fish advisories issued by the two jurisdictions operating on the Detroit River.

Food Web PCB Bioaccumulation Model

Bioaccumulation models are used to translate spatial patterns of water and sediment contamination into tissue residues likely to be achieved in indicator species. Bioaccumulation models for persistent organic pollutants such as polychlorinated biphenyls (PCBs) have been under development since the 1980's (Thomann and Connolly 1984) and progressed from single species, to food chain to food web models (Gobas 1993, Morrison et al 1997). Food web bioaccumulation models are now widely utilized to assess hazard and risk of contaminants in aquatic and terrestrial ecosystems (Gobas et al. 1995; Morrison et al. 1998, 2000, 2002). They have been applied as screening tools to assess emerging chemicals of concern, as decision support tools for point source removal and clean-up strategies (Gobas 1993), to assess validity of environmental quality guidelines (Walker and Gobas 1999) and to facilitate hazard assessments for fish consumption advisories (GLIER 2002).

Morrison et al (1997, 1998, 2002) developed and validated a food web bioaccumulation model to predict PCB concentrations in several sport fish species from Lake Erie and Lake St. Clair. The model was found to provide congener specific PCB predictions that were generally within a factor of 3 to 10 of observations and the authors suggested the use of the model to interpret fish exposures throughout the Huron-Erie corridor. The Morrison et al. model was subsequently adopted by the original Detroit River Fish Consumption Hazard Assessment model and applied to predict bioaccumulation potential of PCBs in 11 distinct food web modelling zones in the Detroit River (GLIER 2002). Since that original assessment, changes to the food web bioaccumulation model algorithms (Arnot and Gobas 2004), changes to fish advisory trigger levels used by Ontario (OMOE 2005) and expansion of available data for use as inputs for water and sediment quality have occurred. As such, the Detroit River Fish Consumption Hazard Assessment was substantially revised along with key input data to perform new model simulations. The revised model remains a steady state food web bioaccumulation model. This means that the model does not consider time as a variable within model equations nor does it consider seasonal changes in model inputs. Instead mean annual temperatures, estimated mean annual feeding proportions and contaminant inputs are used to make predictions.

A full description of the model algorithms are provided by Arnot and Gobas (2004) and readers are referred to this published source for a more detailed explanation of the model structure, predictive bioenergetic and toxicokinetics algorithms and the rationale behind algorithms used within the model. For each PCB congener and species included in the model, the general predictive equation is as follows.

$$C_{org} = \frac{\left(P_{OW} \cdot G_V \cdot E_V \cdot C_w + P_{PW} \cdot G_V \cdot E_V \cdot C_{PW}\right) + \left(P_{Sed} \cdot G_{FEED} \cdot E_{Feed} \cdot C_{Sed}\right) + \left(\sum P \cdot G_{FEED} \cdot E_{Feed} \cdot C_{food}\right)}{\left[\frac{G_V \cdot E_V \cdot Z_W}{Z_{ORG}} + \left(\sum P \cdot \frac{G_{EG} \cdot E_{EG} \cdot Z_{EG}}{Z_{ORG}}\right) + G_{GRO}\right]}$$

Where C_{org} is the congener specific PCB concentration in the whole body of the animal (ng/g wet weight), C_w, C_{PW}, C_{sed}, C_{food} are congener specific concentrations of PCB in water (ng/mL), pore water (ng/mL), sediment (ng/g organic carbon) and food (ng/g wet weight), respectively. The terms P_{OW} and P_{PW} refer to the fraction of overlying water and pore water respired by a given organism. The term P refers to the proportion a given food item contributes to the total diet of a species. The terms G_V, G_{feed} and G_{eg} are organism specific gill ventilation rates (mL/g·d), feeding rates (g/g·d) and fecal egestion rates (g/g·d). The later terms are predicted using the bioenergetic sub-model algorithms specified in Arnot and Gobas (2004) based on average body weight of the species and mean seasonal water temperature (13^{o}C) estimated for the Detroit River. The terms E_V, E_{feed} and E_{EG} refer to transfer efficiency terms of chemical between water and gill, food and organism and organism and feces. Finally, the terms Z_w, Z_{org} and Z_{eg} refer to chemical sorptive capacities of water, organism and feces, respectively. For organisms and feces, the partition capacity is based on relative proportions of water, lipid and non-lipid organic carbon in each organism. Non-lipid organic matter (NLOM) is estimated based on the difference in dry weight of the animal minus the lipid weight in the animal. Non-lipid organic matter was considered to have a partitioning capacity equivalent to 5% of neutral lipids as per convention of DeBruyn and Gobas (2007). Dorsal muscle PCB concentrations in sport fish species are predicted in order to establish PCB residues in edible fish flesh. Dorsal muscle PCB concentrations are estimated by:

$$C_{DM} = C_{org} \cdot \frac{Z_{DM}}{Z_{org}}$$

Where C_{DM} and C_{org} is the dorsal muscle and organism PCB concentration (ng/g wet weight) and Z_{DM} and Z_{ORG} refer to the chemical partition capacities of the dorsal muscle and animal, respectively. Sorptive capacities consider the differences in proximate composition (water, lipids and NLOM) between the whole body of the animal and the dorsal muscle tissue. Ontario and Michigan use difference protocols for preparing sport fish for contaminant analysis. Ontario uses a skin-off protocol that includes only dorsal muscle itself. Michigan uses a skin-on protocol that submits fish and attached integument for contaminant analysis. The integument often contains a larger portion of fat (lipids) than dorsal muscle and this could result in higher contaminant concentrations measured in skin-on fillet compared to skin-off fillets. In the present model, dorsal muscle concentrations did not distinguish between skin-on versus skin off fillets owing to a lack of data to establish species specific generalities for this term. Instead, a combined estimate of dorsal muscle lipid concentrations for samples collected from both jurisdictions was established using the combined sport fish contaminant data base.

The model simultaneously solves for congener specific PCB concentrations in each food web item and sport fish species and then sums the congener specific data together to provide a sum PCB estimate. The congeners utilized by the model are identified in Table 1. The choice of congeners was based primarily on the availability of data in both water and sediment input data bases. The chosen congeners provide a range of hydrophobicities and collectively contribute to a majority of total PCB concentrations when compared against more comprehensive congener methods (Frame et al. 1996).

The primary model inputs included congener specific PCB concentrations in overlying water, pore water and sediments. PCB concentrations in overlying water were taken from the water input data base described in the following section of this report. Since data where calculated from mussel biomonitors, no corrections were made for dissolved versus particulate and DOC-associated fractions. Pore water PCB concentrations were not directly available for the Detroit River and were estimated by assuming equilibrium between sediment and pore water utilizing the organic carbon/water partition coefficient (K_{OC}). The K_{OC} was estimated from the *n*-octanol/water partition coefficient (K_{OW}) as $0.35 \cdot K_{OW}$ as recommended in Arnot and Gobas (2004). Congener specific PCB K_{OW} values were obtained from Hawker and Connell (1988) and are also listed in Table 1. Congener specific PCBs in sediments were expressed on an organic carbon normalized basis. This provides the best estimates of PCB bioavailability (DiToro et al. 1991) and removes high variability in zone wide averages owing to heterogeneity in sediment grain size and composition.

The model predicts sum PCB concentrations in whole body for 37 food web items including 20 species of sport fish. The individual species and proximate compositions of each species included in the model output are summarized in Table 2. The sport fish species included in the model were identified in past creel surveys as being consumed by shore line fishers in the Detroit

River (Fish and Wildlife Nutrition Project 2000). As food web inputs, the model requires species specific feeding relationships (dietary proportions) for all organisms included in the model. We used a combination of recommended feeding relationships outlined by Morrison et al (1998, 2002) and Arnot and Gobas (2004, Supplementary Information) for model simulations. The feeding relationships were assumed to be the same regardless of which food web model zone was being applied. The feeding matrix used by the model is provided in Table 3.

A few alterations were made to model algorithms based on initial examination of model performance and data and availability of certain inputs. In the Arnot and Gobas model, filter feeders (zebra mussels and caddisfly larvae) are treated differently than deposit feeding benthos in that their uptake algorithms considers exposures to suspended particles present in the water column rather than ingestion of sediments. Since data on suspended particle concentrations in overlying water was lacking for the Detroit River, the same model algorithms as applied for deposit feeding organisms to provide predictions of PCB concentrations in filter feeding food items were used. Preliminary evaluation of model trials indicated that this change had a marginal influence on model predictions. A second change to the model structure was that benthic organisms were assumed to ingest and feed on the organic carbon fraction of sediments rather than consuming bulk sediments to satisfy the total feeding requirements. Therefore the organic carbon normalized sediment concentration was used as the concentration estimate that is ingested by benthic feeding organisms included in the model. The rational for this change is described below.

The Arnot and Gobas (2004) model uses a general bioenergetic algorithm to estimate bulk feeding rates of all animals included in the model regardless of feeding niche. The algorithm (Equation 14 in Arnot and Gobas 2004) predicts bulk feeding rate (kg food ingested per day) based on animal body weight and the mean annual water temperature but does not consider differences in energy density of ingested food and the role this plays on animal feeding rates. While such an assumption may be more generally applicable to secondary consumers, it is problematic when applied to benthic invertebrates or other organisms feeding primarily on sediment detritus. Benthic invertebrates ingesting sediments low in organic carbon can processes as much as their own body weight or more per day (Selck et al 1998) of bulk sediments greatly exceeding the 1-5% daily consumption of body weight estimated as part of the Arnot and Gobas general algorithm. During initial trials with the unaltered model, it was found the original model greatly underestimated PCB BSAFs in mayflies as compared to data obtained from bioaccumulation bioassay studies conducted using Trenton Channel sediments (Drouillard et al. 2006). Alternatively, the simple alteration of using organic carbon normalized sediment concentrations in place of bulk sediment concentrations produced BSAFs more in line with empirical data. Thus, this change was established for all animals where sediments formed part of the diet matrix. In practice, this change had the greatest influence on benthic invertebrates (zebra musels; caddisfly, oligochaetes, chironomids, gammerus and mayflies) for which sediments consisted of 40% or more of their total diet. The altered algorithm also applied to benthic feeding fish, although the small percentage of sediments to the total diet (5-10%) resulted in little impact to predict concentrations in these individual species. The major implication of the model alteration is that it produced higher estimates of benthic invertebrate PCB concentrations which increased the overall contribution of sediment-associated contaminants entering the food web.

Table 1. PCB congeners included in food web PCB bioaccumulation model simulations.

Congener (log K_{OW})	Congener (log K_{OW})
PCB 31/28 (5.67)	PCB 141 (6.82)
PCB 52 (5.84)	PCB 138 (6.83)
PCB 44 (5.75)	PCB 158 (7.02)
PCB 42 (5.76)	PCB 129 (6.73)
PCB 41/71/64 (5.95)	PCB 182/187 (7.2)
PCB 74 (6.2)	PCB 183 (7.2)
PCB 70/76 (6.2)	PCB 185 (7.11)
PCB 66/95 (6.2)	PCB 174 (7.11)
PCB 56/60 (6.11)	PCB 171 (7.11)
PCB 90/101 (6.38)	PCB 200 (7.27)
PCB 99 (6.39)	PCB 1732 (7.33)
PCB 97 (6.29)	PCB 180 (7.36)
PCB 110 (6.48)	PCB 170/190 (7.27)
PCB 151 (6.64)	PCB 201 (7.62)
PCB 149 (6.67)	PCB 203 (7.65)
PCB 118 (6.74)	PCB 195 (7.56)
PCB 146 (6.89)	PCB 194 (7.8)
PCB 153/132 (6.92)	PCB 206 (8.09)
PCB 105 (6.65)	

*Log K_{OW} values obtained from Hawker and Connell (1988)

Table 2. Organisms and proximate composition estimates included in the food web PCB bioaccumulation model.

Organism	Body weight (kg)	Whole Body Lipid (%)	Moisture Content (%)	Dorsal Muscle Lipid (%)	Lean Dry Weight (%)
Plankton	1.5625E-08	0.5	79.5	NA	20
Zebra Mussel	0.00011	1.3	78.7	NA	20
Caddisfly	0.00004	1.7	78.3	NA	20
Oligochaetes	0.000004	1	79	NA	20

Chironomids	0.000004	1	79	NA	20
Gammerus	0.00001	2.1	77.9	NA	20
Mayfly	0.0001	2	78	NA	20
Crayfish	0.0018	1.9	78.1	NA	20
YOY Fish	0.0004	2.1	77.9	NA	20
Brook Silverside	0.0015	4.5	75.5	NA	20
Emerald Shiner	0.0025	4.7	75.3	NA	20
Spottail Shiner	0.002	4.5	75.5	NA	20
Round Goby	0.0025	4	76	NA	20
Alewife	0.05	7.4	72.6	NA	20
Smelt	0.05	4	76	NA	20
Small White Sucker	0.029	3.5	76.5	NA	20
Bluegill	0.0705	4	76	0.54	20
Black Crappie	0.5	5.7	74.3	0.07	20
Gizzard Shad	0.75773	5.2	72.8	2.78	22
White Perch	0.159	5.6	74.4	4.02	20
White Bass	0.44188	6.5	73.5	2.12	20
Rock Bass	0.2088	5.7	74.3	0.76	20
Yellow Perch	0.14183	5.5	74.5	0.51	20
Walleye	1.3648	5.54	70.5	1.18	23.96
Smallmout Bass	0.8632	7.6	72.4	1.98	20
Largemouth Bass	0.705	2.46	73	0.6	24.54
Northern Pike	1.978	8	72	0.2	20
Gar Pike	0.70533	8	72	3.58	20
Muskellunge	6.61189	11	69	1.19	20
Bowfin	1.5455	11	69	0.5	20
Redhorse Sucker	0.8037	12	68	2.3	20
White Sucker	0.84637	8.7	71.3	2.3	20
Carp	2.82692	10.2	68	4.08	21.8
Freshwater Drum	1.128159	6.5	73.5	3.1	20
Brown Bullhead	0.4903	10	70	0.33	20
Chanel Catfish	0.784458	10	70	5.97	20

Table 3. Feeding matrix used for food web model simulations.

	Organism	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24
1	Sediment	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
2	Plankton	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
3	Zebra Mussel	40	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
4	Caddisfly	40	60	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
5	Oligochaetes	60	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
6	Chironomids	60	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
7	Gammerus	50	50	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
8	Mayfly	60	40	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
9	Crayfish	28	25	35	1	0	0	9	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
10	YOY Fish	0	100	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
11	Brook Silverside	0	92	0	0	0	8	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
12	Emerald Shiner	9	90	0	0	0	1	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
13	Spottail Shiner	2	81	0	0	15	2	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
14	Round Goby	3	75	12	0	0	0	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
15	Alewife	0	80	0	3	0	0	7	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
16	Smelt	0	65	0	10	0	0	10	10	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
17	Small White Sucker	5	40	0	10	0	0	25	20	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
18	Bluegill	0	40	5	10	10	10	10	10	0	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
19	Black Crappie	0	40	0	10	0	0	40	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
20	Gizzard Shad	0	65	5	5	7.5	7.5	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
21	White Perch	0	54	2	3	0	0	18	10	0	10	0	3	0	0	0	0	0	0	0	0	0	0	0	0
22	White Bass	0	35	2	3	0	0	18	20	2	10	0	5	5	0	0	0	0	0	0	0	0	0	0	0
23	Rock Bass	0	0	0	10	0	8	5	10	50	5	3	3	3	3	0	0	0	0	0	0	0	0	0	0
24	Yellow Perch	0	40	25	1	6	6	6	6	0	7	0	3	0	0	0	0	0	0	0	0	0	0	0	0
25	Walleye	0	10	0	0	0	0	0	0	0	50	0	5	10	5	5	5	5	0	0	0	0	0	0	5
26	Smallmout Bass	0	5	0	0	0	0	0	0	5	30	0	20	20	0	10	10	0	0	0	0	0	0	0	0
27	Largemouth Bass	0	5	0	0	0	0	0	0	25	10	0	20	15	0	10	10	5	0	0	0	0	0	0	0
28	Northern Pike	0	0	0	0	0	0	0	0	3	0	3	3	3	3	3	3	5	10	8	8	12	12	12	12
29	Gar Pike	0	0	0	3	0	0	0	3	5	5	10	12	12	5	5	5	5	5	5	0	5	5	5	5
30	Muskellunge	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	5	5	10	10	15	15	15	25
31	Bowfin	5	0	0	0	0	0	0	0	30	0	0	5	5	5	5	5	5	5	5	5	5	5	5	5
32	Redhorse Sucker	5	25	10	10	10	15	10	15	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
33	White Sucker	5	50	10	5	5	5	10	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
34	Carp	10	25	10	10	15	15	5	10	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0	0
35	Freshwater Drum	5	15	20	5	10	10	15	10	0	5	0	5	0	0	0	0	0	0	0	0	0	0	0	0
36	Brown Bullhead	5	10	10	10	15	15	10	15	5	5	0	0	0	0	0	0	0	0	0	0	0	0	0	0
37	Channel Catfish	5	8	10	10	10	10	10	15	5	5	0	3	3	3	0	0	3	0	0	0	0	0	0	0

Numbers refer to % composition of a given diet item to the total diet of a given species. Organism in Rows, diet items are in columns.

The model was programmed to run in Microsoft Excel. It uses the inputs of congener specific PCB concentrations in water and sediments to solve for sum PCB concentrations in dorsal muscle in the 20 selected sport fish species. The model was run in isolation for each food web modelling zone using zone specific water and sediment PCB inputs. All food web inputs, including species modeled, proximate composition and feeding relationships were assumed to be constant across the different model zones. Initially, the model was applied to the 11 original food web modelling zones used in the initial hazard assessments. However, the model inputs for water PCB contamination were not available for several input zones and required extrapolation. In order to better match the spatial resolution of model inputs with food web modelling zones, the Detroit River was re-partitioned into 6 major food web zones (Figure 1). The food web zones included upstream, midstream and downstream U.S. modelling zones and upstream, mid-stream and downstream Canadian modelling zones. A comparison of initial model validation trials showed that the 6 model zone provided better sport fish concentration estimates than the 11 food web model zones and therefore this partition framework was used for the remainder of the project.

A final change to the model was the implementation of a Monte Carlo interface on top of model simulations to enable the model to operate under a probabilistic framework. The Monte Carlo interface enables input of a mean value and a variability term (standard deviation) for selected model inputs and model parameters included in the model. Using the Monte Carlo interface, the model is run for a total of one thousand iterations. For each model iteration, the Monte Carlo interface randomly chooses a value for each selected model input according to a specified statistical distribution and the output for each model iteration is saved. The interface then provides a summary of mean, standard deviation and frequency distributions of model outputs for sum PCB concentrations in dorsal muscle for the 20 selected sport fish species. Crystal Ball software was used to perform Monte Carlo simulations as this software package directly interfaces with Microsoft excel. The model inputs that had associated error with them included congener specific PCB water and sediment concentrations and dorsal muscle lipid contents. For water and sediments, the zone specific mean and standard deviation values were applied to individual model simulations (See Water and Sediment Input Sections). For dorsal muscle lipid content and standard deviations, the species specific Detroit River average was computed and used for model inputs. For all inputs, a log normal distribution was selected for use with Monte Carlo simulations. Log normal distributions were selected because both water and sediment PCB concentrations were shown to follow this distribution.

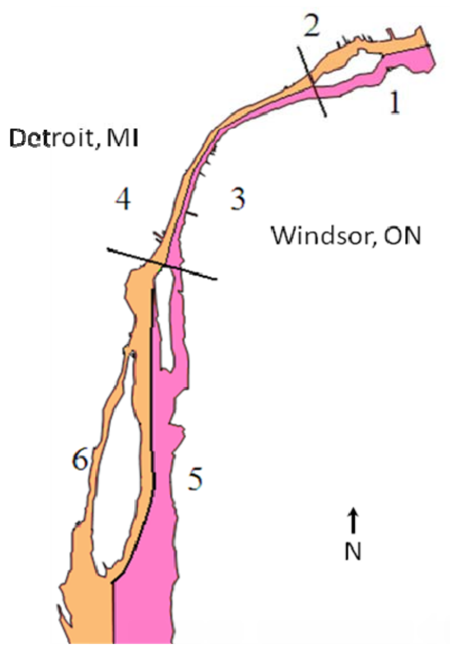


Figure 1. Division of Detroit River into 6 food web model zones used in the Detroit River Fish Consumption Advisory Hazard Assessment model.

Model Input Data: PCB Concentrations in Water

Congener specific data on PCB concentrations in water are a necessary input to the food web bioaccumulation model. However, this parameter represents one of the most challenging inputs to fulfill for model requirements in terms of being able to adequately describe spatial and temporal scales of exposure to water borne contamination by individual organisms included in model simulations. Water has a short, approximate 24-h, overall residence time in the Detroit River with residence times varying between shipping channels and shallow reaches of the river (Quinn 1976; UGLCCS 1988). As a consequence, water concentrations are expected to be highly dynamic within this system and responsive to changes in point source inputs, flow rate and sediment resuspension patterns related to storm events and ice scouring.

Another issue involved with collecting water PCB concentration data for model simulations is the consideration of the time integration experienced by different organisms exposed to water contamination (Leblanc 1995). The time to steady state represents the period of time required by an organism exposed to constant environmental contamination to achieve time independent tissue concentrations of a given contaminant. Time to steady state for PCBs and different congeners varies from short periods of days in phytoplankton (Leblanc 1995) to years in fish (Paterson et al 2007). When computing the potential to bioaccumulation contaminants from water in the field, attention should be placed on estimating the mean water concentration over the steady state period of the organism. Given that the Detroit River Fish Consumption Hazard Assessment model is focussed on sport fish which exhibit slow times to steady state (Paterson et al 2007), this necessitates that water concentration estimates reflect average concentrations computed over several years of data. For example, for PCB 206, the most hydrophobic PCB congener utilized in simulations, the model predicted whole body elimination rate constants (k_{tot}) for different animals ranged from 0.060 (oligochaetes) to 0.00061 d^{-1} (muskellunge). The corresponding time to 95% steady state is approximated by $3/k_{tot}$, resulting in steady state time requirements ranging from 49 days to 13.6 years. For the purposes of model simulations, water data were compiled over the past ten years (1998-2008) to examine for temporal trends in this input and to account for longer term temporal integration of water residues in larger, long lived sport fish included in model simulations.

Finally, data compatibility issues related to different methods used to quantify PCB concentrations in water result in difficulties of establishing weight of evidence assessments of water quality in this system. Some monitoring surveys only report total or sum PCBs while others provide congener specific data. Analytical characterization may include older packed column-gas chromatography or high resolution capillary column-gas chromatography and different analytical standards (Aroclor standards or certified congener-specific standards). Methods for water extraction vary widely over the years and have included liquid-liquid, large volume centrifugal extraction, large volume/solid phase extraction and C18 empore disks (Anderson et al 1999; Froese et al 1997). In addition to the above, the phase partitioning of PCBs in water requires consideration especially when using the data for bioaccumulation model inputs. The bioaccumulation model assumes that PCBs quantified in water reflect the freely dissolved bioavailable, fraction. However, PCBs in water are strongly associated with suspended particulates and dissolve organic carbon (DOC). The fraction of dissolved versus particulate and DOC-associated PCBs may or may not be distinguished or reported as part of published data sets. For example, many recent PCB monitoring programs report PCBs in water as reflecting a combination of dissolved, DOC-associated and particulate associated chemical. In the latter case, corrections are required, based on assumed partitioning behaviour of PCBs, to estimate the freely dissolved concentration (Morrison et al 1997). An alternative approach is the use of biomonitors to extrapolate freely dissolved water concentrations (Gewurtz et al 2003). The latter requires toxicokinetic models to translate bioaccumulated residues in animal tissues to a dissolved concentration (O'Rourke et al 2004, Raesie et al 2009). These methods are more likely to provide a time-integrated estimate of average bioavailable water concentrations but can overestimate residues in water when the models fail to account for dietary-based exposures to the biomonitoring species.

Two primary data sets were considered for use as model inputs to facilitate the Detroit River Fish Consumption Hazard Assessment Model. Large volume water extraction data collected between 1998-2003 were compiled from MDEQ and Environment Canada. In addition, we evaluated a freshwater mussel biomonitoring data base contributed by City of Windsor and GLIER, University of Windsor for use as inputs. Although large volume water extractions are considered the standard method for PCB quantitation in water samples (Froese et al 1997), the data available for large volume PCB concentrations were limited in spatial scope and temporal resolution. As such, our focus was to compare the compatibility of PCB concentration estimates using the much more comprehensive mussel biomonitoring database to those established by the standard analytical method for PCBs in water. The broader spatial and temporal coverage of water quality established by the mussel biomonitoring data base was then used to estimate congener specific PCB water concentration inputs and variability measures for each food web modeling zone.

Large volume water concentration estimates

Analytical challenges and the high costs related to water sampling for PCBs have resulted in a general paucity of data for PCB concentrations in water in the Detroit River that have used high volume water sampling techniques coupled with modern analytical technology for congener specific PCB analysis. Published data sets are minimal and vary widely in the techniques used for the collection, filtration, extraction and analytical determination of PCBs in water. Loading estimates for PCBs have been formulated based on Certificate of Approvals for direct dischargers to the river, e.g. Detroit Water and Sewage Dept., however these data track only sum PCB concentrations and are often censored to indicate only those data which exceed allowable discharges (Heidtke et al 2006.).

For historical data on PCB concentrations in water of the Detroit River, the Upper Great Lakes Connecting Channels Study provided the most comprehensive direct water sampling programs in the system (UGLCCS, 1988, Kaiser et al. 1985). The studies, representing a partnership between U.S. EPA, Environment Canada, Ontario Ministry of Environment (OMOE) and Michigan Department of Environmental Quality (MDEQ) were completed in the mid-1980's and examined the phase distribution, upstream/downstream mass balance and mass balance of water-associated PCBs entering and exiting the Trenton Channel. Upstream of Belle Island, sum PCB concentrations in headwaters of the Detroit River averaged 0.6 ng/L. In downstream Ontario waters, PCB concentrations approached 1 ng/L while downstream PCB concentrations in Michigan were approximately 3.4 ng/L (UGLLCS 1988). Mass balance studies using upstream and downstream transects indicated an average sum PCBs concentration of 1.4±0.6 ng/L at the head of the Detroit River and concentrations of 3.3±1.3 ng/L in downstream waters (UGLCCS 1988). Elevated concentrations were also noted in the Trenton Channel along the western shoreline where daily variations in water concentration ranged from 6.8 to 15.75 ng/L (UGLCCS 1988).

The Trenton Channel mass balance studies were revisited a decade after the UGLCCS studies were completed (1995/96) by US-EPA and MDEQ (Froese et al 1997). In this case, upstream and downstream Trenton Channel transects were sampled to assess seasonal trends. In 1995, the estimated average sum PCB concentration was 17 ng/L and ranged from <5 – 35 ng/L among individual samples (Froese et al. 1997). In the latter estimate, 60% of PCBs were determined to be particulate bound and 40% considered dissolved (i.e. bioavailable) phase. Although the latter data are considered high quality for water trends analysis and analytical methods, the data sets were considered too old to reflect current conditions.

Unpublished PCB water monitoring data were provided by Michigan Department of Environmental Quality/Michigan EPA and by Environment Canada. Both the latter data sets involve limited sampling stations, but provide some temporal trend and location specific information. The Michigan data set included 2 water sampling stations located within the Detroit River (Station 820017, N. Peche Island and 820017 Downstream U.S. Waters) and had congener specific data available over the years 1998-2003. The Environment Canada data only included mean sum PCB concentrations as attempts to locate the original congener-specific data by Environment Canada staff have been unsuccessful.

Table 4 provides a comparison of sum PCB concentrations reported for upper and lower zones of the Detroit River based on data extracted from the UGLCCS, Froese et al (1995) and MDEQ/Enviornment Canada data sets. PCB concentrations in upper Detroit River waters were generally less than 1 ng/L with little apparent change between 1985 and 2003. In the downstream waters, sum PCB concentrations ranged from 0.5 to 1 ng/L in Canadian waters and approximately 3 ng/L in downstream U.S. waters with somewhat elevated concentrations again appearing within waters of Trenton Channel.

Table 4: Sum PCB concentrations in water of the Detroit River based on direct water extractions from different studies.

Zone	UGLCCS (1985)	Froese et al. (1995)	MDEQ (1998-03)	Env. Canada (2001-03)
Upper US	0.6 - 1.4	NA	0.67±0.3 (n=10)	NA
Upper CA	NA	NA	NA	0.25 (mean)
Lower US	3.4 (TT=6.8-15.75)	(TT=<5 - 35)	2.93±1.75 (n=19)	(mean) (TT=4.1)
Lower CA	1	NA	NA	0.49 (mean)

TT = Trenton Channel

Figure 2 summarizes the MDEQ sum PCB concentrations in water at the upstream and downstream sites as a function of time. Although mean PCB concentrations at the downstream site were higher than the upstream station, within and across year variation at this sampling location was observed to be very high. For the Michigan data set, there were no significant differences in sum PCB concentrations between stations (p>0.3, ANOVA) and no significant relationships between sum PCB concentrations and year of sampling (p>0.8, ANOVA, 1998-2008).

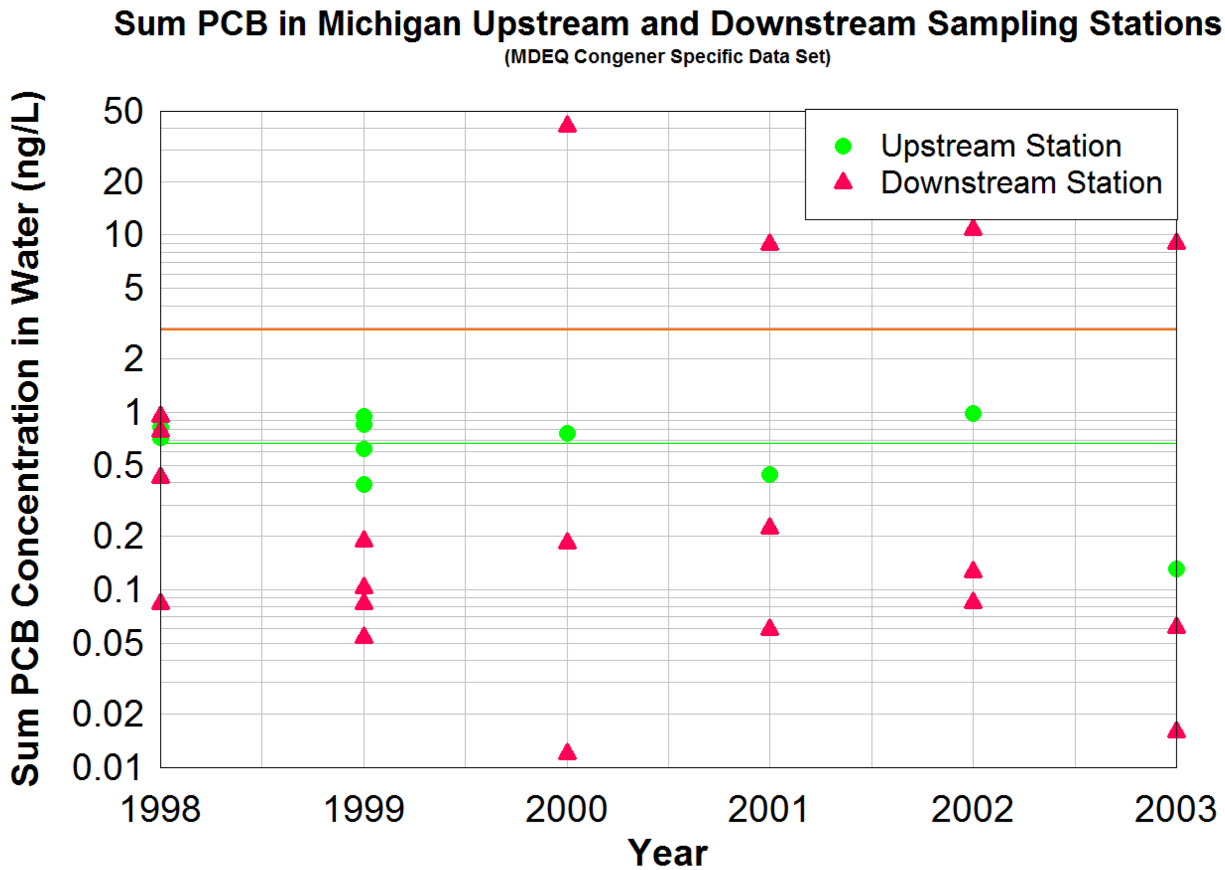


Figure 2. MDEQ sum PCB concentrations in water determined at two stations between 1998 and 2003.

Mussel Biomonitoring

Mussels have a long history of use as biomonitors of pollutant residues in waters of the Detroit River and the Huron-Erie corridor (Pugsley *et al*. 1985; Gewurtz et al. 2003; Raeside et al. 2009). Freshwater mussels are ideal sentinel species in that they are long-lived filter feeders that once settled undergo little or no movements. They accumulate a number of heavy metals and hydrophobic organic contaminants (Pugsley et al., 1985; Gewurtz et al., 2003) and the kinetics of this accumulation have been characterized for a number of species and contaminants such as HCB, PAHs and PCBs (Russell and Gobas, 1989; Morrison et al., 1995; Gewurtz et al., 2002; O'Rourke et al., 2004; Raeside et al 2009). Quantitative biomonitoring involves deploying animals (caged mussels collected from a reference site) at a specific location and allowing them to filter water over an extended time (days to months). This technique is more suited to interpretation using toxicokinetics models because the exposure period of deployed animals are controlled. Quantitative biomonitors, when interpreted using calibrated toxicokinetics models, can be used to provide a time integrated water concentration estimate over the deployment period making them ideal for use systems that undergo frequent flow disturbances or loadings changes (Raeside et al 2009; Gewurtz et al 2003).

The City of Windsor has been conducting a freshwater mussel biomonitoring program since 1996 to monitor upstream and downstream of sewage discharges of bioaccumulative contaminants. The studies used freshwater mussels, *Elliptio complanata*, collected from a clean reference location in Lindsey, ON, and caged on site in the Detroit River for periods ranging from 21 d to 273 d. Triplicate mussels were sampled from the deployment cages at approximately 30 d time points throughout the open water season. The City of Windsor mussel biomonitoring program includes 5 Canadian stations (2 upstream and 3 mid-stream food web modelling zones) within the Detroit River and reflects a near continuous data base of water quality during the open water season over the time period from 1998-2008. This data is unique for its ability to establish temporal patterns of water contamination in the Detroit River.

Additional supplemental biomonitoring surveys were performed in the Detroit River at different time periods. In 1998, Gewurtz et al (2003) deployed biomonitors in a complementary program to the City of Windsor at 4 U.S. stations in the Detroit River. O'Rourke et al. (2004) deployed mussels at 22 stations (both Canadian and U.S. waters) during 2002 to provide a more comprehensive river-wide survey of water quality. Raeside et al. (2009) added mussels throughout the Huron-Erie corridor and this survey included 4 stations in the Detroit River. A data base of water concentration estimates from the biomonitoring data was compiled based on the above survey information. The database consisted of 319 records of congener specific PCB data. Figure 3 summarizes biomontioring station locations utilized in the different biomonitoring surveys. Table 5 summarizes the number of biomonitoring stations and records of water concentration data estimated using biomontiors organized by food web modelling zone.

Model extrapolation of biomonitor resides to water concentrations

Quantitative biomonitoring studies involve using toxicokinetics models to adjust time-dependent bioaccumulated residues in mussels to a steady state concentration estimate (Gewurtz et al 2003, O'Rourke et al 2004; Raeside et al 2009). The model approach to perform steady state conversions are described in Raeside et al. (2009) with some modification to account for sample partitioning capacity of non-lipid organic matter. Briefly, the following data transformations and model calculations are made to convert time-dependent accumulated PCB residues in mussel biomonitors into a time integrate water concentration estimate.

First, the congener specific wet PCB concentration is corrected for partitioning capacity using lipid equivalents outlined by Debruyn and Gobas (2007):

$$C_{mus(leq)} = \frac{C_{mus(wet)}}{f_{lip} + 0.05 \cdot f_{NLOM}}$$

Where $C_{mus(leq)}$ is the lipid-equivalent normalized PCB concentration in the mussel (ng/kg), f_{lip} is the fraction of lipid in mussel and f_{NLOM} is the fraction of non-lipid organic matter in the mussel. The f_{NLOM} is calculated by subtracting the lipid weight in the individual from the lean dry weight and expressing this mass as a proportion to the wet shucked weight of the organism.

The use of lipid equivalents rather than simple lipid normalization accounts for the fact that mussels tent to contain low lipid, usually less than 1%, and thus reliance on only lipid tends to underestimate the actually partition capacity of then animal for hydrophobic chemicals. Following normalization for partitioning capacity a steady state correction is performed:

$$C_{mus(ss)} = \frac{[C_{mus(leq)} - C_{con(leq)} \cdot e^{-k_2 \cdot t}]}{(1 - e^{-k_2 \cdot t})}$$

Where $C_{muss(ss)}$ is the steady state corrected concentration in the mussel (ng/kg) which reflects the model extrapolated concentration in the mussel exposed to an average water concentration equivalent to its exposure during deployment for a period of sufficient time for the organism to achieve steady state with the water. $C_{con(leq)}$ is the lipid equivalent normalized concentration measured in control mussels measured prior to biomonitor deployment (i.e. day 0 mussel PCB concentration). The k_2 value is the congener specific elimination rate coefficient (d^{-1}) and t is the deployment period in days. Raeside et al (2009) measured in-situ PCB elimination rate coefficients in *E. complanata* deployed in the Huron-Erie corridor. The combined data from the above produced the predictive equation:

$$\text{Log } k_2 = -0.34 \cdot \log \cdot K_{ow} + 1.13$$

Finally, the water concentration is estimated from the steady state corrected lipid equivalent concentration in the mussel biomonitor using the equilibrium lipid normalized bioconcentration factor (BCF) as per Gerwurtz et al (2003):

$$C_W = \frac{C_{mus(ss)}}{BCF} = \frac{C_{mus(ss)}}{K_{OW}}$$

Where C_W is the model estimated bioavailable, time-integrated, water concentration (ng/L) K_{OW} is the congener specific *n*-octanol-water partition coefficient for individual PCBs. Water concentrations are estimated for each of the 37 model PCB congeners independently. The model estimated water concentrations for individual congeners are then summed to provide a sum PCB concentration estimate as presented in this report.

Temporal and spatial trends of PCBs in water

Temporal trends in biomonitor estimated water concentrations were evaluated using the City of Windsor biomonitoring stations and combined data sets for the upper and middle Canadian food web zones. These zones were selected for temporal analysis because they represented the longest time span over which continuous data were available. Figure 4 summarizes the water concentration data by site and year in the upper and middle Canadian zones. Despite high year to year variation, there were no significant trends with time in biomonitor estimated sum PCB concentrations for any of the City of Windsor biomonitoring stations ($p>0.2$ all locations, ANOVA). Similarly, no statistical trends in mussel estimated water concentrations with time were detected within each zone when all the data from a given zone were combined ($p>0.2$, Upper Zone, $p> 0.3$ Middle Zone; ANOVA). Based on the lack of statistical trends in water concentration estimates established using both the large volume water sampling data sets (1998-2003) and biomonitoring data sets (1998-2008), data from all years over the period of 1998-2008 were combined for estimating mean PCB concentrations in water in the different food web zones.

Table 6 contrasts the mean sum PCBs determined in water for each food web zone based on the biomonitoring data sets against sum PCB concentrations in water determined using large volume water samples. The large volume and mussel data produced similar order of magnitude estimates in zone specific PCB water concentrations. In the lower zones, the large volume and biomonitor estimated sum PCB concentrations in water were nearly identical after adjusting the total water concentration from direct water measurements to dissolved concentration estimates.

Congener specific data generated by the two different methods were less comparable relative to sum PCB comparisons. In the upper U.S. zone, PCB congener profiles were positively correlated, but not significantly related. In the lower zone, no correlations were apparent with the large volume water samples showing a much greater predominance of higher chlorinated PCBs. There could be a number of reasons for these discrepancies. First, the large volume water concentration measurements were determined at only a single station in each zone whereas the mussel biomonitoring data contained between 3-4 stations in the upper and lower U.S. zones. The large volume water concentration measurements reflect a snapshot of water concentrations at the time of sampling (e.g. 2-3 h), while the mussel estimated water concentrations represent a time-integrated (30-90 d) water concentration averaged over the deployment period of the mussel. Finally, the large volume water concentration data consisted of both particulate-associated PCBs and dissolved fraction. The inclusion of particulate associated PCBs would be expected to bias PCB profiles to more chlorinated congeners which was clearly observed.

Mean zone specific sum PCB concentration estimates in the 6 zones established using the combined mussel biomonitoring data base are summarized in Figure 5. Tables 7 and 8 summarizes the zone and PCB congener specific mean ± standard deviation water concentration values utilized as inputs to the Detroit River Fish Consumption Hazard Assessment model. The finalized input concentrations were established on the basis of combined mussel biomonitors data base across years (1998-2008) and among sites from within each of the model zone.

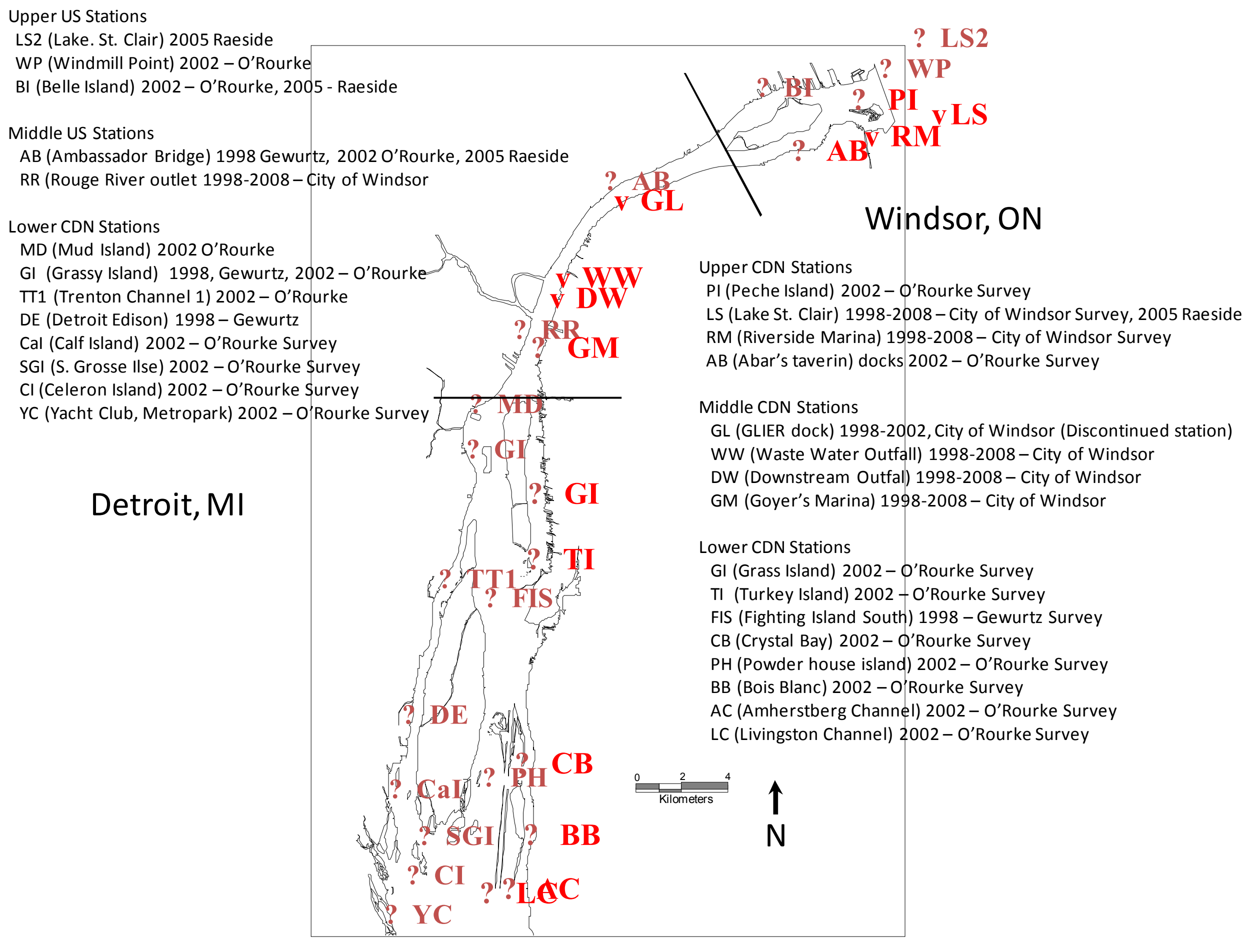


Figure 3: Locations of Biomonitoring Sites in the Detroit River (1998-2008).

Table 5. Summary of biomonitor estimated water concentration records compiled for each food web modelling zone in the Detroit River

Food web Zone	# Biomonitoring Deployment Stations	Years Data Available	# of Records	Survey
Upper US	3	2002,2005	14	O'Rourke 2004 Raeside et al 2009
Middle US	2	1998, 2002, 2005	15	Gewurtz et al. 2003 O'Rourke 2004 Raeside et al. 2009
Lower US	8	1998, 2002	39	Gewurtz et al. 2003 O'Rourke 2004
Upper CDN	4	1998-2008	80	City of Windsor database, O'Rourke 2004 Raeside et al 2009
Middle CDN	4	1998-2008	133	City of Windsor database, O'Rourke 2004
Lower CDN	8	1998, 2002	38	Geurtz et al. 2003 O'Rourke 2004

City of Windsor database =Unpublished database based on City of Windsor mussel biomonitoring on-going from 1996- present. Individual yearly datasets on mussel biomonitors are submitted by the Great Lakes Institute for Environmental Research, University of Windsor, to the City of Windsor as part of an on-going collaboration. The data are used by the city to meet their self monitoring compliance requirements for their certificate of approval of regulated discharge to the Detroit River.

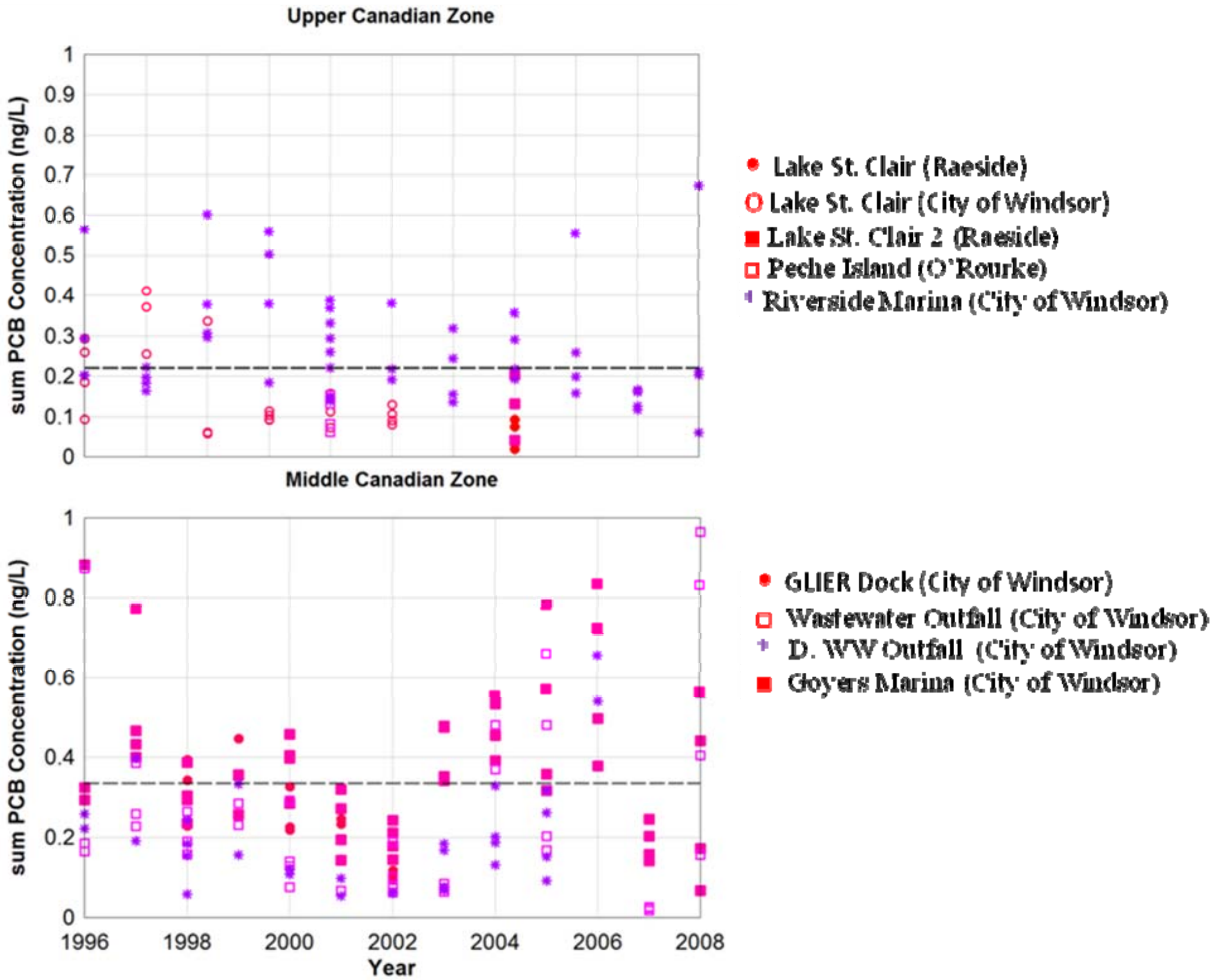


Figure 4. Temporal trends in biomonitor estimated water concentrations in the upper and middle food web zones of the Detroit River. Dashed line represents across site and time mean concentration value for each region.

Table 6 Comparison of zone specific mean sum PCB concentrations in the Detroit River established by large volume water extraction and mussel biomonitoring data.

Zone	UGLCCS (1985)	MDEQ/ Env. Canada (1998-03)	Dissolved Concentration Estimate *	Biomonitor Data (1998-2008)
Upper US	0.6 - 1.4	0.67±0.3 (n=10)	0.27	0.59±0.50 (n=14)
Upper CA	NA	0.25 (n=2)	0.10	0.22±0.14 (n=80)
Middle US	NA	NA	NA	0.78±0.37 (n=15)
Middle CA	NA	NA	NA	0.32±0.22 (n=133)
Lower US	3.4	2.93±1.75 (n=19)	1.17	1.10±0.74 (n=39)
Lower CA	1.0	0.49 (n=1)	0.20	0.19±0.14 (n=38)

* Dissolved concentration was estimated by multiplying the total water concentration from the MDEQ/Env. Canada study by 0.4 to account for suspended solids fraction as described by Froese et al 1997.

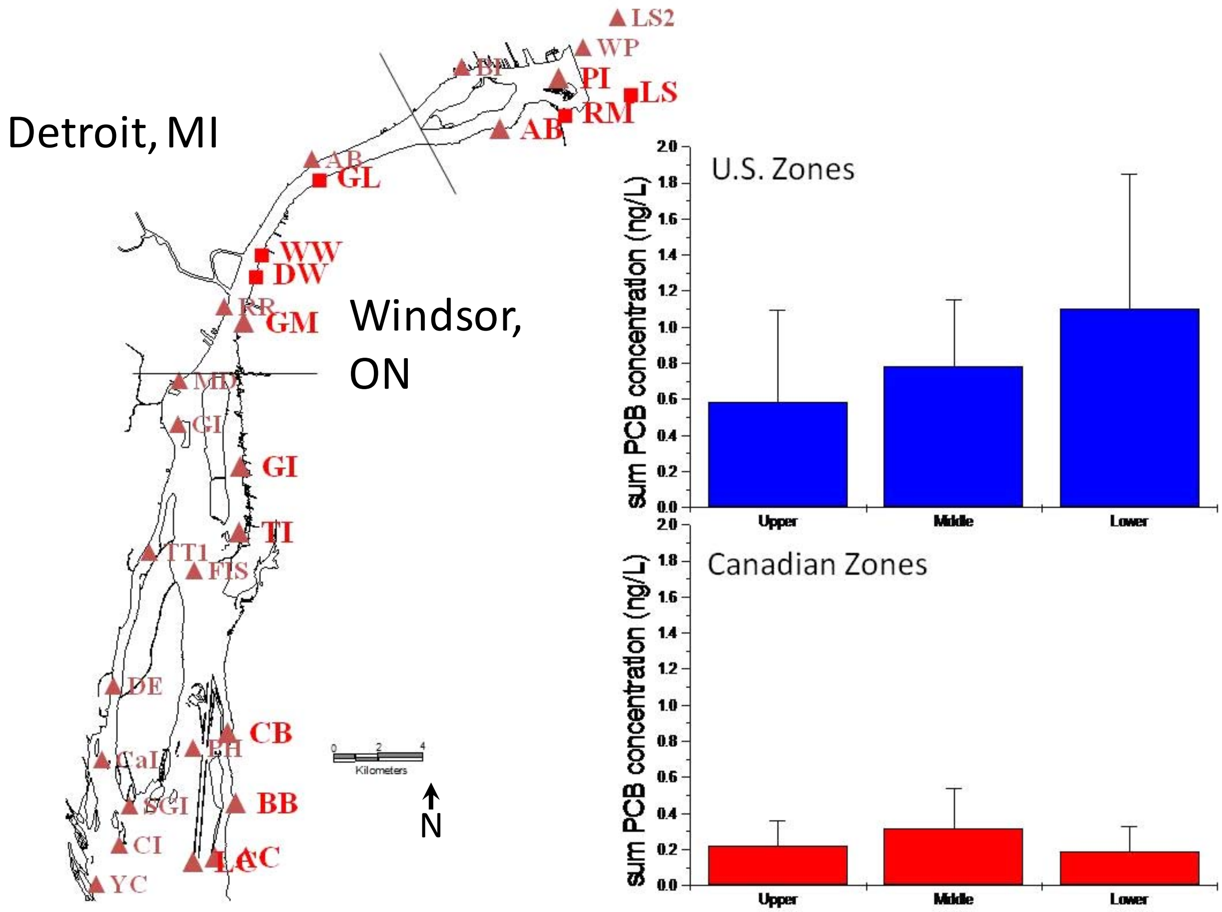


Figure 5. Spatial trends in mean±SD sum PCB concentration estimates averaged over the period of 1998-2008 for food web model zones.

Table 7. Congener specific mean and standard deviation PCB concentrations in water (pg/L) used as model inputs for U.S. upper, middle and lower food web modelling zones.

PCB	Upper		Middle		Lower	
Congener	Mean	SD	Mean	SD	Mean	SD
PCB #31/28	110.9	104.3	138.3	59.8	207.5	124.2
PCB #52	35.2	26.0	66.7	23.1	95.9	68.1
PCB #44	29.6	19.7	32.1	10.6	62.7	43.5
PCB #42/37	15.0	4.7	22.7	22.2	40.3	29.1
PCB #64/41/71	46.9	38.4	52.7	32.7	91.8	66.7
PCB #74	200.7	411.7	22.6	13.7	64.8	47.4
PCB #70/76	26.9	19.9	33.4	24.9	66.2	66.0
PCB #66/95	41.5	41.1	84.9	70.3	123.7	107.9
PCB #60/56	33.1	29.3	42.1	33.6	57.5	42.1
PCB #101	22.5	21.2	53.2	42.4	48.8	32.7
PCB #99	12.5	9.0	21.1	14.6	23.1	14.4
PCB #97	10.1	7.1	7.5	3.0	16.2	11.4
PCB #110/77	16.9	12.4	24.9	13.8	40.1	28.7
PCB #151	13.2	10.1	21.6	23.2	13.1	7.4
PCB #149/123	16.6	18.1	37.8	32.6	29.4	16.4
PCB #118	12.4	8.3	9.8	5.9	21.5	18.3
PCB #146	2.7	1.8	4.5	4.1	3.7	2.2
PCB #153/132	16.6	16.5	29.3	24.4	24.8	14.2
PCB #105	42.0	56.0	34.1	27.0	28.0	17.5
PCB #141	6.5	4.6	7.3	5.9	6.0	3.3
PCB #138/163	18.2	17.3	32.7	28.1	29.9	18.1
PCB #158	3.5	4.3	1.9	1.2	1.7	0.9
PCB #129	14.8	11.4	18.2	22.6	15.1	10.8
PCB #182/187	2.7	1.8	7.2	4.6	3.0	2.1
PCB #183	5.2	4.0	6.3	6.8	4.8	2.8
PCB #185	0.4	0.3	0.0	0.0	0.0	0.0
PCB #174	2.1	2.2	8.2	6.5	3.2	2.6
PCB #171/202	6.2	2.2	18.1	16.3	7.3	6.0
PCB #200	9.0	13.4	4.5	1.7	3.3	2.6
PCB #172	99.2	143.5	39.2	41.5	33.6	20.6
PCB #180	5.8	4.8	9.3	6.7	5.4	3.0
PCB #170/190	4.2	3.4	4.9	2.9	6.0	4.3
PCB #201	0.9	0.7	1.6	0.8	1.0	0.5
PCB #196/203	0.7	0.8	1.2	0.7	0.8	0.6
PCB #195/208	0.9	0.4	1.6	1.1	1.5	1.5
PCB #194	0.4	0.4	0.3	0.2	0.6	0.4
PCB #206	0.2	0.0	0.0	0.0	0.9	0.0

Table mean and standard deviation PCB concentrations in water (pg/L) used as model inputs for Canadian 8. Congener specific upper, middle and lower food web modelling zones.

PCBs	Upper		Middle		Lower	
	Mean	SD	Mean	SD	Mean	SD
PCB #31/28	34.2	32.8	47.5	42.9	49.0	32.2
PCB #52	20.6	16.0	32.6	17.5	28.5	17.4
PCB #44	17.5	15.1	39.6	39.1	21.9	10.1
PCB #42/37	16.3	12.6	32.2	34.9	10.3	6.9
PCB #64/41/71	19.2	14.9	26.9	31.1	27.4	17.8
PCB #74	7.5	3.6	18.1	14.2	13.5	12.5
PCB #70/76	8.6	5.3	14.3	9.3	13.4	5.7
PCB #66/95	15.3	8.0	21.9	12.2	20.7	9.5
PCB #60/56	17.2	37.2	15.1	9.6	11.0	5.7
PCB #101	11.9	7.1	14.5	10.0	12.2	5.2
PCB #99	6.5	7.1	7.6	8.7	9.2	4.9
PCB #97	5.0	5.3	6.5	8.0	5.7	2.8
PCB #110/77	10.3	6.0	14.4	10.3	10.9	4.7
PCB #151	5.6	4.8	4.7	4.0	3.5	2.9
PCB #149/123	12.7	11.7	10.0	8.8	7.2	3.1
PCB #118	5.7	4.6	7.2	5.1	6.5	2.9
PCB #146	2.2	1.8	2.0	1.3	1.3	0.7
PCB #153/132	10.3	8.2	8.0	8.0	6.7	4.4
PCB #105	5.2	3.9	7.2	13.7	3.8	1.7
PCB #141	3.1	2.5	2.8	1.9	2.4	1.6
PCB #138/163	12.7	9.5	10.9	9.4	8.5	4.5
PCB #158	1.4	2.7	1.1	0.9	0.4	0.0
PCB #129	12.6	11.4	6.8	7.4	5.3	2.9
PCB #182/187	1.4	1.3	1.7	1.9	0.9	0.4
PCB #183	3.8	3.9	2.1	1.8	1.6	1.1
PCB #185	0.0	0.0	0.8	0.2	0.0	0.0
PCB #174	1.8	1.5	2.0	2.2	1.0	0.4
PCB #171/202	2.4	1.3	2.1	1.4	4.1	1.3
PCB #200	3.2	1.8	2.1	1.3	1.7	1.2
PCB #172	25.4	24.5	11.7	12.2	10.5	5.7
PCB #180	2.2	2.1	1.6	2.0	2.0	1.0
PCB #170/190	2.8	2.7	1.3	1.2	3.4	3.5
PCB #201	0.9	0.7	0.6	0.5	0.4	0.2
PCB #196/203	0.5	0.4	0.5	0.4	0.4	0.2
PCB #195/208	1.1	1.0	0.6	0.5	0.4	0.2
PCB #194	0.3	0.2	0.3	0.8	0.3	0.3
PCB #206	0.1	0.0	0.4	0.0	0.9	0.0

Model Input Data: PCB Concentrations in Sediments

Contaminated sediments have been identified as a major issue in the Detroit River and have been linked to several beneficial use impairments associated with the remedial action plan for the system (UGLCCS 1989; GLIER 2002, Drouillard et al 2006). Many persistent organic and inorganic compounds released into the environment can bind or partition to particulate matter in the water column and settle on the riverbed. Once settled, the chemical may diffuse into the water column, contaminated particles may become resuspended and become transported downstream or the chemical may enter the food web via benthic feeding organisms.

Sediment concentration data were compiled chiefly from GLIER generated river-wide surveys of sediment quality conducted in 1998 (Drouillard et al 2006) and 2004 (unpublished). Although, additional data sets on sediment PCB concentrations were encountered (e.g. Kannon et al 2001, OMOE station at Fighting Island), it was decided to establish model inputs from the two GLIER data sets because of the comprehensiveness of these data and because both surveys utilized similar sample processing and analytical methods. Details of the sediment sampling design and spatial analysis of PCB contamination in the Detroit River are presented in Drouillard et al. (2006).

Briefly, the 1998 survey consisted of 147 sampling stations in the Detroit River that included the entire length and width of the system. Sampling stations were selected according to a stratified random sampling design to provide a representative description of sediment quality in the river. The stations were assigned to three lengthwise (upper, middle and lower) reaches along the river. The original divisions were based on large-scale features (hydraulic considerations, sediment transport and anthropogenic activities) suspected of being different in each reach. Sample stations were divided evenly between US and Canadian waters in each reach. The upper and middle reaches each contained 30 sample stations (40 percent of the total); the lower reach contained the majority of stations (90 stations or 60 percent of the total) as this portion of the river is downstream from potential chemical sources. The sampling strategy de-emphasized the dredged shipping channels since these areas are less susceptible to sediment accumulation. To minimize spatial clustering of the data set, the distance between stations was at least 300 m. Sediment sampling stations in the 1999 GLIER sediment survey are identified in Figure 6.

In 2004, a Huron-Erie corridor-wide sediment survey was implemented using similar techniques as described for the 1998 survey above. Within the Detroit River, 14 sediment sites were selected for analysis. The 14 Detroit River stations were chosen as randomized sites that had been sampled in the 1999 survey. The 2004 survey included 3 upper U.S., 2 middle U.S. and 3 lower U.S. re-sampled stations and 3 upper Canadian, 2 middle Canadian and 1 lower Canadian re-sampled stations.

Sediment data were analyzed to determine grain size distribution, total organic carbon content (TOC) and congener specific PCB concentrations expressed on a dry weight basis. All PCB concentration data were normalized to the TOC content in each sample to produce congener specific data on a ng/g organic carbon basis. Normalization to organic carbon content provides a better measure of PCB bioavailability from sediments (DiToro et al 1991) and standardizes the expression of PCB chemical potential in sediments across variable sediment types.

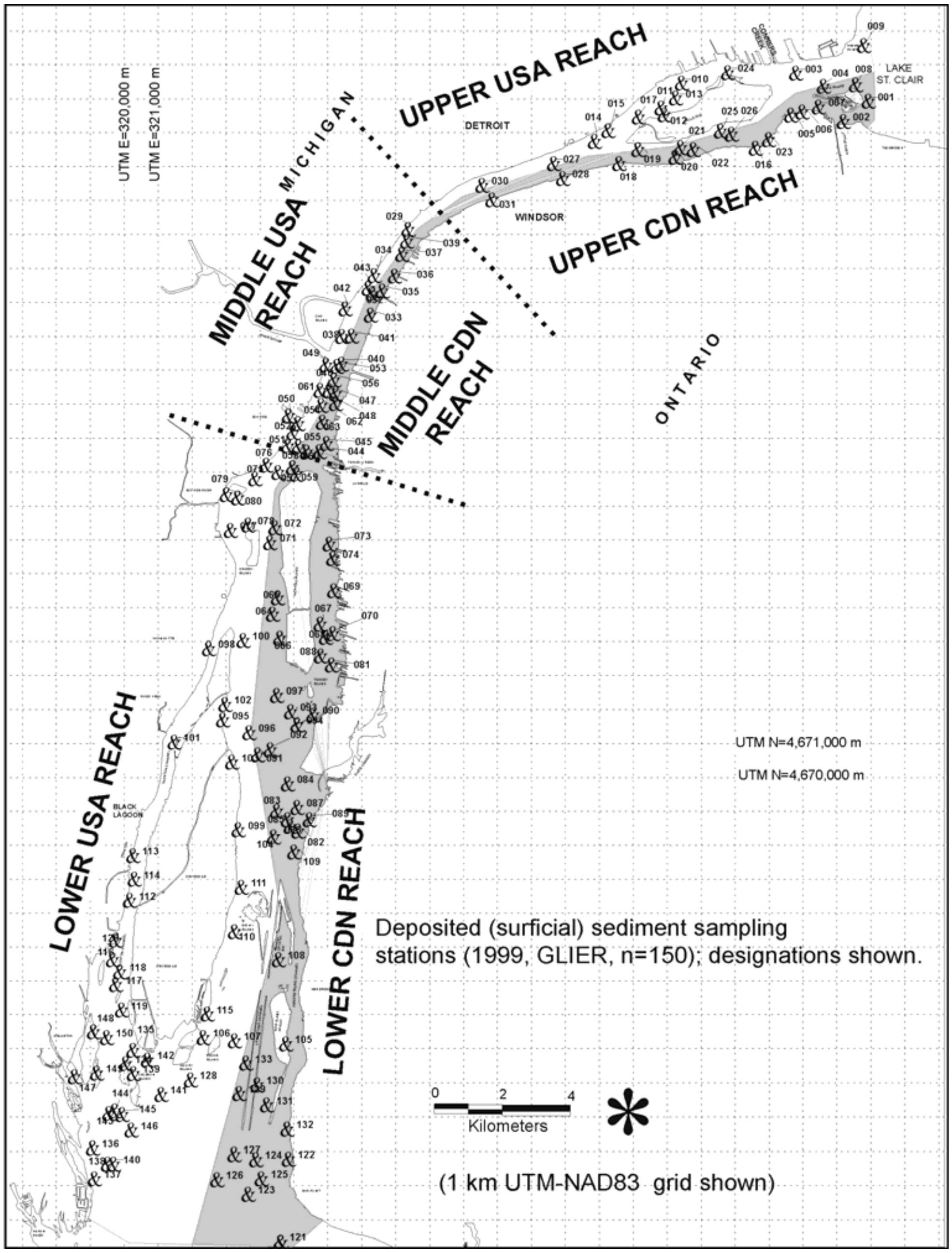


Figure 6. Locations of sediment sampling sites from the Detroit River in the 1999 GLIER sediment survey. In 2004 Canadian stations 1,5, 8, 31, 35, 68, 65and U.S. stations 3, 10, 15, 34, 53, 101, 136 and 145 were sampled again.

Table 9 summarizes station counts having detectable PCB residues allocated into each of the food web zones. For each food web modelling zone, mean TOC normalized congener specific PCB data were compiled as well as the standard deviation about each zone mean.

Table 9. Number of sediment sampling stations from GLIER 1999 and 2004 survey allocated to each of the food web modelling zones.

Food Web Zone	# U.S. Stations in Database	# Cdn Stations in Database
Upper	20	18
Middle	16	15
Lower	48	46

Non-detected data were excluded from central tendency measurement determinations.

Comparison of 1999 and 2004 PCB concentrations in Detroit River sediments

Fourteen stations re-sampled in 2004 had detectable concentrations of individual PCBs. Station specific, TOC-normalized sum PCB concentrations measured in 1999 were highly correlated sum PCB measurements made in 2004 ($R = 0.7$). A paired t-test on log normalized data indicated no significant differences ($p>0.8$; t-test) between station specific sum-PCB concentrations (sum of 37 model congeners) measured in 1999 compared to 2004. Figure 7 presents a scatter plot of 1999 and 2004 station results. The two outliers included station 15 and station 31. Station 15 had the highest measured sum PCB concentration of all stations examined in 1999 and the second highest measured in 2004. However, the 2004 sum PCB value for this site was 17 fold lower than that measured in 1999. This station is located at the near shore upstream U.S. zone of the Detroit River and reflects an area of highly dynamic flow and high suspended sediment resuspension potential. Station 31 was observed to have a 56 fold higher concentration in 2004 compared to 1999. This station was located in Canadian waters in the dynamic mid-stream section of the river. Apart from the above two stations, the 2004 and 1999 data generally yielded comparable PCB concentrations and as such the two data sets were combined to generate zone specific food web bioaccumulation model inputs. The lack of temporal trends in sediment contamination are consistent with the water concentration database that indicated no significant changes in PCBs in water between 1998 to 2008.

Spatial patterns of sum PCB concentrations in the Detroit River sediments.

Spatial patterns of PCB concentrations in sediments of the Detroit River from the 1998 sediment survey are described in detail in Drouillard et al (2006). Stations from the U.S. sediments had significantly higher ($p<0.001$; ANOVA) mean sum PCB concentrations compared to Canadian stations that were 7.3 fold higher on average when stations were grouped by country. Both U.S. and Canadian stations exhibited increasing trends with downstream distance when stations were analyzed as the linear downstream distance for each country (Drouillard et al 2006). The latter gradients were less evident when stations were grouped into the food web modelling zones (Figure 8). Canadian zones exhibited progressive, but non-significant increases ($p>0.05$; ANOVA) in mean zone specific sum PCB concentrations from upstream, mid-stream to downstream zones. U.S. zones exhibited slight, but non-significant ($p>0.05$) declines in mean sum PCB concentrations from upstream to downstream zones. U.S. zones in the upper and lower modelling zones were significantly higher ($p<0.05$) compared to the adjacent Canadian stations but were not significantly different (p>0.1) in the middle zone. Further discussion about potential sources of PCBs to sediments and comparisons of the 1999 data with river wide surveys conducted in the 1980's are described in Drouillard et al. (2006).

Tables 10 and 11 summarizes the zone and PCB congener specific mean ± standard deviation sediment concentration values utilized as inputs to the Detroit River Fish Consumption Hazard Assessment model.

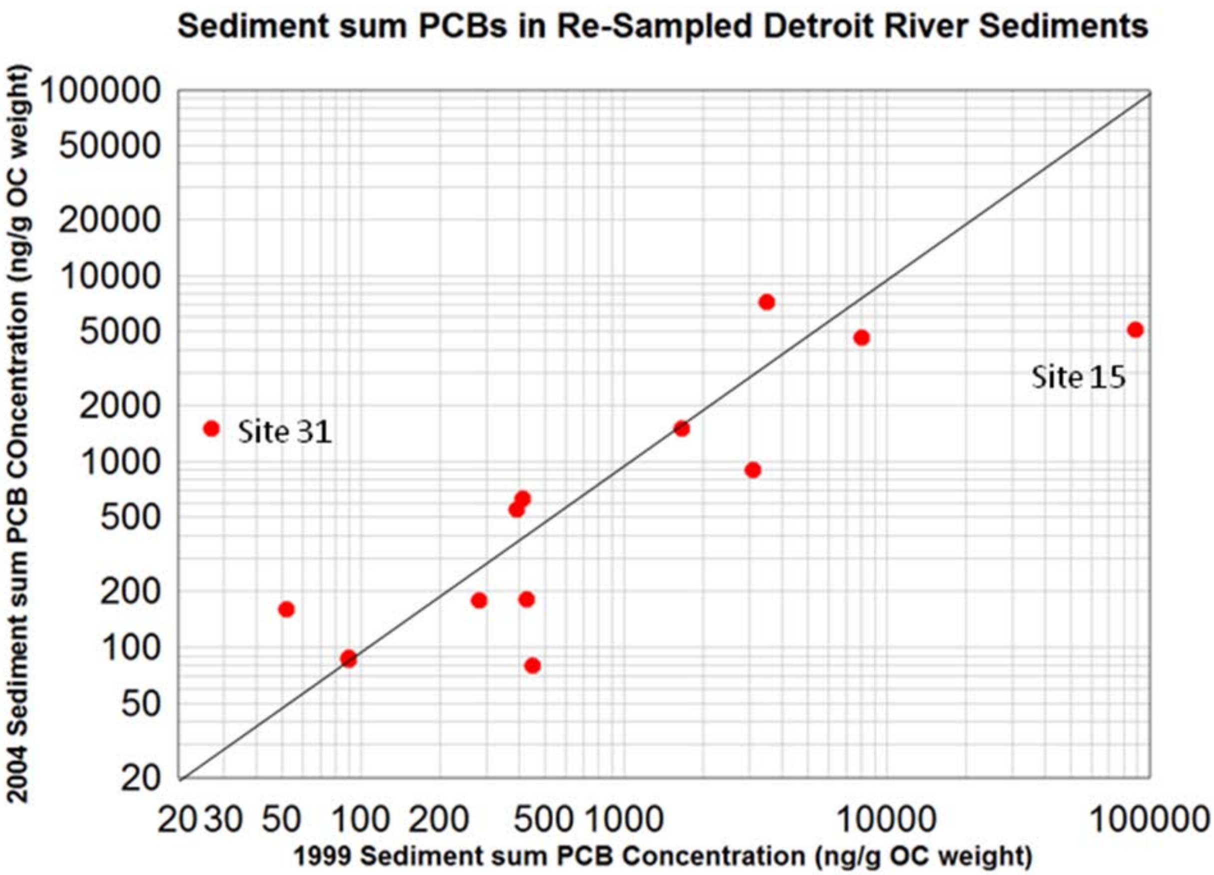


Figure 7. Relationship between station-specific sum PCB concentrations in Detroit River sediments measured in 1999 compared to 2004 sampled locations. Solid line represents the perfect fit relationship between the two data sets.

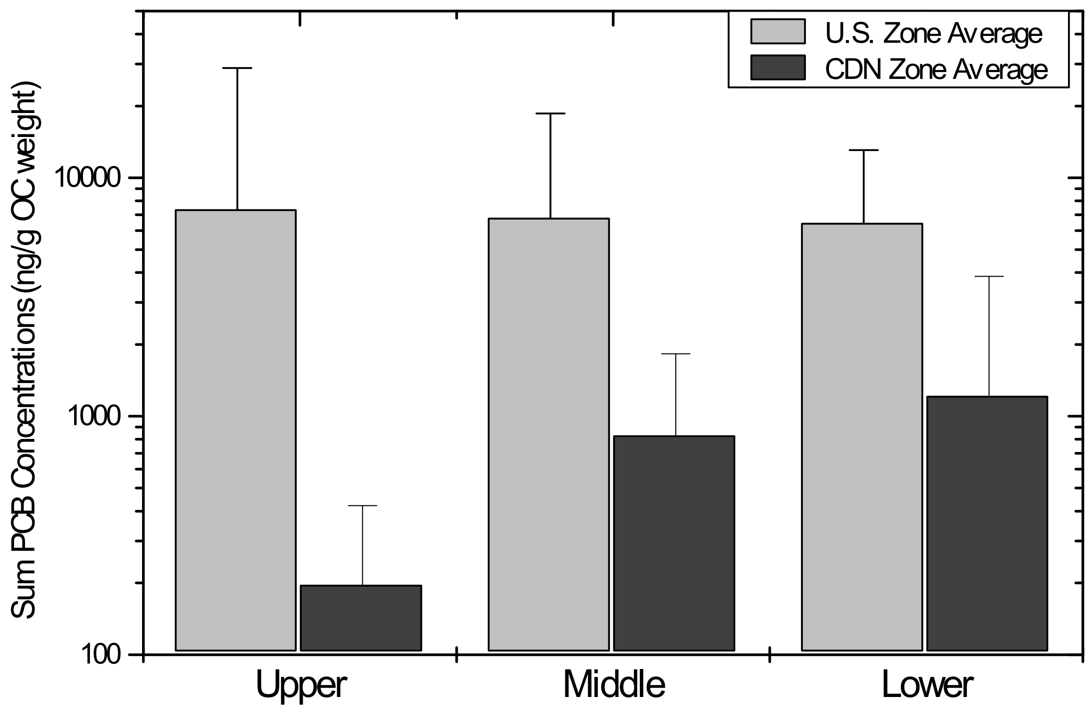


Figure 8. Mean sum PCB concentrations in sediments from each food web modelling zone based on 1999 and 2004 GLIER sediment survey data sets.

Table 10. Mean and standard deviation congener specific PCB concentrations (ng/g OC normalized weight) in sediments in each of the U.S. food web modelling zones.

PCB Congener	Upper Zone			Middle Zone			Lower Zone		
	Mean ng/kg OC	SD	Detects	Mean ng/kg OC	SD	Detects	Mean ng/kg OC	SD	Detects
PCB #31/28	218.9	455.5	16	206.1	379.2	13	262.7	254.2	46
PCB #52	362.4	1021.1	19	426.5	822.0	15	371.9	359.4	47
PCB #44	212.5	590.1	18	172.0	236.6	14	263.0	277.6	47
PCB #42/37	799.6	2007.5	9	271.6	484.7	10	381.0	640.4	45
PCB #64/41/71	53.7	122.3	18	27.0	43.7	12	54.8	83.1	46
PCB #74	121.5	274.2	13	140.4	126.2	7	177.9	207.1	46
PCB #70/76	183.0	481.8	17	241.8	357.6	13	338.1	417.2	47
PCB #66/95	334.6	987.1	18	385.2	703.7	15	320.7	316.6	47
PCB #60/56	194.4	495.6	16	269.4	532.7	14	214.5	237.7	47
PCB #101	347.2	1022.9	18	516.2	989.5	15	277.0	268.8	47
PCB #99	132.4	377.4	18	232.7	480.1	13	104.1	105.8	46
PCB #97	104.1	306.0	17	136.9	238.1	12	72.0	72.9	46
PCB #87	136.1	372.6	17	207.7	422.7	15	115.8	120.4	47
PCB #77/110	293.3	837.9	18	396.4	801.0	15	258.1	249.3	47
PCB #151	125.3	334.6	18	158.9	235.6	14	126.6	116.1	46
PCB #149/123	358.2	1014.0	19	422.9	724.8	15	286.5	272.6	47
PCB #118	392.4	1132.7	17	748.1	1263.8	11	305.1	403.7	46
PCB #146	73.1	197.9	16	118.8	173.7	10	88.9	95.9	45
PCB #153/132	389.2	1030.1	19	485.2	785.8	15	354.1	345.4	47
PCB #105	181.7	442.1	15	149.9	217.1	9	149.2	154.3	43
PCB #141	140.1	388.8	18	165.8	201.2	11	96.8	111.2	41
PCB #138/163	610.7	1829.9	19	693.2	1256.4	15	411.1	427.9	47
PCB #158	88.3	150.4	7	78.3	93.3	8	44.8	73.4	35
PCB #129	88.0	184.3	11	114.6	130.2	9	49.7	51.3	40
PCB #182/187	285.0	720.5	15	155.7	189.0	14	188.5	199.9	46
PCB #183	154.0	365.6	13	81.0	94.7	12	93.9	96.5	45
PCB #185	44.4	63.9	8	42.2	69.9	9	22.0	29.0	40
PCB #174	297.2	739.4	14	157.2	171.2	12	145.7	145.0	45
PCB #171/202	226.2	436.2	9	87.4	74.4	9	77.9	87.1	45
PCB #200	86.3	107.5	5	63.7	41.7	8	29.3	34.4	37
PCB #172	39.3	67.0	12	109.7	246.9	9	25.3	53.1	43
PCB #180	651.8	1742.8	16	305.7	354.8	14	307.9	312.2	47
PCB #170/190	373.9	937.6	15	211.0	267.9	13	167.7	170.2	46
PCB #201	195.1	457.4	13	96.5	92.8	11	143.1	164.4	44
PCB #196/203	124.8	321.3	15	63.4	58.4	11	98.0	120.5	43
PCB #195/208	91.2	177.1	9	54.4	69.4	10	52.0	57.6	43
PCB #194	139.7	348.2	14	59.6	59.0	12	99.3	112.1	44

PCB #206	112.4	305.2	12	22.6	21.0	9	73.2	109.2	45

Table 11. Mean and standard deviation congener specific PCB concentrations (ng/g OC weight) in sediments in each of the Canadian food web modelling zones.

PCB Congener	Upper Zone			Middle Zone			Lower Zone		
	Mean	SD	Detects	Mean	SD	Detects	Mean	SD	Detects
	ng/kg OC			ng/kg OC			ng/kg OC		
PCB #31/28	63.2	112.6	5	73.0	87.4	11	79.3	199.3	41
PCB #52	35.5	52.9	12	99.5	114.2	12	114.8	254.5	43
PCB #44	21.4	28.8	15	56.5	62.0	13	75.9	158.7	44
PCB #42/37	24.3	31.3	2	51.7	55.0	9	66.3	156.3	33
PCB #64/41/71	22.8	57.4	8	15.1	15.7	11	9.7	22.6	43
PCB #74	16.0	21.2	3	62.7	51.7	9	57.3	113.0	32
PCB #70/76	20.2	32.5	6	95.0	83.9	9	92.6	232.9	39
PCB #66/95	17.4	20.8	15	64.6	68.7	13	79.9	184.1	46
PCB #60/56	16.6	20.0	7	53.7	43.6	10	58.4	127.9	42
PCB #101	17.6	14.5	12	51.1	47.9	12	64.8	131.0	44
PCB #99	8.2	8.3	6	29.9	29.5	10	31.0	60.6	41
PCB #97	6.7	7.9	5	19.3	15.0	10	23.0	45.8	41
PCB #87	8.5	7.2	9	25.1	21.2	11	31.1	62.7	42
PCB #77/110	14.7	15.9	16	43.0	46.7	14	67.7	139.3	44
PCB #151	9.1	6.8	8	17.5	14.4	10	17.4	30.9	42
PCB #149/123	17.5	18.9	14	32.3	34.3	12	42.9	67.3	45
PCB #118	13.8	14.4	5	59.8	63.7	10	91.6	222.0	40
PCB #146	4.0	3.6	5	6.6	4.7	8	7.6	10.9	36
PCB #153/132	21.3	25.1	13	31.9	32.2	12	44.2	72.6	44
PCB #105	9.3	9.0	8	28.6	21.2	10	28.9	36.0	40
PCB #141	6.4	7.3	7	12.3	11.8	9	14.8	21.7	37
PCB #138/163	19.8	24.5	16	41.2	41.1	12	61.3	107.8	45
PCB #158	40.9	67.1	3	4.0	1.6	6	5.5	10.8	22
PCB #129	3.2	2.5	4	6.9	5.1	5	7.7	9.8	30
PCB #182/187	18.6	17.3	9	17.8	24.1	10	18.7	25.0	42
PCB #183	7.2	7.3	7	12.5	12.6	6	8.7	12.3	40
PCB #185	6.4	0.3	2	4.9	3.4	4	3.0	2.3	8
PCB #174	12.4	12.5	7	16.7	19.6	7	16.1	26.3	33
PCB #171/202	4.2	3.7	3	14.9	17.3	4	8.9	15.4	30
PCB #200	10.5	14.9	2	5.1	5.5	3	5.5	5.2	10
PCB #172	3.5	4.8	5	6.3	4.2	5	3.4	4.8	23
PCB #180	27.1	32.2	9	29.0	45.8	11	28.8	42.0	43
PCB #170/190	15.7	21.3	7	28.5	26.3	6	19.0	29.3	42
PCB #201	7.7	6.7	6	14.7	15.9	7	11.5	15.3	37
PCB #196/203	5.3	5.4	6	10.0	11.8	6	7.7	11.1	36
PCB #195/208	7.3	9.2	4	7.2	8.0	4	5.9	7.5	27
PCB #194	8.0	8.2	8	9.6	12.5	7	8.4	12.4	34

PCB #206	11.0	13.2	6	8.2	8.7	9	8.7	13.3	34

Empirical Data Base on Sport Fish PCB Concentrations

The original Detroit River Fish Consumption Hazard Assessment model was validated using a GLIER generated food web data set that included PCB analysis in 108 sport fish samples collected from 4 locations in the Detroit River. As part of the present project, additional data were compiled for sum PCB concentrations, fillet lipid and body length for sport fish generated by the Michigan and Ontario sport fish contaminant monitoring programs. Prior to inclusion in the database, samples were censored to exclude fish caught outside of the Detroit River boundaries (i.e. Lakes Erie and Lake Huron fish) and fish data from sample collections taken prior to 1998. The combined validation data set provided a total of 621 sample records distributed across 18 sport fish species and collected in 5 of the 6 modelling zones.

Dorsal muscle lipid content is an important parameter input to the Detroit River Fish Consumption Hazard Assessment model. Thus, the data on dorsal muscle lipid contents were compiled for all species included in the model. Differences in fillet sample processing methods between the two jurisdictions (Ontario and Michigan) explains some of the variation in lipid content by species. Michigan uses a skin-on sample fillet, whereas, Ontario uses a skin-off sample fillet for contaminant residue analysis. Dorsal muscle lipid contents for each species are summarized in Table 13. Unfortunately, there were relatively few species available that had adequate replicates of both skin-on and skin-off dorsal muscle lipid contents to generalize comparisons. For three species (common carp, freshwater drum and walleye) skin-on dorsal muscle samples had mean lipid contents from 40 to 200% higher compared to mean values generated for skin-off fillet samples. For yellow perch, skin-on samples had lower lipid contents compared to skin-off species. Due to the lack of data comparing the two fillet processing methods for most species, the difference in lipid content of fillets were not taken into consideration when parameterizing model simulations. For model inputs, the combined lipid estimate using all samples from a given species collected from the Detroit River was used.

A summary of the frequencies over which different species of sport fish exceed fish advisory trigger levels are provided in Table 14. Combining all species, 82.8% of sport fish had PCB concentrations in excess of the least restrictive threshold of 50 ng/g applied by Michigan while 63.8% of samples had sum PCB concentrations above Ontario's least restrictive threshold of 105 ng/g. No consumption advisory triggers for the Ontario sensitive sub population begin at 211 ng/g, 844 ng/g (Ontario general public) and 1890 ng/g (Michigan general public). Exceedences above these thresholds were 39.1%, 5.3% and 2.1% across species and zones in the Detroit River, respectively. The river wide mean common carp sum PCB concentrations exceeded the Ontario Sensitive Population No Consumption advisory trigger threshold of 211

Table 12: Mean±Standard deviation sum PCB concentrations in sport fish dorsal muscle measured from government fish advisory programs and GLIER surveys over the period of 1999-2008.

Sport Fish Species	Upper Canadian Zone	Middle U.S. Zone	Middle Canadian Zone	Lower U.S. Zone	Lower Canadian Zone
Black Crappie					3 (1, GLI)
Bluegill Sunfish	276 (1, GLI)		30±18 (3, GLI)		42±22 (4, GLI)
Brown Bullhead	10 (2, GLI)				
Common Carp	444±751 (33, GLI, MOE)	1905±2956 (8, MDQ)	1221±1937 (7, GLI)	628 (2, GLI)	232±234 (16, GLI, MOE)
Channel Catfish	522±785 (18, GLI, MOE)				
Freshwater Drum	127±200 (18,MOE)	414±251 (10, MDQ)			169±189 (31, MOE)
Gar Pike	252±108 (3, GLI)		374±282 (8, GLI)		456 (2, GLI)
Gizzard Shad	80±95 (6, GLI)				136±99 (7, GLI)
Largemouth Bass	42±14 (5, GLI)				59±23 (5, GLI)
Muskellung	1056 (2, GLI)				115±54 (8, GLI)
Northern Pike	14±4 (5, GLI)				29 (2, GLI)
Rock Bass	130±136 (9, GLI, MOE)			47±23 (3, GLI)	69±22 (5, MOE)
Smallmouth Bass	85±96 (3, GLI)				256±96 (4, GLI)
Sucker (White, Redhorse)	180 (1,GLI)	339±286 (10, MDQ)			
Walleye	129±148 (56, GLI, MOE)			593±401 (16, MDQ)	140±121 (44, MOE, GLI)
White Bass	285±182 (97, MOE)			229±50 (3, GLI)	280±202 (101, MOE, GLI)
White Perch	171±71 (10, GLI, MOE)				362±185 (20, MOE)
Yellow Perch	43±23 (11, GLI, MOE)	28 ±18 (10, MDEQ)		82±76 (5, GLI)	64±31 (5, MOE)

Number in bracket indicates number of replicate fish per species in each zone. Source of information is also identified. MOE = Ontario Ministry of Environment, GLI=Great Lakes Institue for Environmental Research, MDQ = Michigan Department of Environmental Quality.

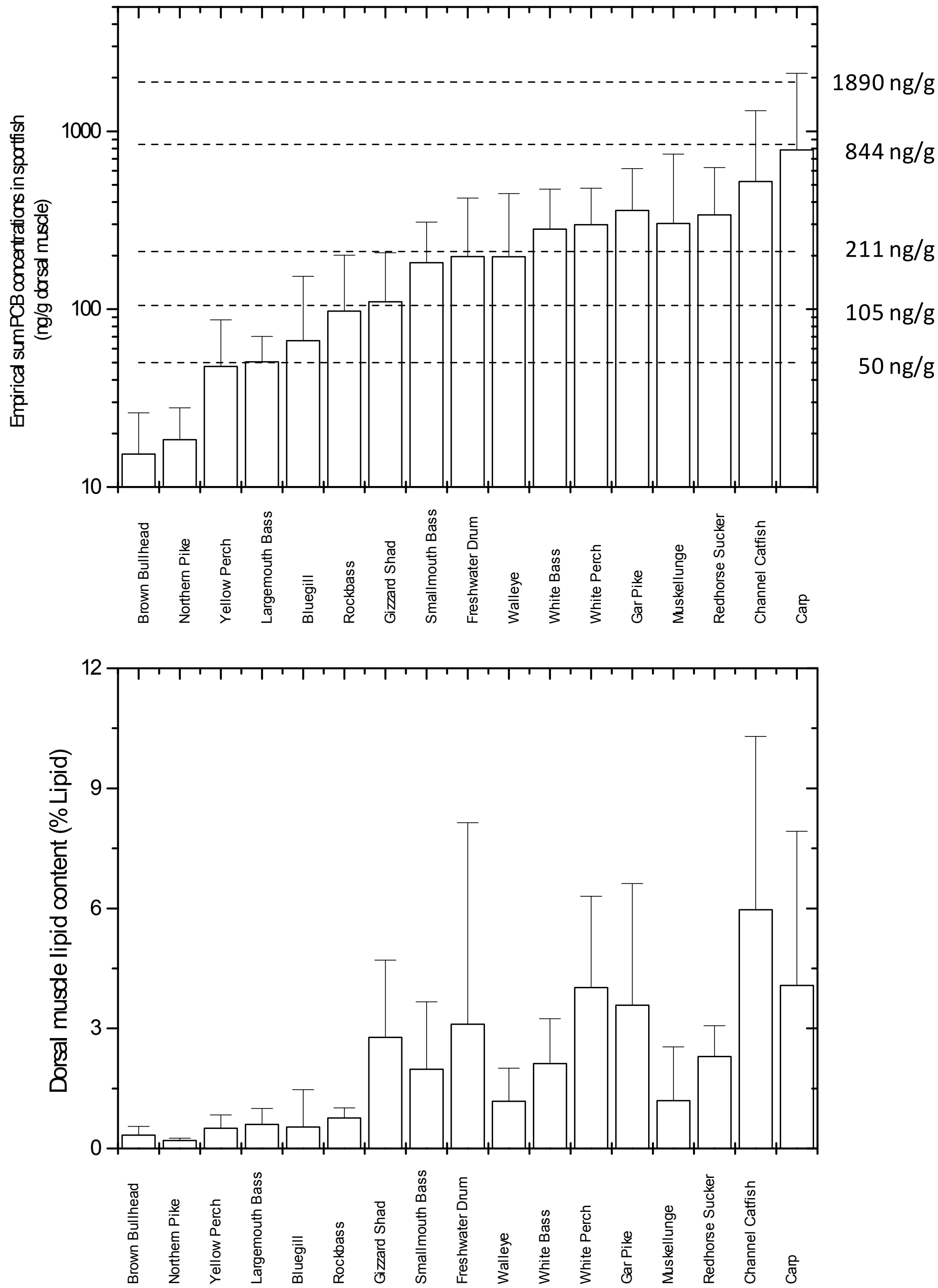


Figure 9. Measured mean±standard deviation (error bars) sum PCB concentrations in sport fish in the Detroit River organized by species (top graphic). Dashed horizontal lines present threshold trigger levels used to set fish consumption advisory advice. Mean±standard deviation dorsal muscle lipid contents in sport fish species from the Detroit River (bottom graphic).

ng/g and approached the Ontario General Public No Consumption advisory trigger threshold of 844 ng/g. No other species had mean measured sum PCB concentrations at the General Public No Consumption advisory trigger. However, several species had river-wide mean sum PCB concentrations in dorsal muscle exceeding the Ontario Sensitive Population No Consumption advisory trigger. This included: common carp, channel catfish, sucker, muskellunge, gar pike, white perch and white bass. Mean river wide sum PCB concentrations for smallmouth bass, freshwater drum and walleye were close to the Ontario Sensitive Population No Consumption advisory trigger. Only two species, brown bullhead and northern pike, had concentrations below the least restrictive fish advisory trigger established at 50 ng/g dorsal muscle tissue by Michigan.

Analysis of variance performed on log normalized data indicated that zone, species, dorsal muscle lipid content and total length were all significant predictors ($p<0.001$; ANOVA) of sum PCB concentrations in Detroit River fish samples. The overall statistical model explained 55% of the variation among samples. Lipid content explained most of the variation (52%) in the model with smaller variation explained by the variables in order of importance: species, fish length and zone. However, the uneven distribution of samples across different zones and low replicate sizes in some areas of the Detroit River negated the ability to generate a strong statistical predictive model for sport sum PCB concentrations. A more detailed examination of the influence of collection site, lipid content and total length was performed on common carp, freshwater drum, walleye and yellow perch since these species had data associated with at least three food web modelling zones and had at least 20 sample replicates for generating simple specifies specific statistical models.

For common carp, 66 samples were available from 5 food web modelling zones. The different samples ranged from 0.12 to 16.4% lipid in dorsal muscle samples and from 28 to 72.7 cm in length. Sum PCB concentrations ranged from 22 to 6754 ng/g wet weight with an overall river wide mean of 785±1330 ng/g. Mean Sum PCB concentrations by model zone for common carp are presented in Figure 10. The middle U.S. zone had the highest mean sum PCB concentration at 2956±1905 ng/g that was above the most restrictive advice threshold trigger (Michigan General Public). Common carp sum PCB concentrations in the middle Canadian zone were second highest, with a mean value above the Ontario General Population No Consumption threshold trigger. In the Upper Canadian and Lower U.S./Canadian Zones, common carp sum PCB concentrations were generally above the Ontario Sensitive Sub-Population no consumption trigger, but lower than the general population no consumption trigger thresholds. Sum PCBs in common carp were highly significantly related to dorsal muscle lipid content ($p<0.001$; ANOVA) and zone of capture ($p<0.001$; ANOVA), but not significantly related to total length ($p>0.05$; ANOVA). An ANCOVA was performed to compare zone specific differences in sum PCB concentrations of carp after adjusting for lipid content as a covariate. The analysis and post-hoc comparisons indicated significant differences between common carp concentrations between upper Canadian and middle US ($p<0.001$; Tukey's HSD) and between lower Canadian and middle US ($P<0.001$; Tukey's HSD). No differences in lipid-adjusted carp PCB concentrations were apparent between the middle U.S. and middle Canadian zone (>0.3) and between middle and lower U.S. zones ($p>0.1$) although such comparisons were limited by small sample sizes of fish collections in the two zones.

For freshwater drum, there were 59 samples available from the upper Canadian, middle U.S. and lower Canadian zones. Dorsal muscle lipid contents varied from 0.2 to 34% and total lengths ranged from 30.6 to 57.7 cm. Mean sum PCB concentrations by zone are summarized in Figure 11. Middle U.S. zone had the highest mean sum PCB concentration averaging 413±251 ng/g and exceeded the Ontario sensitive sub-population 'No consumption' advisory trigger. Upper and lower Canadian zones had sum PCB concentrations that exceeded the Ontario least restrictive fish consumption advisory triggers of (105 ng/g). For this species, sum PCB concentrations were highly significantly related to lipid ($p<0.001$; ANOVA) and total fish length ($p<0.05$) but not significantly related to zone of capture ($p>0.05$).

Table 13: Mean lipid contents in sport fish dorsal muscle measured from government fish advisory programs and GLIER surveys over the period of 1999-2008.

Sport Fish Species	Skin-off	Skin-on	Combined
Black Crappie	0.07 (1)	NA	0.07
Bluegill Sunfish	0.54±0.93 (8)	NA	0.54±0.93
Brown Bullhead	0.33±0.22 (3)	NA	0.33±0.22
Common Carp	3.47±3.35 (58)	8.49±4.60 (8)	4.08±3.85
Channel Catfish	5.97±4.33 (18)	NA	5.97±4.33
Freshwater Drum	2.91±5.47 (49)	4.05±1.60 (10)	3.10±5.04
Gar Pike	3.58±3.04 (13)	NA	3.58±3.04
Gizzard Shad	2.78±1.93 (13)	NA	2.78±1.93
Largemouth Bass	0.6±0.4 (10)	NA	0.6±0.4
Muskellung	1.19±1.3 (10)	NA	1.19±1.3
Northern Pike	0.20±0.06 (7)	NA	0.20±0.06
Rock Bass	0.76±0.25 (17)	NA	0.76±0.25
Smallmouth Bass	1.98±1.65 (7)	NA	1.98±1.65
Sucker (White, Redhorse)	7.57 (1)	2.3±0.77 (10)	2.3±0.77
Walleye	1.08±0.75 (100)	1.81±1.02 (16)	1.18±0.83
White Bass	2.12±1.12 (201)	NA	2.12±1.12
White Perch	4.02±2.28 (30)	NA	4.02±2.28
Yellow Perch	0.61±0.36 (21)	0.29±0.12 (10)	0.51±0.33

Table 14: Percent of fish (Number) exceeding threshold trigger levels in all zones

Sport Fish Species	Michigan Least Restrictive Advice Trigger (50 ng/g ww)	Ontario Least Restrictive Advice Trigger (105 ng/g ww)	Ontario No Consumption Sensitive Sub. Pop. Trigger (211 ng/g)	Ontario No Consumption General Pop. Trigger (844 ng/g)	Michigan No Consumption General Pop. Trigger (1890 ng/g)
All Species	83% (514/621)	64% (396/621)	39% (243/621)	5% (33/621)	2% (13/621)
Black Crappie	0% (1)	0%	0%	0%	0%
Bluegill Sunfish	38% (3/8)	13% (1/8)	13% (1/8)	0 %	0%
Brown Bullhead	0% (0/3)	0%	0%	0%	0%
Common Carp	85% (56/66)	67% (44/66)	46% (30/66)	24% (16/66)	18% (12/66)
Channel Catfish	100% (18/18)	94% (17/18)	56% (10/18)	17% (3/18)	6% (1/18)
Freshwater Drum	70% (41/59)	46% (27/59)	34% (20/59)	27% (1/59)	0%
Gar Pike	100% (13/13)	92% (12/13)	54% (7/13)	0%	0%
Gizzard Shad	548% (7/13)	46% (6/13)	15% (2/13)	0%	0%
Largemouth Bass	40% (4/10)	0%	0%	0%	0%
Muskellunge	100% (10/10)	50% (6/10)	20% (2/10)	10% (1/10)	0%
Northern Pike	0% (0/8)	0%	0%	0%	0%
Rock Bass	59% (10/17)	24% (4/17)	12% (2/17)	0%	0%
Smallmouth Bass	71% (5/7)	71% (5/7)	43% (3/7)	0%	0%
Sucker (White, Redhorse)	100% (11/11)	82% (9/11)	46% (5/11)	9% (1/11)	0%
Walleye	82% (95/116)	46% (54/116)	24% (28/116)	5% (6/116)	0%
White Bass	100% (201/201)	92% (184/201)	56%(113/201)	3%(5/201)	0%
White Perch	97% (29/30)	87% (26/30)	63% (19/30)	0%	0%
Yellow Perch	39% (12/31)	3% (1/31)	3% (1/31)	0%	0%

Walleye had 116 samples available from three food web zones having lipid contents in the range of 0.1 to 5.25% and body lengths of 28.6 to 72.2 cm. The highest mean sum PCB concentrations were observed in samples collected from the Lower U.S. food web zone which averaged 593±400 ng/g wet weight (Figure 12). The latter level exceeded the Ontario Sensitive sub-population trigger for 'No consumption' advice. Mean walleye sum PCB concentrations in the upper Canadian and lower Canadian zones were above the Ontario least restrictive trigger threshold but below the 'No Consumption' advice threasholds for this jurisdiction. As with other fish species, dorsal muscle lipid was a highly significant ($p<0.001$; ANOVA) predictor of fish sum PCB concentrations but not fish length ($p>0.8$; ANOVA). After adjustment for lipid concentrations using ANCOVA, sum PCB concentrations were observed to be highly significantly different in the lower U.S. zone compared to the upper Canadian ($p<0.001$; Tukey's HSD) and lower ($p<0.001$; Tukey's HSD) Canadian zones.

The last species for zone wide comparisons was yellow perch which had samples collected from 4 food web modelling zones. A total of 31 samples were available for this species having lipid contents in the range of 0.1 to 1.38% and total lengths from 15.4 to 35.9 cm. The highest mean sum PCB concentrations were observed in the Lower U.S. zone closely followed by the lower Canadian zone (Figure 13). In both the above zones, mean sum PCB concentrations in yellow perch exceeded the threshold trigger for Michigan's least restrictive advice information (50 ng/g), but were below the threshold trigger for Ontario's least restrictive advice information (105 ng/g). Mean sum PCB concentrations in yellow perch from the upper Canadian and Middle U.S. zones were below least restrictive advice thresholds in both jurisdictions. For this species, there were no significant relationships between sum PCB concentrations in dorsal muscle and dorsal muscle lipid content ($p>0.1$) or fish length ($p>0.8$). Between food web sampling zones, sum PCB concentrations approached a significant difference ($p=0.052$; ANOVA) among zones driven largely by the difference between sum PCB concentrations in middle U.S. and lower U.S. collected fish.

Overall, the empirical data base provides evidence for differences in sum PCB concentrations between different sport fish species and across different spatial zones with the Detroit River. With the exception of yellow perch, the dorsal muscle lipid content was strongly associated with the amount of PCB measured in sport fish fillet samples. In particular, those species with more than 3.5% lipid in their dorsal muscle were more likely to have sum PCB concentrations that exceeding the Ontario No Consumption advice trigger for the Women and Children. Fish species that had high lipid content and were also benthic feeders such as common carp and channel catfish had the highest sum PCB concentrations in edible fish flesh. Fish length was weakly associated with sum PCB concentrations when using the constrained empirical data set. The significance of this parameter towards predicting PCB residues levels was also found to differ from species to species. Despite the relatively large empirical data base on sum PCB concentrations in Detroit River Sportfish, there were clear data gaps evident with respect to where fish collections were made and availability of replicates at different spatial locations within the river. In the U.S. zones, there were much fewer fish species represented in the empirical data base compared to upper and lower Canadian zones. For example, no empirical data for the U.S. was available for bluegill sunfish, brown bullhead, channel catfish, gar pike, gizzard shad, largemouth bass, muskellunge, northern pike, rock bass, smallmouth bass or white perch.

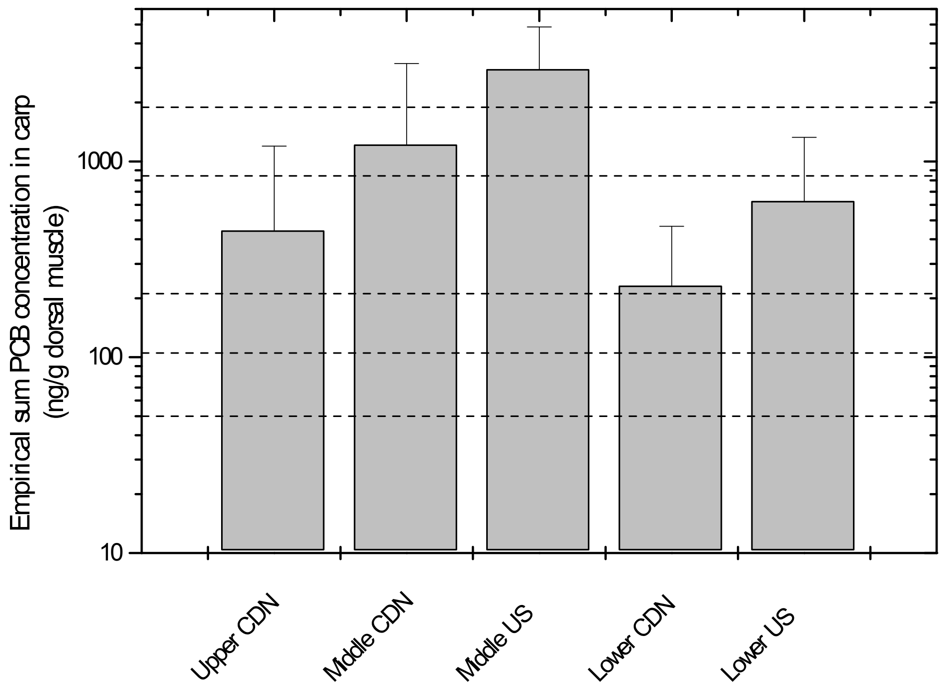


Figure 10. Sum PCB concentrations in common carp from the Detroit River.

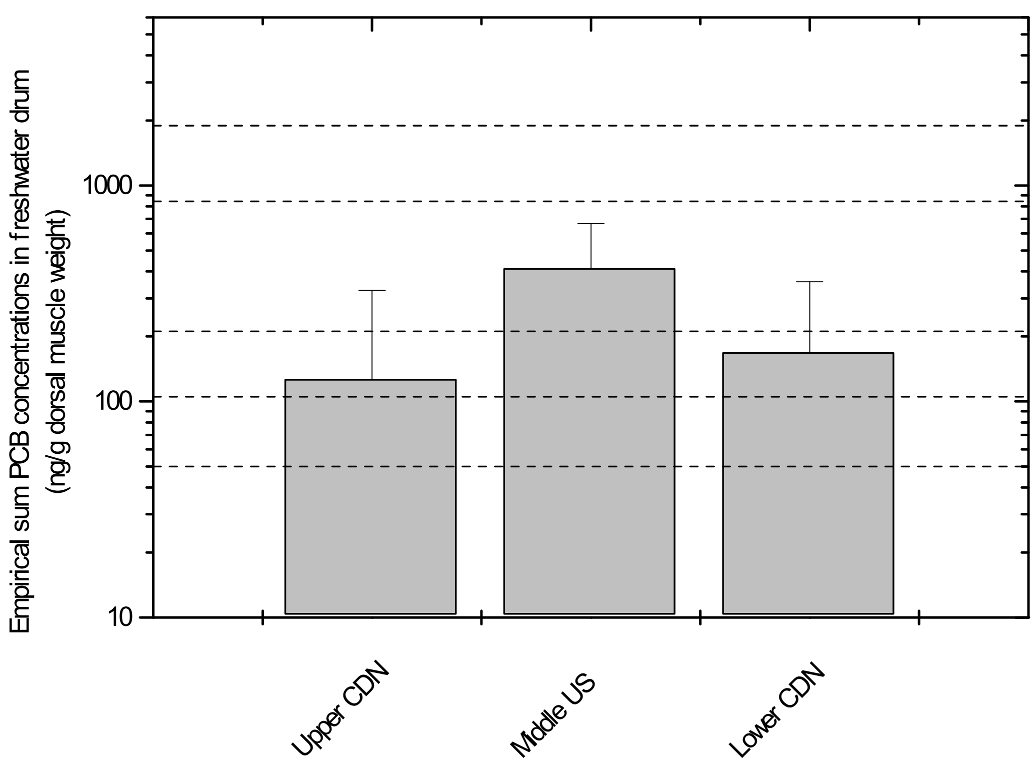


Figure 11. Sum PCB concentrations in freshwater drum from the Detroit River

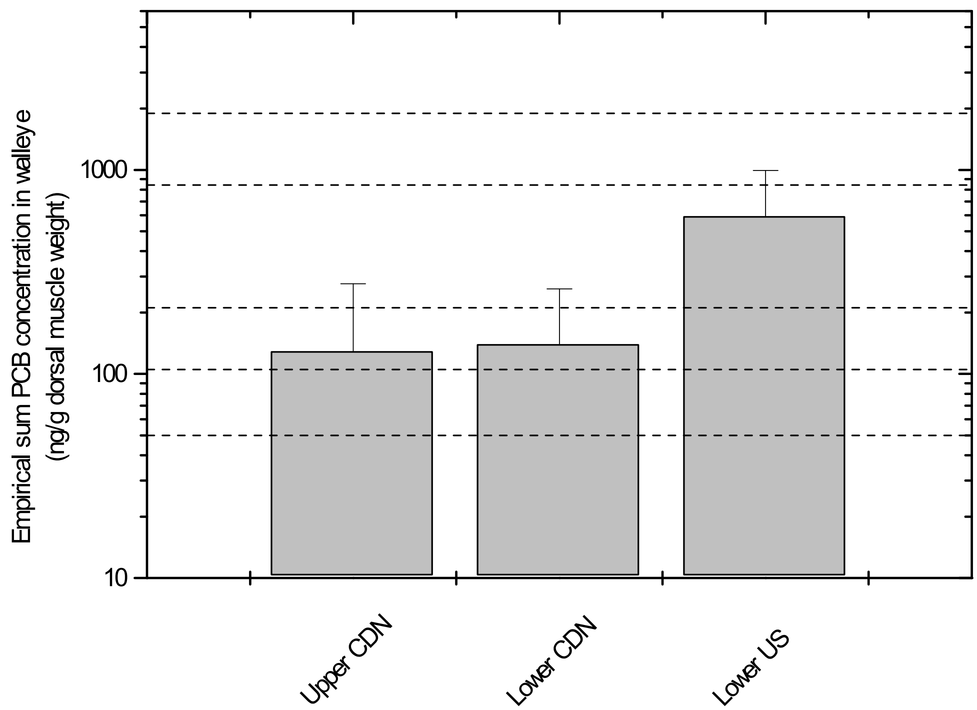


Figure 12. Sum PCB concentrations in walleye from the Detroit River.

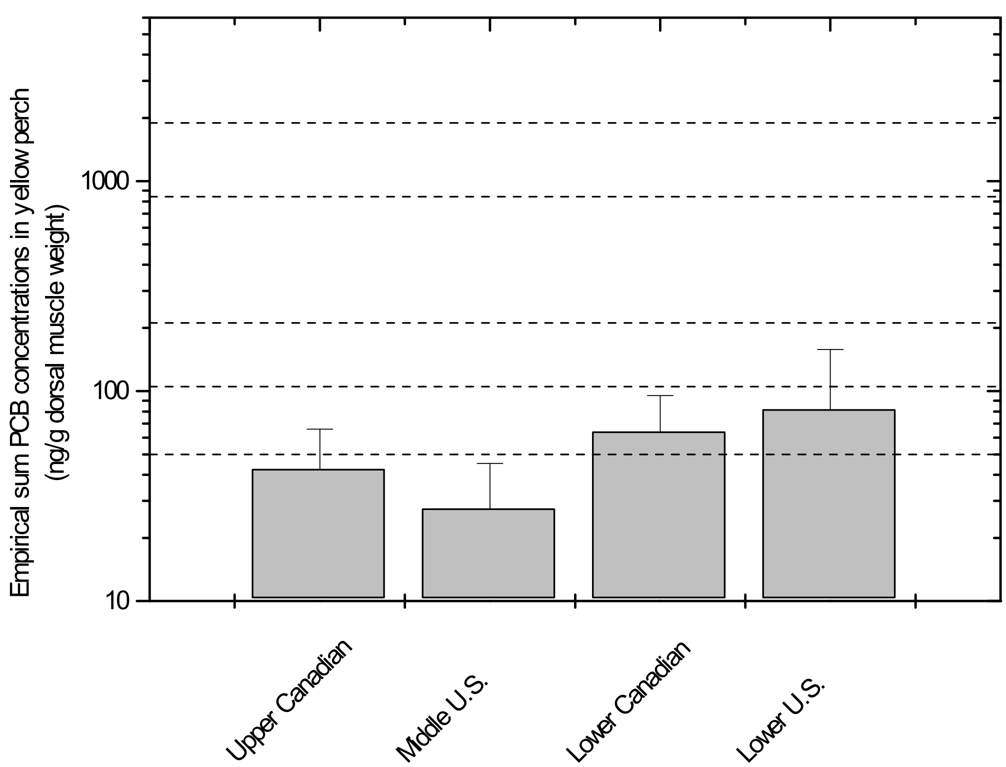


Figure 13. Sum PCB concentrations in yellow perch from the Detroit River.

Model Evaluation

The modified, updated Detroit River Fish Consumption Hazard Assessment model was used to provide predictions of sum PCB concentrations in sport fish and contrasted against the empirical data set to compare model performance. The model inputs included zone- and congener specific mean±standard deviation PCB concentrations in water and sediments outlined in the Water Inputs and Sediment Input sections of this report. In addition, mean ±standard deviation species specific lipid contents, compiled from the empirical data base on sport fish database (Table 13), was included as a model input with associated error. As a probabilistic model, the Detroit River Fish Consumption Hazard Assessment model provides both mean estimates as well as estimates of standard deviation and expected frequency distributions of sum PCBs in a given sport fish species and food web modelling zone.

Figure 14 provides a global summary of model predictions against empirically measured PCB concentrations in sport fish for individual samples across the 5 food web modelling zones for which data were available. Model predictions were highly significantly ($p<0.001$; ANOVA) correlated to measured sum PCB concentrations in sport fish. A linear regression between log observed (x-axis) and log predicted (y-axis) sum PCB concentrations explained 21.5% of the variation of the empirical data. The slope of the above regression equation was significantly lower than a value of unity ($p<0.001$; ANOVA) indicating that model bias tended towards under prediction of measured PCB concentrations in sport fish. A total of 77% of measured concentrations were under predicted by the model with 23% of observations being over predicted. The overall mean model bias (observed/predicted sum PCB concentration) was 3.1± 3.5. As indicated by the dashed lines on Figure 14, a majority of model predictions (95.3%) were within a factor of 10 of measured concentrations with only 29/629 observations being outside of this range. A total of 72% of model predictions were observed to be within a factor of 4 of individual observations. This level of performance is consistent with past reports of the model predictive success (Morrison et al 1997, Arnot and Gobas 2004).

Figure 15 summarizes geometric mean model predictions by species against geometric mean species specific measured PCB concentrations combined across the different modelling zones. Error bars on the figure refer to 95% confidence intervals above the geometric mean species estimate (horizontal error bars) and Monte Carlo estimated 3x standard deviations above the geometric mean model prediction for a given species. The model explained 53% of the variation of observed species PCB concentrations in the river. As with the global model, the model exhibited a bias towards underestimating sum PCB concentrations in several species. Geometric model predictions were usually within the 95% confidence interval of the 1:1 fit line. Under predictions of mean species concentrations by a factor of 4 or less occurred for all species included in the evaluation data set. Model evaluations were also compared within individual zones to examine for differences in model bias between Canadian and U.S. food web modelling zones.

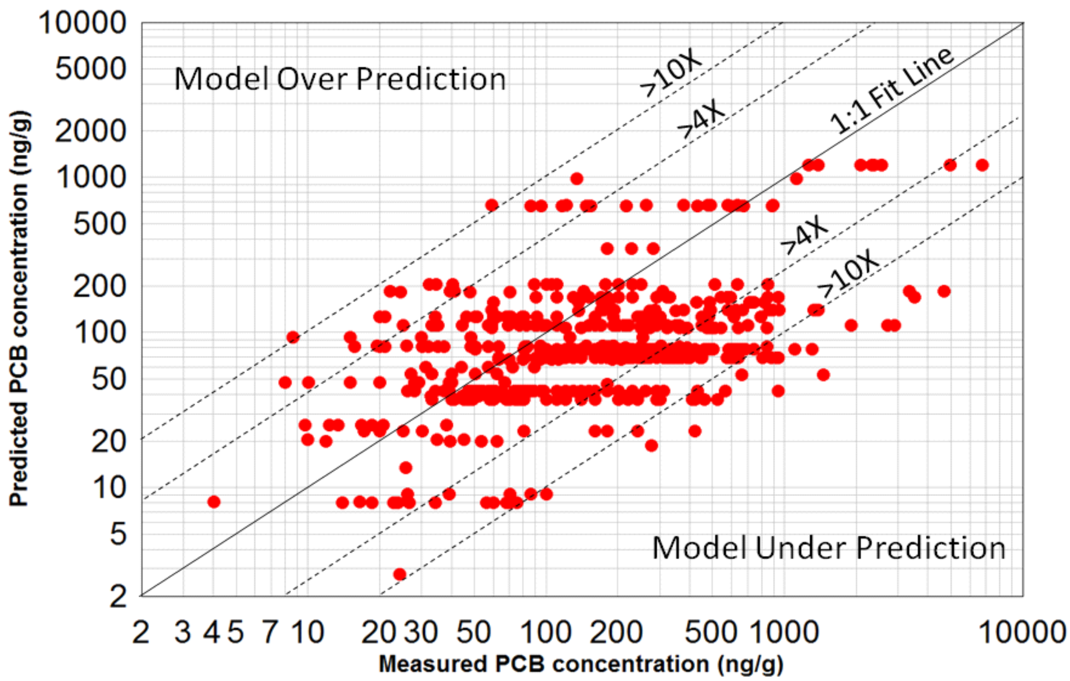


Figure 14. Observed versus predicted PCB concentrations in Detroit River Sportfish across zones and sport fish species.

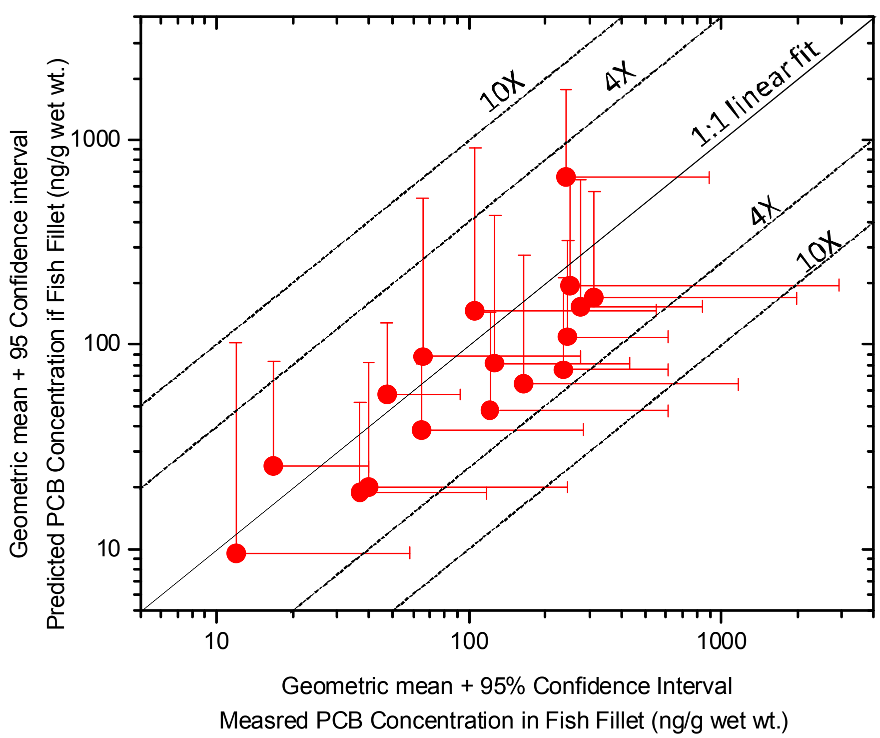


Figure 15. Geometric mean + 95% confidence interval species specific observed and predicted PCB concentrations in Detroit River Sport fish species across model zones.

Upper and Middle Canadian Zone: The upper and middle Canadian zones correspond approximately with the upper Detroit River fish advisory boundary used by Ontario Ministry of the Environment to establish its fish advice information. These two food web model zones have among the lowest PCB concentrations in water and sediments, exhibit relatively small spatial areas with restricted habitats that lie directly adjacent to the upper and middle U.S. zones which are among the most contaminated with respect to Sum PCBs in water and sediments. As such, both of these zones were considered to be the most susceptible to model bias towards under prediction as a consequence of fish movements in and out of the model zones. Model validations were performed by comparing measured sum PCB concentrations in sport fish species with model predicted values in the two zones. Species with less than 3 replicates were excluded from this comparison.

Of the 293 individual samples collected from the upper and middle Canadian reaches of the river, 77% were under predicted by the model. Average model bias was 3.44 fold under-predicted across individual samples with 18/293 (6%) samples having model underestimates less than observed by more than a factor of 10. Figure 16 presents the model predicted + 95% confidence interval sum PCB concentration against measured values for individual samples across species. Mean predicted sum PCB concentrations in the two model zones were observed to be within 1 model standard deviation of measured values for 6 of the 14 species where replicate validation data were available. The model performed most poorly for rock bass (5.6 fold under prediction), yellow perch (5.3 fold under prediction), common carp (4.6 fold underprediction), bluegill (4.5 fold under prediction) and white bass (4.1 fold under prediction).

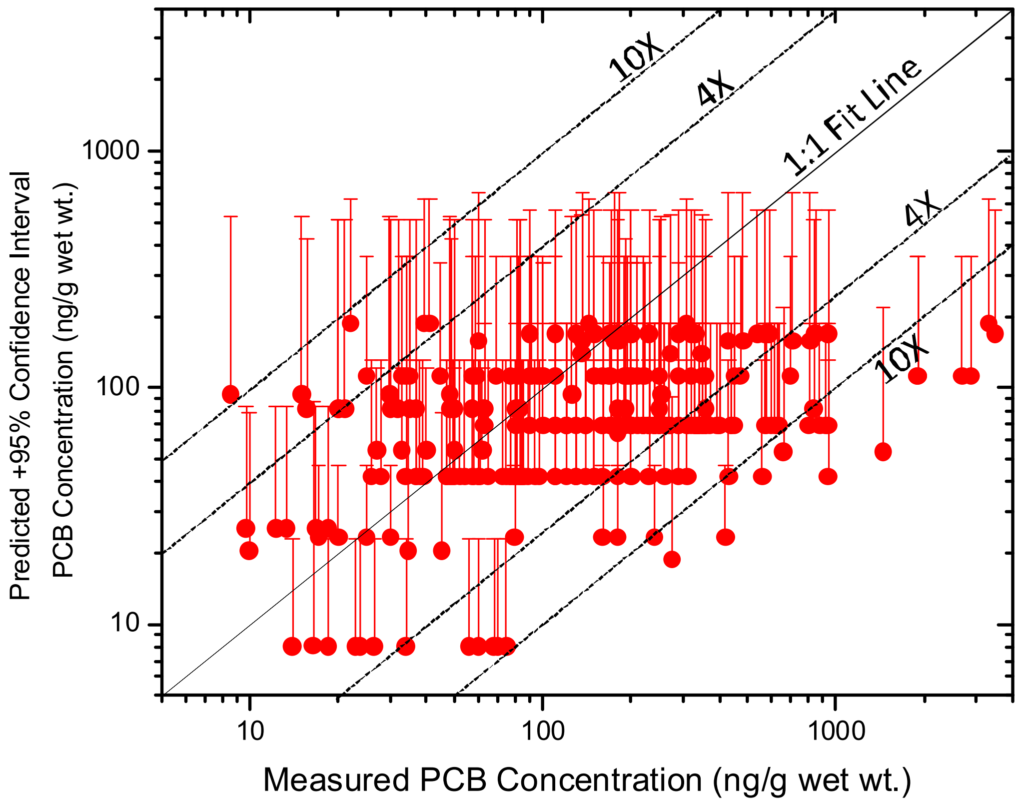


Figure 16. Mean species specific observed and predicted PCB concentrations in sport fish from the upper and middle Canadian model zones of the Detroit River.

Lower Canadian Zone. Overall, model bias tended towards under prediction in this zone. Of the 250 samples collected from the lower Canadian region of the river, 84% had measured sum PCB concentrations that were greater than the model predicted value. The average model bias was 2.99 fold across species. Only 7/250 (2.8%) of model predictions were found to be underestimated by more than a factor of 10 from measured values. Figure 17 presents the model predicted mean + 95% confidence interval sum PCB concentration against measured values for each individual and species from the Canadian lower zone. Mean predicted sum PCB concentrations in this zone were generally observed to be within 1 model standard deviation of measured values for 4 of the 12 species where replicate validation data were available. The model performed most poorly for yellow perch (7.1 fold under prediction), but yielded predictions that were less than a factor of 4 from observed for walleye, white bass, white perch and smallmouth bass. The model was within a factor of 2 for mean sum PCB concentrations measured in bluegill, carp, freshwater drum, gizzard shad, largemouth bass, muskellunge and rock bass.

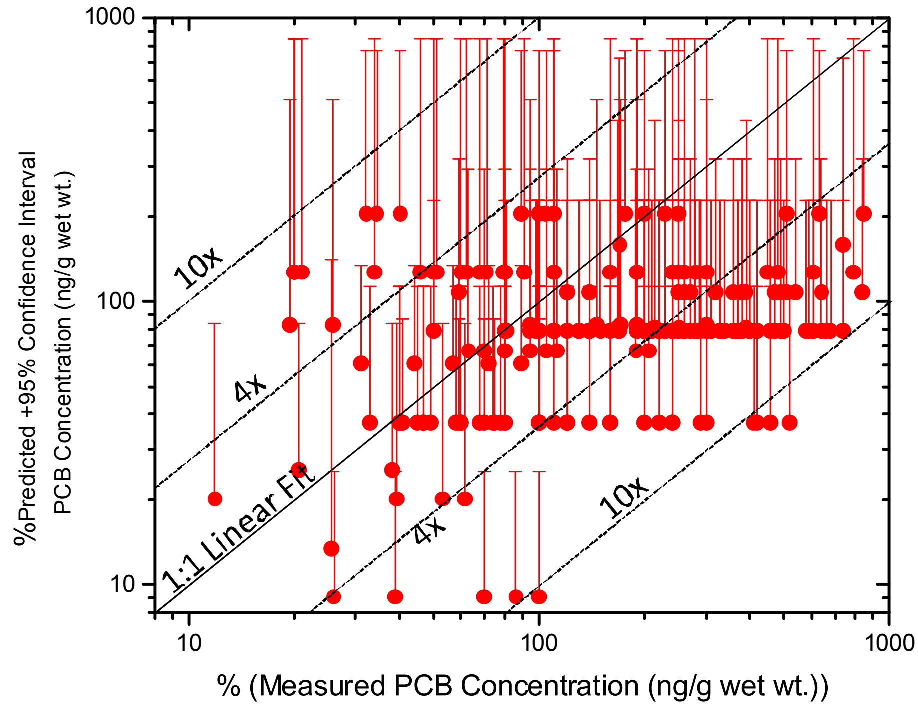


Figure 17. Mean species specific observed and predicted PCB concentrations in sport fish from the lower Canadian model zone of the Detroit River .

Middle and lower U.S. Zone. No empirical data were available for the upper U.S. zone on which to compare model performance. The number of samples and species in the middle and lower U.S. food web zones were also substantially fewer than available in Canadian waters. As such, these data were combined to evaluate overall performance of the model in the middle and lower U.S. zones. Since Michigan does not distinguish upper, middle or lower zones within its fish advice information for the Detroit River, this level of model analysis corresponds with the Michigan fish advice information.

Of the 67 samples collected from the middle and lower U.S. region of the river, 47.8% had measured sum PCB concentrations that were greater than the model predicted value. The average model bias was 1.77 fold lower predicted concentrations relative to measured concentrations and 80% of model predictions were within a factor of 3 to observed values. Although the model still provided underestimates in the U.S. zones, the degree of model bias was considerably less than in Canadian waters. This provides indirect evidence that fish movements between Canadian and U.S. waters are responsible for additional PCB exposures in Canadian captured fish. That the model still produces underestimates in PCB concentrations may be a result of errors in the assumed food web feeding matrix, underestimates of sediment and water contamination experienced by fish, failure of the model to consider size-related increases in PCB residues in a given fish species or other calibration problems associated with the model. In the case of sediments in the upper, middle and lower U.S. zones, considerable heterogeneity in sediment contamination was apparent. There are also notably higher sum PCB concentrations in sediments in proximity to the shore line and in deposition areas that often support high macrophyte growth (e.g. lower reaches of Trenton Channel and near Celeron Island). If fish indeed spend a larger fraction of their time in these areas of the river, than the zone-wide sum PCB concentration estimates may underestimate the actual sediment and water PCB concentrations experienced by fish.

Figure 18 presents the model predicted ± 95% confidence interval sum PCB concentration against measured values for each individual sample collected from the middle and lower U.S. zones. Geomean predicted sum PCB concentrations in this zone were generally observed to be within 1 model standard deviation of measured values for 5 of the 7 species where replicate validation data were available. The model performed most poorly for walleye (4.2 fold under predicted). All other species had measured sum PCB concentrations that approached a 2 of the model predicted geomean value.

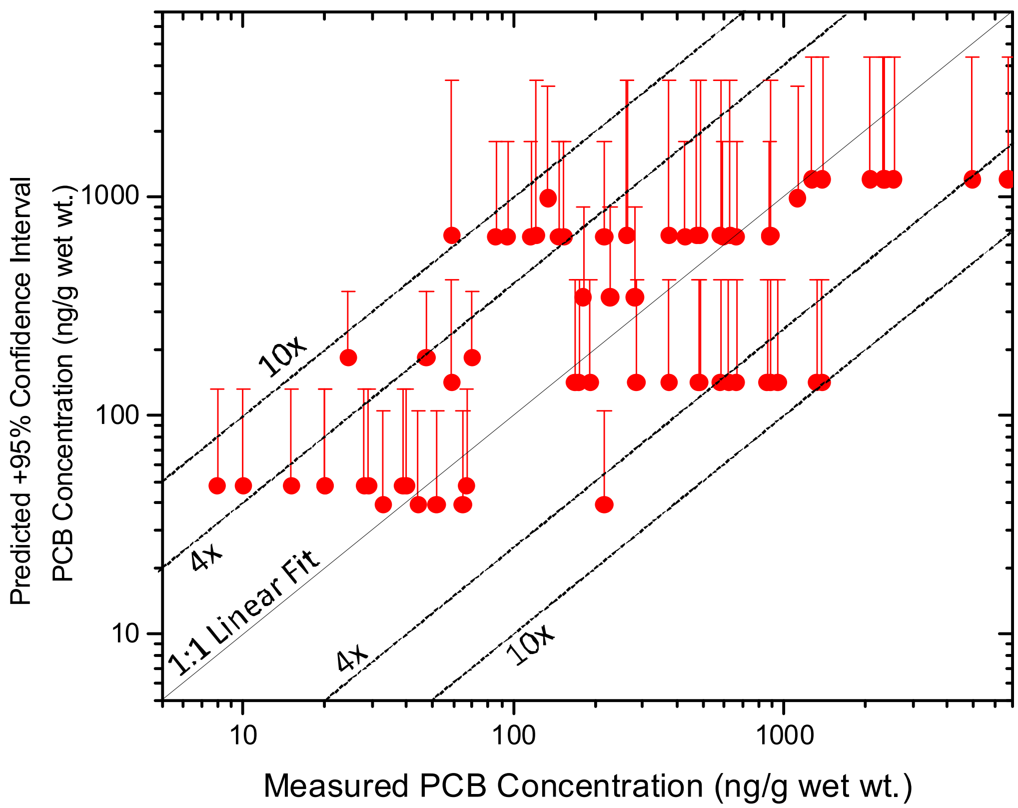


Figure 18. Mean species specific observed and predicted PCB concentrations in sport fish from the middle and lower U.S. model zones of the Detroit River .

Table 16 Model bias towards under prediction for individual species in different model zones.

Species	Recommended Spp. Adjustment Factor	Global (All Zones)	Upper/Middle CDN	Lower CDN	Middle/Lower US
Bluegill	3.5	3.4	4.5	2.1	NA
Common Carp	3.5	3.2	4.6	1.1	2.1
Channel Catfish	3.0	3.1	3.1	NA	NA
Freshwater Drum	**1.5**	**1.3**	**1.6**	**1.3**	**0.6**
Gar Pike	2.5	2.3	2.2	NA	NA
Gizzard Shad	**1.5**	**1.3**	**0.9**	**1.6**	NA
Largemouth Bass	**1.0**	**0.9**	**0.8**	**1.0**	NA
Muskellunge	**1.5**	**1.7**	**NA**	**1.7**	**NA**
Northern Pike	**1.0**	**0.7**	**0.6**	NA	NA
Rock Bass	3.0	3.6	5.6	1.9	0.3
Smallmouth Bass	2.5	2.3	1.0	3.2	NA
Sucker	**1.0**	**0.5**	NA	NA	**0.5**
Walleye	3.5	3.5	3.1	3.7	4.2
White Bass	4.0	3.8	4.1	3.6	0.7
White Perch	3.0	2.8	1.5	3.4	NA
Yellow Perch	4.0	3.5	5.3	7.1	1.0

Table 16 provides a summary of overall model bias (defined as the degree of underprediction prediction by the model expressed as the ratio of mean observed/mean predicted sum PCB concentration for a given species and model zone). Some across zone consistencies in model bias were notable. In general, the model performed relatively well for freshwater drum, gizzard shad, largemouth bass, muskellunge, northern pike and sucker yielding predictions that were typically within a factor of less than 2 of measured concentrations. Model performance generally had associated with it a 3-4 fold bias towards under prediction for many species. A recommended species adjustment factor was subsequently established to calibrate the model and correct for the above noted tendency towards under prediction of sum PCB residues. In cases where there was deviation across zones in model bias for a given species, the recommended species adjustment factor tended towards a conservative correction factor. This provides a degree of built in safety factor for model predictions making the calibrated model more often over predictive of fish contamination compared to under predicting fish contamination. Species adjustment factors were established on a global basis, i.e. they apply to all food web modelling zones in the Detroit River. The requirement for model calibration by incorporating species adjustment factors may be due to incorrect assumptions related to the feeding matrix, lower estimates associated with actual fish exposures to sediment and water PCB concentration compared to zone wide averages, fish movements between zones and outside of the Detroit River or due to size and/or age-related non-steady state bioaccumulation of PCBs.

Subsequent model simulations were established by applying the recommended species adjustment factors to the model output on sum PCB concentrations in dorsal muscle tissue. The adjustment factors were incorporated into model output used for Monte Carlo simulation trials thus enabling the probabilistic model to provide error estimates and expected frequency distributions of sum PCB concentrations in sport fish species. Monte Carlo simulations did not consider error in the species adjustment factor as part of the error propagation algorithms.

Figure 19 summarizes the calibrated model output using the species adjustment factors contrasted against measured predictions. Linear regression on log observed against log predicted PCB concentrations produced a linear regression equation that explained 57% of the mean species and food web model zone specific sum PCB concentrations in sport fish. In the above case, and as expected from the calibrated model, the constant was not significantly different from zero and the slope was not significantly different from a value of 1. Three species, muskellunge, white sucker and bluegill in zone 1 (Upper Canadian zone) still had predictions that were under estimated by the model. However, the measured data for these samples reflected only n=2 (muskellunge, 13 fold underestimate), n=1 (bluegill, 5.7 fold underestimate) and n= 1 (sucker; 3.2 fold underestimate) samples and therefore may not be representative of species sum PCB concentrations in this zone. No other species had sum PCB concentration predictions that were more than a factor of 2 fold lower then measured concentrations. Thus, the calibrated model can be considered generally conservative of the empirical data base tending towards over-prediction rather than under prediction of contaminant levels in sport fish fillet samples.

Model over predictions occurred primarily in the U.S. middle and lower zones. Species over predicted by the model included yellow perch (3.5 – 12 fold over predicted), common carp (1.7 to 4.95 fold over predicted), rock bass (9.95 over predicted), white bass (6 fold over predicted) and freshwater drum (3 fold over predicted). In the case of common carp, only 2 samples were available for the lower U.S. reach where over predictions were most pronounced. Other species, particularly in the lower U.S. river zone had small replicate numbers on which to formulate geometric mean species concentrations. An exception was yellow perch which was relatively well sampled in both the middle and lower U.S. zone and found to be over predicted by the calibrated model in both zones. This may indicate species movements outside of the more contaminated areas of the river dampening residues found in these species or mistakes in the diet matrix used as the food web input to the model. Likewise, overestimates related to white bass are likely due to substantive movements known for this species and/or other errors in the ecological attributes of this species.

Figures 20 and 21 provide observed and predicted frequency distributions for sum PCB concentrations for common carp and walleye. The above species were chosen for presentation because they had the largest number of samples distributed across the widest number of food web zones. These species are also important for fish advice information, reflecting highly contaminated species (common carp) or highly sought after sport fish (walleye). The model generated frequency distributions predict a log normal distribution pattern, influenced primarily by the log normal distributions observed for water and sediments. For walleye and common carp collected in the Canadian zones, log normal frequency distributions for the observed data were evident and tended to match those of the model relatively well. In the lower U.S. zone, the breadth of concentration estimates were widened, but relatively low replicate numbers prevented the defining of concentration distributions with any accuracy for the measured samples. The highest measured sample concentrations in the most contaminated zone were predicted to occur, but at lower frequencies by the model. Log normal frequency distributions of sum PCB concentrations were also evident in white bass from the upper and lower Canadian zones which had high sample numbers (data not shown).

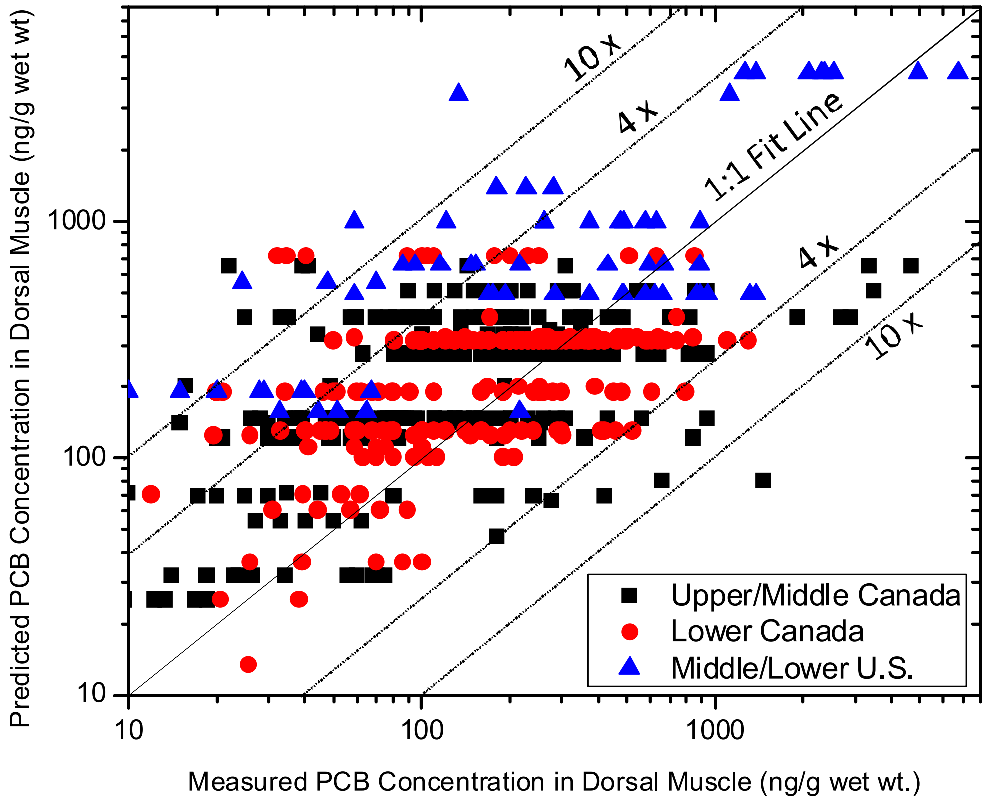


Figure 19. Observed and predicted PCB concentrations in Detroit River Sport fish species and zones generated using the calibrated model incorporating species adjustment factors to model output.

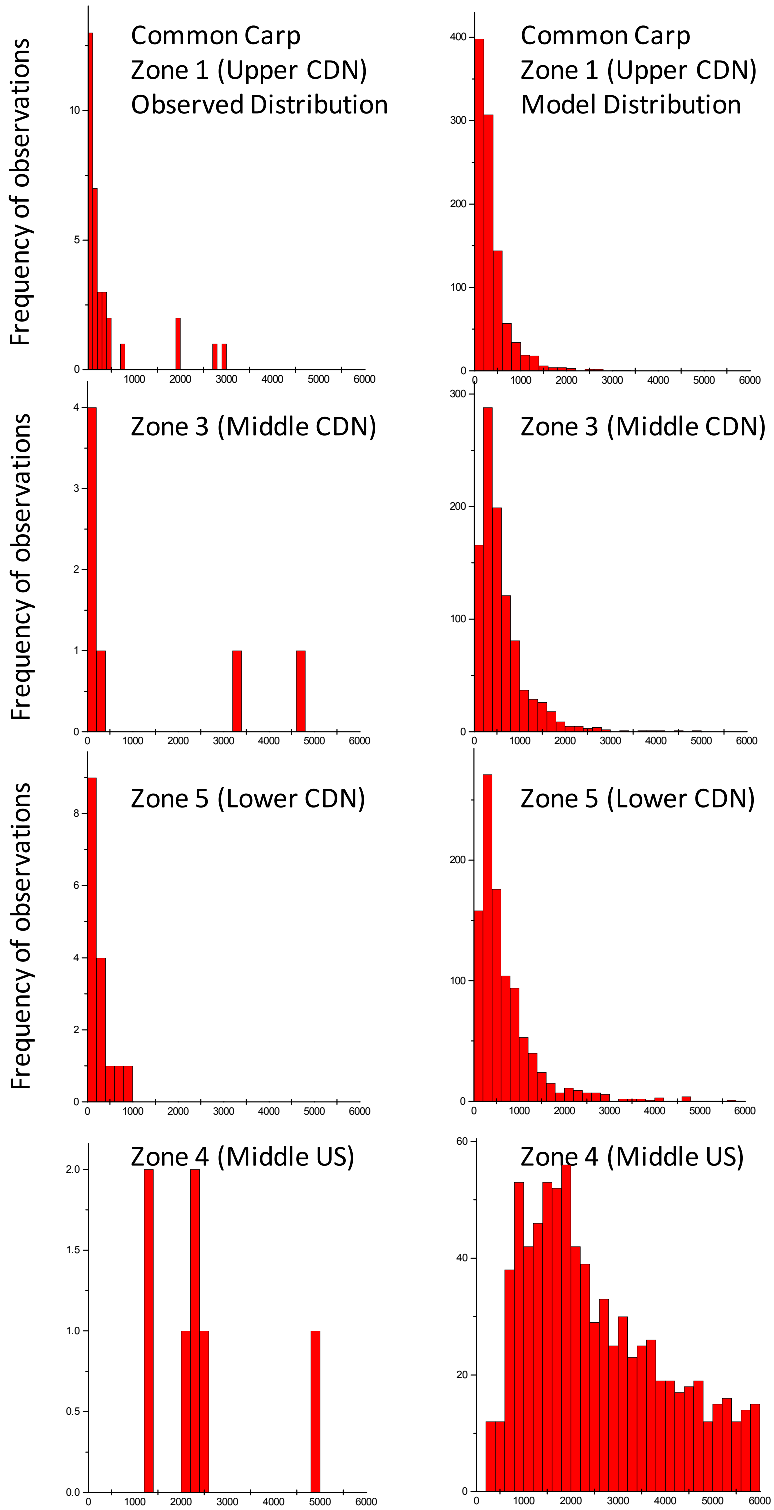


Figure 20. Observed and predicted frequency distributions of PCB concentrations in carp.

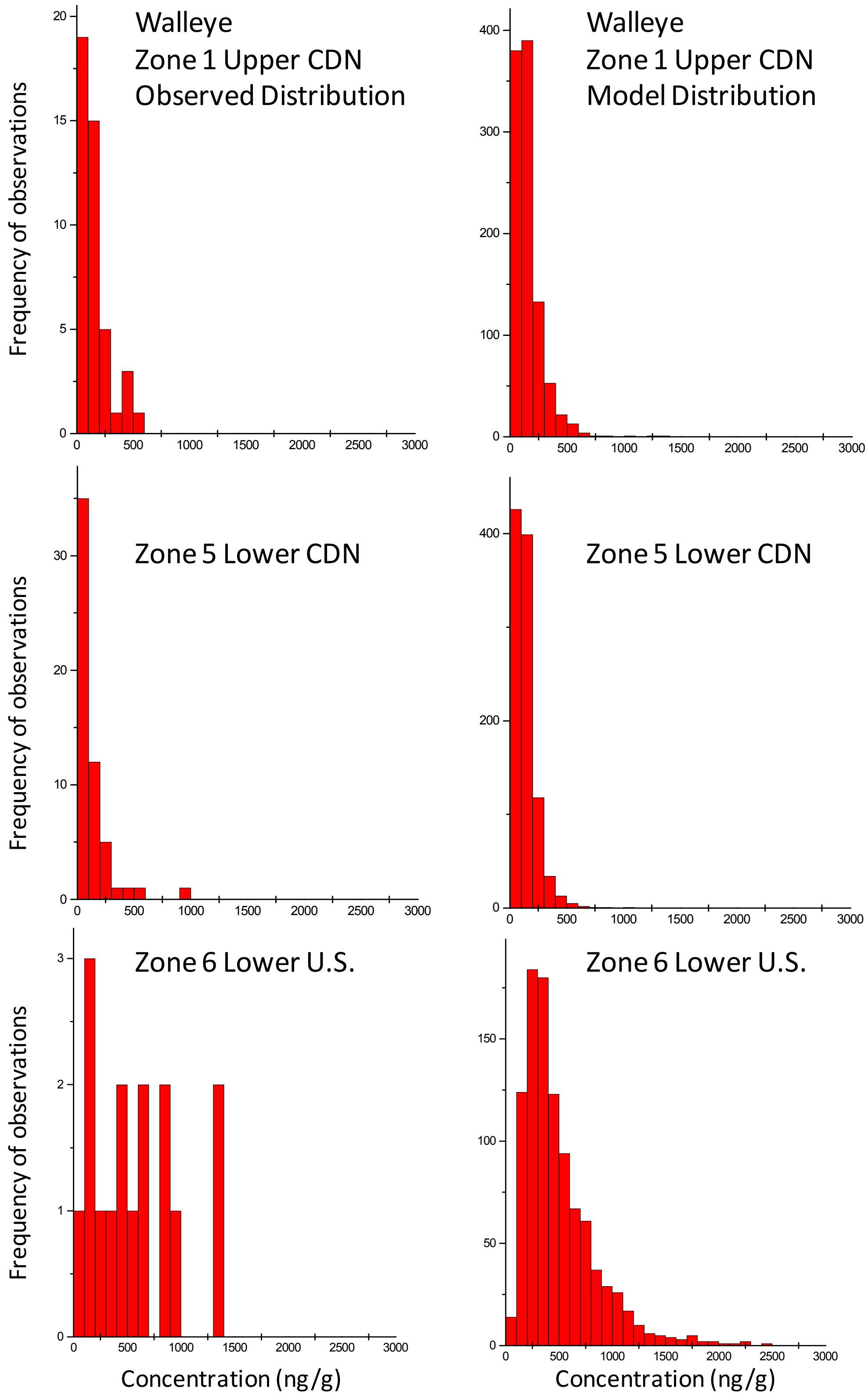


Figure 21. Observed and predicted frequency distributions of PCB concentrations in walleye.

A consequence of the use of the arithmetic mean fish species concentration to generate fish consumption advice information is that the utilization of this measure of central tendency generally produces an overestimate of the true modal concentration in the population. This bias is reflected to the same degree in both measured concentration distributions as well as mean model output. Use of geometric mean and associated confidence intervals would provide a more accurate measure of the central tendency sum PCB concentrations in individual fish species from the Detroit River. Alternatively, cumulative frequency distributions of fish concentrations can be generated using empirical or measured data that have been categorized into bins bounded by the threshold trigger levels used to establish fish advice. Advice can then be established based on the minimum bin that contains at least 50% of the fish concentration estimates. This method, based primarily on a rank/frequency spectrum would avoid biases related to choosing the wrong central tendency measure due to incorrect assumptions about the distribution of samples concentrations.

Calibrated Model Output

The calibrated model was subsequently used to generate species and zone specific estimates of sum PCB concentrations in each of the six Detroit River food web zones. One of the requested applications of the Detroit River Fish Consumption Hazard Assessment model was to provide model predicted concentrations of PCBs and likely advice information for sport fish species not presently included in the advisory information. This information was generated for 17 standardized sport fish species in each model zone and summarized in Tables 17-22 below.

Data for the upper, middle and lower Canadian food web modelling zones are presented in Tables 17 – 19. Relatively similar concentration estimates and advice information are predicted for the upper, middle and lower Canadian modelling zones. A number of species including: bluegill, brown bullhead, freshwater drum (upper and middle zone), gizzard shad, largemouth bass, muskellunge, northern pike, rock bass, sucker (upper and middle zone) and yellow perch are predicted to have no fish consumption advisories associated with them when applying the minimum Ontario threshold trigger of 105 ng/g wet dorsal muscle weight. The species: freshwater drum (lower zone) walleye and smallmouth bass are predicted to have advice information that recommend restricted numbers of meals for the general public and sensitive sub-populations. The species channel catfish, common carp, gar pike, gizzard shad (upper zone only), white bass and white perch are predicted to have advisory information on the order of "No consumption" for the sensitive sub-population and restricted number of meals advice for the general population. The model did not predict sum PCB concentrations in excess of concentrations that would warrant advice information of 'No consumption' for the general public using Ontario's trigger threshold of 844 ng/g or Michigan's more conservative trigger of 1890 ng/g.

Data for the upper, middle and lower U.S. food web modelling zones are presented in Tables 20 – 22 below. The highest concentrations in sport fish were predicted for the Middle U.S. zone, although all three zones were relatively similar in terms of model predicted advice information. The minimum Michigan threshold trigger of 50 ng/g wet weight was predicted to be exceeded in all sport fish species throughout all of the zones necessitating restricted meal advice information for any fish captured on the U.S. portion of the Detroit River. The most severe restrictions of

'No Consumption' by the general public were predicted for channel catfish and common carp in all three zones on the U.S. side of the river. When considering Ontario fish advisory trigger levels, three additional fish species (gar pike, white bass and white perch) were predicted to have concentrations exceeding the 'No Consumption' threshold for the Ontario general public. Several fish species including freshwater drum, gizzard shad, muskellunge, rock bass, smallmouth bass, sucker, walleye and yellow perch would be expected to accumulate PCBs above the no-consumption threshold for the Ontario sensitive sub-population. Only brown bullhead and northern pike were predicted to have no Ontario advisory information associated with them for U.S. captured fish.

Overall, PCB concentrations in fish from the U.S. food web modelling zones were predicted to achieve PCB concentrations that were 4.4 to 7.3 fold higher than concentrations observed in the same species on the Canadian side of the river. Across species, the mean predicted sum PCB concentrations in sport fish on the U.S. side of the Detroit River was 5.7±1.0 fold higher than the Canadian side. An important observation from the model outputs was that mean sum PCB concentrations in Canadian fish are always predicted to be less than the most stringent Ontario trigger threshold of 844 ng/g that would necessitate a 'No Consumption' advice for the general public. Considering the frequency distribution output from the probabilistic model, channel catfish and carp are still predicted to exceed the 844 ng/g threshold for 7-30% of samples depending on the zone of capture. These predictions indicate a potential for Canadian fish to achieve high concentrations of PCBs in Canadian zones, although the latter results are driven primarily by the species adjustment factors which may correct for some fish movement artifacts through the model calibration process. The expected frequency of Canadian fish exceeding Michigan's most stringing fish consumption advice trigger at 1890 ng/g was always less than 6% of the sample population. In contrast, 84% of U.S. channel catfish were predicted to exceed the 1890 ng/g trigger value in the middle U.S. zone. These results re-affirm past conclusions of the Detroit River PCB fish consumption hazard assessment model; that the most contaminated fish in the Detroit River are generated via fish exposures to contaminated sediments on the U.S. side of the river. The model simulations also indicate that the most severe restrictive advice information of 'no consumption' for the general public are most likely to be generated by fish exposures on the U.S. side of the Detroit River.

Model simulations were also performed to establish the fraction of PCB burden in sport fish associated with water versus that due to sediment contamination in each zone. This was accomplished by performing simulations using a zero value in place of water or sediment PCB inputs and the normal zone specific input for the second (water or sediment) input parameter. Tables 23-28 summarize the results of these trials. Species such as walleye, gizzard shad and white perch were more often predicted to be strongly influenced by water contamination while benthic feeding species were most strongly influenced by sediment contamination in all of the food web zones. However, the ratio of congener specific PCB concentrations in water and sediments also impacts the predicted proportional contribution of water and sediment PCBs to fish contamination depending on fish feeding ecology (relative incorporation of benthic and pelagic diet items in each species' diet). Thus the water/sediment contribution estimates varied on a zone and species specific basis. In Canadian waters, the average across species contribution of water was 46.5±21.5% and for sediments was 52.6±22%. The proportion changed with downstream distance among the three food web modelling zones. Water contamination dominated the total bioaccumulated fraction (mean 60.3%) in the upper zone and then progressively declined in the middle (42.9%) and lower zones (36.3%) as a consequence of increases in sediment contamination and relatively steady water contamination.

The above simulation trials suggest that both water quality (upstream and in-stream) and in-stream sediment quality play important roles to PCB exposures by Canadian resident sport fish. Given the lack of spatial trends of water PCB contamination on the Canadian side of the river, and similar concentration estimates observed in Lake St. Clair (Raeside et al. 2009), it would appear that further improvements in source water protection on Canadian side of the river would be unlikely to have large effects on the number of fish advisories issued in this jurisdiction. For example, attaining the technologically unrealistic complete removal of PCBs from water on the Canadian side of the river would result in the removal of the 'no consumption advice information' for the sensitive sub-population consuming white bass, gar pike and common carp (upstream and middle stream) and white bass and gar pike (downstream) with little change to fish advice information predicted for other sport fish species. Complete removal of sediment contamination from the Canadian zones would have an approximate equal impact as removal of contamination from water in the upper and middle zone, but would be more effective at removing the most restricted advice information for the downstream Canadian zone. Under both of the above clean-up scenarios, the model predicts fish consumption advice information to persist in the Canadian side Detroit River fish, although the number of advisories by species and degree of restrictiveness of advice information would decrease for some species. Complete removal of Canadian fish advice information is unlikely to occur unless a combination of clean-up strategies are performed on both water and sediments. Degraded water quality coming from upstream of the Detroit River will likely negate the feasibility of the above management goals.

For the U.S. food web modelling zones, the contributions of sediments to PCB exposures in sport fish generally exceeded those of water. Across the U.S. zones and sport fish species, the average contribution of sediments to sport fish contamination was 73.3±16.1% and exhibited a decreasing trend from upstream to downstream as a result of increases in water PCB inputs in the downstream zones and relatively little change across zones for sediment contamination. Even for the downstream zone, sediments were estimated to contribute an average of 70.5% of the sport fish contaminant burden and water 28.5%, respectively. Complete removal of PCBs from water in the upper U.S. modelling zone had little effect on expected number and intensity of fish advisories issued by species with the exception that no advice information would be expected for brown bullhead in the upper and middle U.S. zones. Removal of PCBs from water without effect on sediment contamination in the lower U.S. zone would decrease the number of fish species having PCB concentrations above the Ontario 211 ng/g trigger threshold (bluegill, sucker and freshwater drum) and would also downgrade the U.S. general public 'No fish consumption' advisories issued for gar pike and common carp predicted for the upper and middle zones of the Detroit River. Remediating PCBs in water would have no effect on the U.S. general public 'No fish consumption' advisories issued for white perch and channel catfish predicted to occur (based on mean model estimates) in all three zones.

Performing model simulations where sediment contamination was set to zero without altering water concentration inputs resulted in the most dramatic decreases in the intensity of fish advisories issued for the U.S. side of the river. This resulted in the removal of the U.S. general public 'No fish consumption' advice for gar pike, common carp, white perch and channel catfish for upper, middle and lower U.S. zones. It also resulted in the removal of Ontario general public 'no fish consumption' advice information predicted for all species except for gar pike in the upper U.S. zone. These trials indicate that continued sediment remediation efforts, with the result of lowering the mean zone specific sediment concentration, is expected to produce positive results in terms of decreasing the intensity of fish advice information across different species of U.S. sport fish. Sediment remediation in the U.S. side of the river may also potentially yield positive benefits to the quality of fish captured in Canadian waters. It could, for example, eliminate the need for issuing general public 'No fish consumption' advice information in Ontario and reduce the number of 'No consumption' advice information by species for Ontario's sensitive sub-population.

Similar to the simulations performed in Canadian waters, complete removal of sediment contamination as a model input would not result in removal of all fish consumption advice information issued by the State of Michigan. This is particularly the case since water contamination in the U.S. zones was considerably higher than that present in the upstream waters of Lake St. Clair and adjacent waters in Canada (Raeside et al 2009; Gewurtz 2003). Thus, a combination of PCB reductions in water and sediments are necessary to achieve the goal of complete elimination of fish advisory information in the U.S. portion of the Detroit River. As indicated for the Canadian waters, practical limitations exist due to degraded water quality in upstream waters are likely to limit the feasibility of such clean-up objectives. However, cleanup of water and contaminated sediments on the U.S. side of the Detroit River could lead to similar advice information as observed in the upper Canadian food web modelling zone given that water and sediment quality at this location approaches the background PCB contamination present within the Huron-Erie corridor.

Table 17. Model predicted sum PCB concentrations and fish consumption advice information in the upper Canadian food web modelling zone.

	Concentration (ng/g)		Cummulative Frequencies Below Trigger Boundary						Jursidiction	
Species	Mean	SD	0-50	50-105	105-211	211-844	844-1890	>1890	Michigan	Ontario
Bluegill	48.3	72.2	72	89	97	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Brown Bullhead	7.7	5.3	100	100	100	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Channel Catfish	473.1	346.0	0	3	21	88	99	100	Limited Meals Advisory	**No Consumption W & C**
Common Carp	373.6	387.8	4	14	40	92	99	100	Limited Meals Advisory	**No Consumption W & C**
Freshwater Drum	119.1	166.5	40	67	85	99	100	100	Limited Meals Advisory	*No Advisory Issued*
Gar Pike	367.4	344.4	2	11	36	93	99	100	Limited Meals Advisory	**No Consumption W & C**
Gizzard Shad	132.6	111.8	14	51	86	100	100	100	Limited Meals Advisory	**No Consumption W & C**
Largemouth Bass	25.2	19.1	92	99	100	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Muskellunge	80.5	89.1	49	78	93	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Northern Pike	9.1	3.8	100	100	100	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Rock Bass	59.6	24.6	40	96	100	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Smallmouth Bass	195.7	157.8	9	33	66	99	100	100	Limited Meals Advisory	Limited Meals Advisory
Sucker	56.6	26.1	46	96	100	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Walleye	154.1	122.4	10	41	78	100	100	100	Limited Meals Advisory	Limited Meals Advisory
White Bass	265.5	151.6	0	9	47	99	100	100	Limited Meals Advisory	**No Consumption W & C**
White Perch	384.3	254.2	0	3	26	94	100	100	Limited Meals Advisory	**No Consumption W & C**
Yellow Perch	57.0	40.0	54	90	99	100	100	100	*No Advisory Issued*	*No Advisory Issued*

Suggested fish advice information established using the minimum bin category whose cumulative frequency distribution of samples exceeded 50% (area marked in Grey).

Table 18. Model predicted sum PCB concentrations and fish consumption advice information in the middle Canadian food web modelling zone.

	Concentration (ng/g)		Cummulative Frequencies of Fish PCBs Below Trigger Boundary						Predicted Most Restrictie Advice Information	
Species	Mean	SD	0-50	50-105	105-211	211-844	844-1890	>1890	Michigan	Ontario
Bluegill	60.3	89.0	67	84	95	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Brown Bullhead	12.7	9.1	99	100	100	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Channel Catfish	754.0	578.8	0	1	6	69	96	100	Limited Meals Advisory	**No Consumption W & C**
Common Carp	608.2	577.0	1	5	18	79	96	100	Limited Meals Advisory	**No Consumption W & C**
Freshwater Drum	184.5	263.7	29	53	75	97	100	100	Limited Meals Advisory	*No Advisory Issued*
Gar Pike	428.9	358.4	1	7	28	90	980	100	Limited Meals Advisory	**No Consumption W & C**
Gizzard Shad	129.5	93.3	12	50	86	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Largemouth Bass	28.2	21.1	89	99	100	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Muskellunge	96.5	98.1	39	72	90	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Northern Pike	10.6	3.5	100	100	100	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Rock Bass	92.3	37.3	8	68	99	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Smallmouth Bass	201.0	167.3	6	29	67	99	100	100	Limited Meals Advisory	Limited Meals Advisory
Sucker	88.2	33.8	11	73	100	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Walleye	144.4	112.6	11	48	81	100	100	100	Limited Meals Advisory	Limited Meals Advisory
White Bass	304.0	168.5	0	4	34	99	100	100	Limited Meals Advisory	**No Consumption W & C**
White Perch	402.3	244.6	0	1	19	95	100	100	Limited Meals Advisory	**No Consumption W & C**
Yellow Perch	64.9	45.1	45	87	98	100	100	100	Limited Meals Advisory	*No Advisory Issued*

Suggested fish advice information established using the minimum bin category whose cumulative frequency distribution of samples exceeded 50% (area marked in Grey).

Table 19. Model predicted sum PCB concentrations and fish consumption advice information in the lower Canadian food web modelling zone.

	Concentration (ng/g)		Cummulative Frequencies of Fish PCBs Below Trigger Boundary						Predicted Most Restrictie Advice Information	
Species	Mean	SD	0-50	50-105	105-211	211-844	844-1890	>1890	Michigan	Ontario
Bluegill	60.4	96.8	65	85	95	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Brown Bullhead	13.8	11.4	99	100	100	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Channel Catfish	784.1	617.7	0	1	8	67	95	100	Limited Meals Advisory	**No Consumption W & C**
Common Carp	693.4	728.8	1	5	17	76	94	100	Limited Meals Advisory	**No Consumption W & C**
Freshwater Drum	201.0	305.1	27	49	72	97	99	100	Limited Meals Advisory	Limited Meals Advisory
Gar Pike	450.4	411.7	1	7	28	89	99	100	Limited Meals Advisory	**No Consumption W & C**
Gizzard Shad	125.6	88.4	14	51	87	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Largemouth Bass	29.2	22.0	88	99	100	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Muskellunge	103.7	125.8	39	69	89	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Northern Pike	10.9	4.9	100	100	100	100	100	100	*No Advisory Issued*	*No Advisory Issued*
Rock Bass	97.9	51.0	9	68	97	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Smallmouth Bass	187.4	158.8	7	35	69	99	100	100	Limited Meals Advisory	Limited Meals Advisory
Sucker	94.2	49.6	12	71	97	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Walleye	135.4	101.6	12	49	84	100	100	100	Limited Meals Advisory	Limited Meals Advisory
White Bass	313.9	193.2	0	4	34	98	100	100	Limited Meals Advisory	**No Consumption W & C**
White Perch	392.2	229.9	0	2	19	95	100	100	Limited Meals Advisory	**No Consumption W & C**
Yellow Perch	64.7	49.8	48	86	99	100	100	100	Limited Meals Advisory	*No Advisory Issued*

Suggested fish advice information established using the minimum bin category whose cumulative frequency distribution of samples exceeded 50% (area marked in Grey).

Table 20. Model predicted sum PCB concentrations and fish consumption advice information in the upper U.S. food web modelling zone.

	Concentration (ng/g)		Cummulative Frequencies of Fish PCBs Below Trigger Boundary						Predicted Most Restrictie Advice Information	
Species	Mean	SD	0-50	50-105	105-211	211-844	844-1890	>1890	Michigan	Ontario
Bluegill	338.6	650.8	18	35	58	92	98	100	Limited Meals Advisory	Limited Meals Advisory
Brown Bullhead	88.2	73.7	35	73	94	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Channel Catfish	4793.4	4342.6	0	0	0	3	19	100	**No Consumption Advisory**	**No Consumption GP**
Common Carp	4088.2	4486.0	0	0	0	10	33	100	**No Consumption Advisory**	**No Consumption GP**
Freshwater Drum	1297.4	1960.4	3	7	16	59	82	100	Limited Meals Advisory	**No Consumption W & C**
Gar Pike	2263.0	2401.8	0	0	1	20	58	100	Limited Meals Advisory	**No Consumption GP**
Gizzard Shad	624.2	497.6	0	2	11	78	97	100	Limited Meals Advisory	**No Consumption W & C**
Largemouth Bass	148.7	116.3	10	44	80	100	100	100	Limited Meals Advisory	Limited Meals Advisory
Muskellunge	541.0	672.4	2	11	29	82	97	100	Limited Meals Advisory	**No Consumption W & C**
Northern Pike	58.8	29.0	46	95	100	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Rock Bass	613.2	322.9	0	0	2	82	100	100	Limited Meals Advisory	**No Consumption W & C**
Smallmouth Bass	914.2	867.3	0	1	8	61	91	100	Limited Meals Advisory	**No Consumption W & C**
Sucker	567.0	288.9	0	0	2	86	100	100	Limited Meals Advisory	**No Consumption W & C**
Walleye	616.3	510.7	0	2	11	79	98	100	Limited Meals Advisory	**No Consumption W & C**
White Bass	1780.6	1255.1	0	0	0	18	67	100	Limited Meals Advisory	**No Consumption GP**
White Perch	2049.3	1468.7	0	0	0	14	59	100	Limited Meals Advisory	**No Consumption GP**
Yellow Perch	344.3	262.7	0	8	33	96	100	100	Limited Meals Advisory	**No Consumption W & C**

Suggested fish advice information established using the minimum bin category whose cumulative frequency distribution of samples exceeded 50% (area marked in Grey).

Table 21. Model predicted sum PCB concentrations and fish consumption advice information in the middle U.S. food web modelling zone.

	Concentration (ng/g)		Cummulative Frequencies of Fish PCBs Below Trigger Boundary						Predicted Most Restrictie Advice Information	
Species	Mean	SD	0-50	50-105	105-211	211-844	844-1890	>1890	Michigan	Ontario
Bluegill	351.6	570.8	16	34	58	90	98	100	Limited Meals Advisory	Limited Meals Advisory
Brown Bullhead	89.9	74.5	31	71	94	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Channel Catfish	4948.5	4277.0	0	0	0	2	16	100	**No Consumption Advisory**	**No Consumption GP**
Common Carp	4110.4	4545.2	0	0	0	7	31	100	**No Consumption Advisory**	**No Consumption GP**
Freshwater Drum	1338.3	2026.2	2	8	19	60	79	100	Limited Meals Advisory	**No Consumption W & C**
Gar Pike	2273.8	2130.8	0	0	0	20	57	100	Limited Meals Advisory	**No Consumption GP**
Gizzard Shad	584.3	404.7	0	1	11	82	98	100	Limited Meals Advisory	**No Consumption W & C**
Largemouth Bass	151.8	115.5	10	43	79	100	100	100	Limited Meals Advisory	Limited Meals Advisory
Muskellunge	531.5	566.2	2	10	28	84	97	100	Limited Meals Advisory	**No Consumption W & C**
Northern Pike	58.1	25.1	43	95	100	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Rock Bass	596.3	287.4	0	0	1	84	100	100	Limited Meals Advisory	**No Consumption W & C**
Smallmouth Bass	933.3	977.4	0	1	7	62	90	100	Limited Meals Advisory	**No Consumption W & C**
Sucker	567.6	271.9	0	0	2	88	100	100	Limited Meals Advisory	**No Consumption W & C**
Walleye	591.5	427.3	0	1	12	81	98	100	Limited Meals Advisory	**No Consumption W & C**
White Bass	1657.2	1016.1	0	0	0	18	70	100	Limited Meals Advisory	**No Consumption GP**
White Perch	1903.3	1204.2	0	0	0	13	62	100	Limited Meals Advisory	**No Consumption GP**
Yellow Perch	346.0	276.8	1	7	34	96	100	100	Limited Meals Advisory	**No Consumption W & C**

Suggested fish advice information established using the minimum bin category whose cumulative frequency distribution of samples exceeded 50% (area marked in Grey).

Table 22. Model predicted sum PCB concentrations and fish consumption advice information in the lower U.S. food web modelling zone.

	Concentration (ng/g)		Cummulative Frequencies of Fish PCBs Below Trigger Boundary						Predicted Most Restrictie Advice Information	
Species	Mean	SD	0-50	50-105	105-211	211-844	844-1890	>1890	Michigan	Ontario
Bluegill	271.1	497.5	21	44	68	94	99	100	Limited Meals Advisory	Limited Meals Advisory
Brown Bullhead	68.3	56.2	45	84	97	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Channel Catfish	3644.8	2855.1	0	0	0	3	26	100	**No Consumption Advisory**	**No Consumption GP**
Common Carp	3109.1	2965.0	0	0	0	11	41	100	**No Consumption Advisory**	**No Consumption GP**
Freshwater Drum	1038.9	1837.2	2	8	21	66	87	100	Limited Meals Advisory	**No Consumption W & C**
Gar Pike	1850.6	1575.4	0	0	0	26	65	100	Limited Meals Advisory	**No Consumption GP**
Gizzard Shad	507.5	377.1	0	1	16	86	99	100	Limited Meals Advisory	**No Consumption W & C**
Largemouth Bass	119.0	80.1	14	53	89	100	100	100	Limited Meals Advisory	*No Advisory Issued*
Muskellunge	457.5	546.6	3	13	35	88	98	100	Limited Meals Advisory	**No Consumption W & C**
Northern Pike	47.6	16.2	63	100	100	100	100	100	No Advisory Issued	*No Advisory Issued*
Rock Bass	471.1	182.0	0	0	2	97	100	100	Limited Meals Advisory	**No Consumption W & C**
Smallmouth Bass	788.9	705.3	0	1	8	69	93	100	Limited Meals Advisory	**No Consumption W & C**
Sucker	444.7	178.1	0	0	4	96	100	100	Limited Meals Advisory	**No Consumption W & C**
Walleye	482.7	329.3	0	2	16	88	100	100	Limited Meals Advisory	**No Consumption W & C**
White Bass	1383.2	737.7	0	0	0	22	82	100	Limited Meals Advisory	**No Consumption GP**
White Perch	1569.1	902.4	0	0	0	17	74	100	Limited Meals Advisory	**No Consumption GP**
Yellow Perch	288.6	184.1	0	7	42	98	100	100	Limited Meals Advisory	**No Consumption W & C**

Suggested fish advice information established using the minimum bin category whose cumulative frequency distribution of samples exceeded 50% (area marked in Grey).

Table 23. Model simulations for the upper Canadian zone contrasting original model output (zone specific water and sediment PCB concentrations) and predicted fish advice information against simulations where water or sediment concentrations were set to a value of zero.

Species	Original Model		Model $C_w = 0$		Model $C_{sed} = 0$		% Sed.	% Water
	Conc. (ng/g) Mean	Fish Advice	Conc. (ng/g) Mean	Fish Advice Mean	Conc. (ng/g) Mean	Fish Advice Mean		
Brown Bullhead	7.7	No advice information	5.5	No advice information	2.27	No advice information	70.6	29.4
Northern Pike	9.1	No advice information	2.8	No advice information	6.26	No advice information	30.5	68.8
Largemouth Bass	25.2	No advice information	6.6	No advice information	18.12	No advice information	26.4	72.0
Bluegill	48.3	No advice information	14.6	No advice information	33.12	No advice information	30.2	68.5
Sucker	56.6	MI Least Restrictive Trigger	34.6	No advice information	21.21	No advice information	61.1	37.5
Yellow Perch	57.0	MI Least Restrictive Trigger	15.5	No advice information	41.59	No advice information	27.2	72.9
Rock Bass	59.6	MI Least Restrictive Trigger	35.4	No advice information	23.5	No advice information	59.4	39.4
Muskellunge	80.5	MI Least Restrictive Trigger	27.4	No advice information	50.95	MI Least Restrictive Trigger	34.0	63.3
Freshwater Drum	119.1	ON Least Restrictive Trigger	84.9	MI Least Restrictive Trigger	50.25	MI Least Restrictive Trigger	71.3	42.2
Gizzard Shad	132.6	ON Least Restrictive Trigger	22.9	No advice information	106.17	ON Least Restrictive Trigger	17.2	80.1
Walleye	154.1	ON Least Restrictive Trigger	16.8	No advice information	132.42	ON Least Restrictive Trigger	10.9	86.0
Smallmouth Bass	195.7	ON Least Restrictive Trigger	31.7	No advice information	161.5	ON Least Restrictive Trigger	16.2	82.5
White Bass	265.5	**ON SP No Consumption**	81.4	MI Least Restrictive Trigger	180.25	ON Least Restrictive Trigger	30.6	67.9
Gar Pike	367.4	**ON SP No Consumption**	97.8	MI Least Restrictive Trigger	272.92	**ON SP No Consumption**	26.6	74.3
Common Carp	373.6	**ON SP No Consumption**	263.7	**ON SP No Consumption**	114.63	ON Least Restrictive Trigger	70.6	30.7
White Perch	384.3	**ON SP No Consumption**	79.0	MI Least Restrictive Trigger	293.24	**ON SP No Consumption**	20.6	76.3
Channel Catfish	473.1	**ON SP No Consumption**	310.1	**ON SP No Consumption**	158.87	ON Least Restrictive Trigger	65.5	33.6

Species sorted by concentration as predicted in the original model simulations.

% Sed. = the % PCB burden contributed by contaminated sediment inputs in the original model simulation.
%Water = the % PCB burden contributed by contaminated water inputs in the original model simulation.

Table 24. Model simulations for the middle Canadian zone contrasting original model output (zone specific water and sediment PCB concentrations) and predicted fish advice information against simulations where water or sediment concentrations were set to a value of zero.

Species	Original Model		Model C_w = 0		Model C_{sed} = 0		% Sed	% Water
	Conc. (ng/g) Mean	Fish Advice	Conc. (ng/g) Mean	Fish Advice Mean	Conc. (ng/g) Mean	Fish Advice Mean		
Northern Pike	10.6	No advice information	5.5	No advice information	5.3	No advice information	51.8	49.9
Brown Bullhead	12.7	No advice information	11.1	No advice information	1.87	No advice information	87.8	14.8
Largemouth Bass	28.2	No advice information	13.4	No advice information	14.32	No advice information	47.6	50.8
Bluegill	60.3	MI Least Restrictive Trigger	30.2	No advice information	27.73	No advice information	50.1	46.0
Yellow Perch	64.9	MI Least Restrictive Trigger	31.2	No advice information	32.81	No advice information	48.1	50.6
Sucker	88.2	MI Least Restrictive Trigger	69.6	MI Least Restrictive Trigger	17.9	No advice information	79.0	20.3
Rock Bass	92.3	MI Least Restrictive Trigger	69.5	MI Least Restrictive Trigger	19.75	No advice information	75.4	21.4
Muskellunge	96.5	MI Least Restrictive Trigger	52.9	MI Least Restrictive Trigger	46.4	MI Least Restrictive Trigger	54.8	48.1
Gizzard Shad	129.5	ON Least Restrictive Trigger	46.3	No advice information	87.75	MI Least Restrictive Trigger	35.8	67.8
Walleye	144.4	ON Least Restrictive Trigger	35.2	No advice information	106	MI Least Restrictive Trigger	24.4	73.4
Freshwater Drum	184.5	ON Least Restrictive Trigger	140.8	ON Least Restrictive Trigger	39.1	MI Least Restrictive Trigger	76.4	21.2
Smallmouth Bass	201.0	ON Least Restrictive Trigger	64.7	MI Least Restrictive Trigger	137.27	ON Least Restrictive Trigger	32.2	68.3
White Bass	304.0	**ON SP No Consumption**	163.2	ON Least Restrictive Trigger	144.27	MI Least Restrictive Trigger	53.7	47.5
White Perch	402.3	**ON SP No Consumption**	158.4	ON Least Restrictive Trigger	240.96	ON Least Restrictive Trigger	39.4	59.9
Gar Pike	428.9	**ON SP No Consumption**	200.8	ON Least Restrictive Trigger	239.54	**ON SP No Consumption**	46.8	55.8
Common Carp	608.2	**ON SP No Consumption**	531.9	**ON SP No Consumption**	98.2	MI Least Restrictive Trigger	87.4	16.1
Channel Catfish	754.0	**ON SP No Consumption**	575.7	**ON SP No Consumption**	134.3	MI Least Restrictive Trigger	76.3	17.8

Species sorted by concentration as predicted in the original model simulations.

% Sed. = the % PCB burden contributed by contaminated sediment inputs in the original model simulation.

%Water = the % PCB burden contributed by contaminated water inputs in the original model simulation.

Table 25. Model simulations for the lower Canadian zone contrasting original model output (zone specific water and sediment PCB concentrations) and predicted fish advice information against simulations where water or sediment concentrations were set to a value of zero.

Species	Original Model		Model Cw = 0		Model Csed = 0		% Sed	%Water
	Conc. (ng/g)	Fish Advice	Conc. (ng/g)	Fish Advice	Conc. (ng/g)	Fish Advice		
	Mean		Mean	Mean	Mean	Mean		
Northern Pike	10.9	No advice information	6.2	No advice information	4.38	No advice information	56.9	40.3
Brown Bullhead	13.8	No advice information	11.9	No advice information	1.68	No advice information	86.3	12.1
Largemouth Bass	29.2	No advice information	14.3	No advice information	13.2	No advice information	49.0	45.2
Bluegill	60.4	MI Least Restrictive Trigger	36.4	No advice information	25.49	No advice information	60.2	42.2
Yellow Perch	64.7	MI Least Restrictive Trigger	36.0	No advice information	28.65	No advice information	55.6	44.3
Sucker	94.2	MI Least Restrictive Trigger	77.1	MI Least Restrictive Trigger	15.14	No advice information	81.8	16.1
Rock Bass	97.9	MI Least Restrictive Trigger	77.9	MI Least Restrictive Trigger	17.02	No advice information	79.5	17.4
Muskellunge	103.7	MI Least Restrictive Trigger	60.4	MI Least Restrictive Trigger	37.86	No advice information	58.3	36.5
Gizzard Shad	125.6	ON Least Restrictive Trigger	50.2	MI Least Restrictive Trigger	75.19	MI Least Restrictive Trigger	40.0	59.9
Walleye	135.4	ON Least Restrictive Trigger	38.8	MI Least Restrictive Trigger	78.44	MI Least Restrictive Trigger	28.6	57.9
Smallmouth Bass	187.4	ON Least Restrictive Trigger	70.4	MI Least Restrictive Trigger	116.25	ON Least Restrictive Trigger	37.6	62.0
Freshwater Drum	201.0	ON Least Restrictive Trigger	172.5	ON Least Restrictive Trigger	35.51	No advice information	85.8	17.7
White Bass	313.9	**ON SP No Consumption**	186.9	ON Least Restrictive Trigger	127.66	ON Least Restrictive Trigger	59.5	40.7
White Perch	392.2	**ON SP No Consumption**	176.7	ON Least Restrictive Trigger	214.8	**ON SP No Consumption**	45.0	54.8
Gar Pike	450.4	**ON SP No Consumption**	221.6	**ON SP No Consumption**	193.56	ON Least Restrictive Trigger	49.2	43.0
Common Carp	693.4	**ON SP No Consumption**	590.5	**ON SP No Consumption**	83.41	MI Least Restrictive Trigger	85.2	12.0
Channel Catfish	784.1	**ON SP No Consumption**	674.4	**ON SP No Consumption**	118.38	ON Least Restrictive Trigger	86.0	15.1

Species sorted by concentration as predicted in the original model simulations.

% Sed. = the % PCB burden contributed by contaminated sediment inputs in the original model simulation.

%Water = the % PCB burden contributed by contaminated water inputs in the original model simulation.

Table 26. Model simulations for the upper U.S. zone contrasting original model output (zone specific water and sediment PCB concentrations) and predicted fish advice information against simulations where water or sediment concentrations were set to a value of zero.

Species	Original Model		Model Cw = 0		Model Csed = 0		% Sed	%Water
	Conc. (ng/g)	Fish Advice	Conc. (ng/g)	Fish Advice	Conc. (ng/g)	Fish Advice		
	Mean		Mean	Mean	Mean	Mean		
Northern Pike	58.8	MI Least Restrictive Trigger	43.3	No advice information	17.23	No advice information	73.7	29.3
Brown Bullhead	88.2	MI Least Restrictive Trigger	84.0	MI Least Restrictive Trigger	6.05	No advice information	95.2	6.9
Largemouth Bass	148.7	ON Least Restrictive Trigger	105.6	ON Least Restrictive Trigger	49.32	No advice information	71.0	33.2
Bluegill	338.6	**ON SP No Consumption**	246.0	**ON SP No Consumption**	90.16	ON Least Restrictive Trigger	72.6	26.6
Yellow Perch	344.3	**ON SP No Consumption**	256.6	**ON SP No Consumption**	107.97	ON Least Restrictive Trigger	74.5	31.4
Muskellunge	541.0	**ON SP No Consumption**	422.0	**ON SP No Consumption**	160.94	ON Least Restrictive Trigger	78.0	29.7
Sucker	567.0	**ON SP No Consumption**	541.9	**ON SP No Consumption**	58.76	MI Least Restrictive Trigger	95.6	10.4
Rock Bass	613.2	**ON SP No Consumption**	553.3	**ON SP No Consumption**	64.21	MI Least Restrictive Trigger	90.2	10.5
Walleye	616.3	**ON SP No Consumption**	261.5	**ON SP No Consumption**	266.03	**ON SP No Consumption**	42.4	43.2
Gizzard Shad	624.2	**ON SP No Consumption**	356.5	**ON SP No Consumption**	296.82	**ON SP No Consumption**	57.1	47.6
Smallmouth Bass	914.2	**ON GP No Consumption**	477.4	**ON SP No Consumption**	428.53	**ON SP No Consumption**	52.2	46.9
Freshwater Drum	1297.4	**ON GP No Consumption**	1192.0	**ON GP No Consumption**	129.97	ON Least Restrictive Trigger	91.9	10.0
White Bass	1780.6	**ON GP No Consumption**	1307.7	**ON GP No Consumption**	503.63	**ON SP No Consumption**	73.4	28.3
White Perch	2049.3	**MI GP No Consumption**	1247.7	**ON GP No Consumption**	847.85	**ON GP No Consumption**	60.9	41.4
Gar Pike	2263.0	**MI GP No Consumption**	1492.8	**ON GP No Consumption**	758.29	**ON SP No Consumption**	66.0	33.5
Common Carp	4088.2	**MI GP No Consumption**	4081.1	**MI GP No Consumption**	314.31	**ON SP No Consumption**	99.8	7.7
Channel Catfish	4793.4	**MI GP No Consumption**	4652.6	**MI GP No Consumption**	444.76	**ON SP No Consumption**	97.1	9.3

Species sorted by concentration as predicted in the original model simulations.

% Sed. = the % PCB burden contributed by contaminated sediment inputs in the original model simulation.

%Water = the % PCB burden contributed by contaminated water inputs in the original model simulation.

Table 27. Model simulations for the middle U.S. zone contrasting original model output (zone specific water and sediment PCB concentrations) and predicted fish advice information against simulations where water or sediment concentrations were set to a value of zero.

Species	Original Model Conc. (ng/g) Mean	Original Model Fish Advice	Model Cw = 0 Conc. (ng/g) Mean	Model Cw = 0 Fish Advice Mean	Model Csed = 0 Conc. (ng/g) Mean	Model Csed = 0 Fish Advice Mean	% Sed	% Water
Northern Pike	58.1	MI Least Restrictive Trigger	43.0	No advice information	4.99	No advice information	74.0	8.6
Brown Bullhead	89.9	MI Least Restrictive Trigger	80.3	MI Least Restrictive Trigger	1.7	No advice information	89.3	1.9
Largemouth Bass	151.8	ON Least Restrictive Trigger	100.6	MI Least Restrictive Trigger	14.29	No advice information	66.3	9.4
Yellow Perch	346.0	**ON SP No Consumption**	238.1	**ON SP No Consumption**	30.02	No advice information	68.8	8.7
Bluegill	351.6	**ON SP No Consumption**	251.6	**ON SP No Consumption**	25.66	No advice information	71.6	7.3
Muskellunge	531.5	**ON SP No Consumption**	418.1	**ON SP No Consumption**	42	No advice information	78.7	7.9
Sucker	567.6	**ON SP No Consumption**	503.9	**ON SP No Consumption**	17.08	No advice information	88.8	3.0
Gizzard Shad	584.3	**ON SP No Consumption**	339.4	**ON SP No Consumption**	84.56	MI Least Restrictive Trigger	58.1	14.5
Walleye	591.5	**ON SP No Consumption**	269.0	**ON SP No Consumption**	103.17	MI Least Restrictive Trigger	45.5	17.4
Rock Bass	596.3	**ON SP No Consumption**	527.0	**ON SP No Consumption**	18.57	MI Least Restrictive Trigger	88.4	3.1
Smallmouth Bass	933.3	**ON GP No Consumption**	463.7	**ON SP No Consumption**	122.37	ON Least Restrictive Trigger	49.7	13.1
Freshwater Drum	1338.3	**ON GP No Consumption**	1062.1	**ON GP No Consumption**	40.38	No advice information	79.4	3.0
White Bass	1657.2	**ON GP No Consumption**	1246.9	**ON GP No Consumption**	138.27	ON Least Restrictive Trigger	75.2	8.3
White Perch	1903.3	**MI GP No Consumption**	1237.3	**ON GP No Consumption**	226.12	**ON SP No Consumption**	65.0	11.9
Gar Pike	2273.8	**MI GP No Consumption**	1530.9	**ON GP No Consumption**	216.05	**ON SP No Consumption**	67.3	9.5
Common Carp	4110.4	**MI GP No Consumption**	4220.5	**MI GP No Consumption**	88.24	MI Least Restrictive Trigger	102.7	2.1
Channel Catfish	4948.5	**MI GP No Consumption**	4076.5	**MI GP No Consumption**	130.35	ON Least Restrictive Trigger	82.4	2.6

Species sorted by concentration as predicted in the original model simulations.

% Sed. = the % PCB burden contributed by contaminated sediment inputs in the original model simulation.

%Water = the % PCB burden contributed by contaminated water inputs in the original model simulation.

Table 28. Model simulations for the lower U.S. zone contrasting original model output (zone specific water and sediment PCB concentrations) and predicted fish advice information against simulations where water or sediment concentrations were set to a value of zero.

Species	Original Model Conc. (ng/g) Mean	Original Model Fish Advice	Model Cw = 0 Conc. (ng/g) Mean	Model Cw = 0 Fish Advice Mean	Model Csed = 0 Conc. (ng/g) Mean	Model Csed = 0 Fish Advice Mean	% Sed	%Water
Northern Pike	47.6	No advice information	32.5	No advice information	14.72	No advice information	68.2	30.9
Brown Bullhead	68.3	MI Least Restrictive Trigger	62.5	MI Least Restrictive Trigger	5.38	No advice information	91.5	7.9
Largemouth Bass	119.0	ON Least Restrictive Trigger	76.7	MI Least Restrictive Trigger	41.66	No advice information	64.5	35.0
Bluegill	271.1	**ON SP No Consumption**	171.8	ON Least Restrictive Trigger	83.36	MI Least Restrictive Trigger	63.4	30.7
Yellow Perch	288.6	**ON SP No Consumption**	187.4	ON Least Restrictive Trigger	92.79	MI Least Restrictive Trigger	64.9	32.2
Sucker	444.7	**ON SP No Consumption**	394.1	**ON SP No Consumption**	50.67	MI Least Restrictive Trigger	88.6	11.4
Muskellunge	457.5	**ON SP No Consumption**	301.7	**ON SP No Consumption**	122.08	ON Least Restrictive Trigger	66.0	26.7
Rock Bass	471.1	**ON SP No Consumption**	398.1	**ON SP No Consumption**	56.45	MI Least Restrictive Trigger	84.5	12.0
Walleye	482.7	**ON SP No Consumption**	201.2	ON Least Restrictive Trigger	309.83	**ON SP No Consumption**	41.7	64.2
Gizzard Shad	507.5	**ON SP No Consumption**	261.5	**ON SP No Consumption**	236.22	**ON SP No Consumption**	51.5	46.5
Smallmouth Bass	788.9	**ON SP No Consumption**	376.9	**ON SP No Consumption**	397.63	**ON SP No Consumption**	47.8	50.4
Freshwater Drum	1038.9	**ON GP No Consumption**	881.0	**ON GP No Consumption**	97.34	MI Least Restrictive Trigger	84.8	9.4
White Bass	1383.2	**ON GP No Consumption**	963.5	**ON GP No Consumption**	417.08	**ON SP No Consumption**	69.7	30.2
White Perch	1569.1	**ON GP No Consumption**	925.5	**ON GP No Consumption**	677.94	**ON SP No Consumption**	59.0	43.2
Gar Pike	1850.6	**ON GP No Consumption**	1107.2	**ON GP No Consumption**	627.37	**ON SP No Consumption**	59.8	33.9
Common Carp	3109.1	**MI GP No Consumption**	3027.9	**MI GP No Consumption**	272.57	**ON SP No Consumption**	97.4	8.8
Channel Catfish	3644.8	**MI GP No Consumption**	3448.5	**MI GP No Consumption**	383.08	**ON SP No Consumption**	94.6	10.5

Species sorted by concentration as predicted in the original model simulations.

% Sed. = the % PCB burden contributed by contaminated sediment inputs in the original model simulation.

%Water = the % PCB burden contributed by contaminated water inputs in the original model simulation.

Recommendations

The top priority questions and issues identified in Workshop 1 by stakeholders were:

1) How can we increase public awareness of fish consumption advisories?
2) Do fish collected for contaminant analysis represent the population of fish accurately?
3) What are contaminant levels of fish not included in the advisory that are consumed from the Detroit River?
4) Where are the sources of contaminant in the basin that are high enough to translate into a fish consumption advisory?
5) Are we appropriately measuring emerging contaminants?

The modelling sub-group updated and revised the Detroit River Fish Consumption Hazard Assessment model to address questions 2, 3 and 4 with emphasis on questions 3 and 4. The conclusions from modelling activities relating to the above stakeholder generated questions are summarized below.

2) Do fish collected for contaminant analysis represent the population of fish accurately?

Creel surveys were performed as part of the fish advisory awareness sub-group. The modelling sub-group examined this question by performing an analysis of the available data for the empirical sport fish contaminant data base and to characterize expected frequency distributions of PCB concentrations in different sport fish species in 6 areas within the Detroit River.

The empirical data based demonstrated major data gaps in the availability of measured PCB concentrations in several sport fish species on the U.S. side of the Detroit River. Of the 20 sport fish species considered in the Detroit River Fish Consumption Hazard Assessment model and considered to be consumed by the shore line fishers in Canada and the U.S., 13 species had available data for the Detroit River during the period of 1998-2008 with replicate sizes greater than n=10/species. However, replicate numbers of fish sampled in different portions of the Detroit River and by international jurisdiction was uneven. In the U.S., MDEQ data were only available for 5 species of sport fish at two sampling locations. Replicate numbers were also low in this jurisdiction ranging from 8-16 fish/species. *It is recommended that additional fish sampling and contaminant analysis be performed on the Michigan side of the Detroit River to capture a minimum of n=10 fish per species of the following sport fish: black crappie, bluegill sunfish, brown bullhead, channel catfish, gar pike, gizzard shad, largemouth bass, muskellunge, northern pike, rock bass, smallmouth bass, white bass and white perch.*

The Ontario jurisdiction had more extensive contaminant data for a more diverse number of species. To complete an empirical data base on all sport fish species commonly consumed in the river it *is recommended that supplemental information by Ontario MOE be generated to capture and analyse a minimum of n=10 of the following species: black crappie, bluegill sunfish, brown bullhead, northern pike, sucker and smallmouth bass from Ontario waters of the Detroit River.*

Ontario divides the Detroit River into an upstream and downstream boundary for establishing fish advisory information while Michigan provides a single set of advice information for the entire U.S. side of the Detroit River. Examination of the empirical data base provided little support for differences in fish concentrations by species between the upper, middle or lower zones within a given jurisdiction, i.e. no differences in the upstream to downstream zones within Canadian waters or within U.S. waters. These analyses were restricted to common carp, freshwater drum, walleye and yellow perch owing to a general paucity of sample replicates across different areas and international boundaries in the Detroit River. However, the Detroit River Fish Consumption Hazard Assessment model produced similar results with the empirical data when applied across multiple sport fish species and zones. Neither the model or empirical observations on PCB concentrations in sport fish indicated major differences in observed or expected PCB bioaccumulation between the different modelling zones encompassed by U.S. waters only or between the different zones associated with the Canadian waters. Model differences on a species specific basis were almost always within a factor of 2 or less when comparing the different food web modelling zones in the Canadian waters or between the three food web modelling zones in U.S. waters. These combined empirical and model based simulations suggest that *Ontario OMOE consider adopting a single advice information geographic boundary that includes the entire Canadian portion of the Detroit River as opposed to separating the river into upstream and downstream sections.* Implementing this policy would help harmonize advisory information across the two international jurisdictions and provide a more simpler presentation of fish advice information to the Ontario public.

3) What are contaminant levels of fish not included in the advisory that are consumed from the Detroit River?

The calibrated Detroit River Fish Consumption Hazard Assessment model was used to predict PCB concentrations in 18 sport fish species in upper, middle and lower U.S. and Canadian modelling zones. As per recommendations in (2) above, the data generated for the three different modelling zones in U.S. waters were combined to establish a single set of predicted PCB concentrations in sport fish by species and to contrast such predictions with advice trigger levels used by Michigan. Similarly, data were combined across Canadian waters to provide a single table of expected PCB concentrations in each sport fish species in the Ontario jurisdiction. These data are summarized in Tables 29 and 30 below.

For the U.S. jurisdiction, there was no sport fish advice information available for the following species: blugill, brown bullhead, channel catfish, gar pike, gizzard shad, largemouth bass, muskellunge, rock bass, smallmouth bass, white bass and white perch. Model predicted PCB concentrations in each of the above species are presented in Table 29. *Predicted fish consumption advice for species not included in currently issued fish consumption advisories by Michigan range from 1 meal/week (bluegill, brown bullhead, largemouth bass, northern pike), 1 meal/mo (gizzard shad, largemouth bass, rock bass, smallmouth bass), 6 meal/year (gar pike, white bass, white perch) and no consumption (channel catfish).* In general, predicted fish advisories by the model were more conservative (i.e. more restrictive) compared to existing Michigan fish advisories currently in place for the U.S. portion of the Detroit River. This is partly due to the use of species adjustment factors in the calibrated model framework which led to more conservative estimates of PCB bioaccumulation in fish from U.S. waters. The conservative aspect of the model was considered appropriate given the relative lack of empirical sport fish data across many species and small replicate sizes available in the fish contaminant data base for the U.S. side of the river.

For the Canadian jurisdiction, sport fish advice information was not available for bluegill, brown bullhead, gar pike, gizzard shad, muskellunge, sucker and smallmouth bass. *Model predicted Ontario advisories for these species ranged from no advisories necessary (bluegill, brown bullhead, gizzard shad, muskellunge and sucker), limited meals (smallmouth bass) and no consumption for sensitive sub populations (gar pike).* In general, model predicted fish consumption advisories were less conservative (i.e. less restricted) than the most restrictive advice information advisories issued by Ontario.

Table 29. Model predicted PCB concentrations in sport fish and model generated fish consumption advice (Predicted) as compared to advice information issued by MDEQ (Issued) for the U.S. waters of the Detroit River.

	Conc. (ng/g)		Cummulative Frequencies Below Trigger Boundary					Predicted	Issued
Species	Mean	SD	<50	50 - 200	200-1000	1000-1890	>1890	Michigan	Michigan
Bluegill	335.8	717.9	18.6	58.0	93.8	98.1	100.0	1 meal/week	NA
Brown bullhead	80.5	68.2	36.8	95.2	100.0	100.0	100.0	1 meal/week	NA
Carp	3950.0	4389.8	0.0	0.1	12.9	35.3	100.0	No Consumption	**Advisories**
Channel Cat	4661.8	5309.3	0.0	0.0	4.4	20.4	100.0	No Consumption	NA
Freshwater Drum	1199.1	2095.5	1.7	18.4	67.5	83.0	100.0	1 meal/mo	**Advisories**
Gar Pike	2137.3	2295.9	0.0	0.4	30.2	60.3	100.0	6 meal/yr	NA
Gizzard Shad	579.6	476.8	0.1	9.6	88.5	98.1	100.0	1 meal/mo	NA
Largemouth Bass	142.8	134.5	10.0	81.2	99.8	100.0	100.0	1 meal/week	NA
Muskellunge	524.2	636.2	1.9	29.3	88.0	96.8	100.0	1 meal/mo	NA
Northern Pike	56.3	29.9	47.7	99.6	100.0	100.0	100.0	1 meal/week	**Advisories**
Sucker	546.2	559.9	0.0	2.0	94.4	99.3	100.0	1 meal/mo	**Advisories**
Rock Bass	567.7	390.8	0.0	1.3	93.2	99.2	100.0	1 meal/mo	NA
Smallmout Bass	879.8	833.7	0.0	6.1	72.0	91.5	100.0	1 meal/mo	NA
Walleye	593.9	513.8	0.0	11.3	86.8	97.6	100.0	1 meal/mo	**Advisories**
White Bass	1610.4	1146.5	0.0	0.0	29.6	72.9	100.0	6 meal/yr	NA
White Perch	1874.0	1245.9	0.0	0.0	22.8	62.7	100.0	6 meal/yr	NA
Yellow Perch	327.8	287.6	0.6	34.1	97.8	99.7	100.0	1 meal/mo	**Advisories**

Table 30. Model predicted PCB concentrations in sport fish and advice information for Canadian waters of the Detroit River.

	Conc. (ng/g)		Cummulative Frequencies Below Trigger Boundary				Predicted	Issued
Species	Mean	SD	<105	105-211	211-844	>844	Ontario	Ontario
Bluegill	57.7	92.0	86.2	95.4	99.8	100	*No advisories*	NA
Brown bullhead	11.5	9.5	99.9	100.0	100.0	100	*No advisories*	NA
Carp	560.1	614.4	7.2	26.1	81.2	100	**No Consumption W&C**	**Advisories**
Channel Cat	668.1	591.6	1.5	11.5	75.0	100	**No Consumption W&C**	**Advisories**
Freshwater Drum	171.3	276.2	56.1	77.7	97.5	100	*No advisories*	**Advisories**
Gar Pike	397.3	356.3	8.6	31.5	91.1	100	**No Consumption W&C**	NA
Gizzard Shad	126.5	93.8	51.9	86.5	99.7	100	*No advisories*	NA
Largemouth Bass	27.2	19.3	99.1	100.0	100.0	100	*No advisories*	**Advisories**
Muskellunge	88.6	100.6	73.4	92.3	99.5	100	*No advisories*	NA
Northern Pike	10.2	4.0	100.0	100.0	100.0	100	*No advisories*	**Advisories**
Sucker	78.6	42.0	81.1	98.9	99.9	100	*No advisories*	NA
Rock Bass	81.5	40.7	79.0	98.8	100.0	100	*No advisories*	**Advisories**
Smallmout Bass	191.6	166.7	33.3	69.6	98.9	100	Limited fish consumption	NA
Walleye	145.0	109.6	43.8	81.6	99.8	100	Limited fish consumption	**Advisories**
White Bass	288.5	175.8	5.5	36.5	98.5	100	**No Consumption W&C**	**Advisories**
White Perch	388.6	227.8	2.1	20.8	95.4	100	**No Consumption W&C**	**Advisories**
Yellow Perch	59.9	40.8	88.2	99.0	99.9	100	*No advisories*	**Advisories**

Note: W&C refers to the sensitive sub-population of women and children.

4) Where are the sources of contaminant in the basin that are high enough to translate into a fish consumption advisory?

The Detroit River Fish Consumption Hazard Assessment model was used to predict fish bioaccumulation in 6 different food web modelling zones that encompassed the entire waters of the Detroit River. The upper Canadian food web modelling zone had the lowest PCB concentrations in its water and sediments. The levels of PCBs in environmental media found within this zone are similar to background contamination present in Lake St. Clair (Raeside et al 2009). As such, this modelling zone provides a good surrogate measure of likely contributions of upstream waters and contaminated particles to PCB bioaccumulation in fish under conditions of extensive clean-up occurring in the upper Canadian food web modelling zone. For the upper Canadian zone, PCBs in water contributed to an average of 60.3% of the bioaccumulated residues in the different species of sport fish. Given that water quality in this region of the river is mostly influenced by upstream contributions, *this suggests that contaminated water, originating from Lake St. Clair, will contribute to PCB bioaccumulation in fish that will warrant fish advice information be issued even under a virtual PCB elimination scenario for Canadian* *waters of the Detroit River.* For example, complete removal of PCBs from sediments in this zone, without impacting water quality, would reduce the number of advisories issues by Ontario for only 1 species (freshwater drum). The above actions would have the additional benefit of decreasing the intensity of advice information issued for white bass, common carp and channel catfish. PCB bioaccumulation in the Ontario middle and lower food web modelling zones were predicted to be higher than the upper zone, but only moderately so. Sediment remediation in these areas of the river would have an effect that approaches those described for the upper Ontario zone.

The model predicted PCB concentrations in Canadian sport fish were always predicted to be lower than Ontario's most restrictive advice trigger of 'No consumption' for the general public. Yet currently issued sport fish advisories by Ontario include 'No consumption' advice information for the general public for common carp, channel catfish and white bass. These same species, along with gar pike and white perch, were predicted to exceed the Ontario 'No consumption' advice triggers in all three U.S. modelling zones. Common carp and channel catfish were also predicted to exceed the Michigan 'No consumption' advice trigger for the general public. *This suggests that the most restrictive advice information currently being issued in Ontario waters for common carp, channel catfish and white bass are attributed to fish movements that involve spatially integrated exposures outside of the modelling zone.* Indeed, prior to calibration, the Detroit River Fish Consumption Hazard Assessment model exhibited a bias towards under prediction of residues that was most pronounced in Canadian waters. The implementation of species adjustment factors to correct this bias are likely related to the degree of fish movements and/or size and age effects not considered by the hazard model. For evaluation of fish movements on model output are explored in Chapter 6. For the upper Canadian model zones, the issuing of 'No consumption' advice information for channel catfish and common carp would appear to be a result of fish exposures to contaminated sediments occurring on the U.S. side of the Detroit River.

For the U.S. side of the Detroit River, all three zones had similar zone wide sediment contamination, whereas PCBs in water increased from upstream to downstream sections of the river. PCB concentrations in waters of the upper U.S. zone were well above those measured in upper Canadian and Lake St. Clair suggesting that in-stream sources of PCBs contribute to degraded water quality. *However, a primary conclusion of the Detroit River Fish Consumption Hazard Assessment Model was that contaminated sediments in the U.S. zones were the most important driver of bioaccumulated PCB residues in fish, contributing to an average of 73.3±16.1% of total bioaccumulated residues across the different species.* Model simulations were performed where PCB concentrations in water were set to zero but sediment inputs were maintained as the zone wide average. Under these scenarios, only one predicted advisory would be removed (brown bullhead) and between 1 to 4 advisories would decrease in the intensity of advice information issued. However, running simulations with virtual elimination of PCBs from sediments while maintaining the same water quality, resulted in predicted removal of between 2-8 advisories and reduction in the intensities of advice information for between 8 to 12 sport fish species depending on the zone. *These results provide a strong rationale for the continued management focus on remediation of contaminated sediments within the U.S. side of the Detroit River.* Since the 1999 comprehensive sediment survey, sediment remediation projects have already been completed in Connor's Creek and Black Lagoon. Recent sediment quality survey updates (GLIER 2008/2009) will enable a river wide re-assessment of Detroit River sediment quality to determine the above past remediation activities have changed the zone wide concentration trends deduced using the earlier surveys.

In order to achieve sediment clean-up results that translate into reductions in number and intensities of fish advice information, mass balance assessments and river-wide surveys of water and sediment quality must be performed to demonstrate the effect that smaller scale clean-up activities have on zone-wide mean PCB concentrations in sediments. With its focus on predicting PCB residues in sport fish, the Detroit River Fish Consumption Hazard assessment in its current format lacks the spatial resolution necessary to provide recommendations on areas of priority for sediment remediation. *It is therefore recommended that a sediment clean-up sub-model be developed that can be linked with the Detroit River Fish Consumption Hazard Assessment models to aid as a decision support tool for sediment remediation.* The sediment clean-up model should be able to provide high resolution sediment contamination maps, contaminant mass balances and be able to translate how specific sediment dredging and clean-up activities influence zone wide average contaminant concentrations. The summarized data can then serve as inputs to the fish consumption hazard assessment model to determine anticipated effects of specific sediment dredging and clean-up activities.

5) Are we appropriately measuring emerging contaminants?

The Detroit River Fish Consumption Hazard Assessment model was formulated for PCBs as a priority contaminant contributing to the majority of fish advice information issued for the Detroit River. The model could, with modification, be extended to address bioaccumulation of other classes of hydrophobic, bioaccumulative contaminants such as polybrominated diphenyl ethers (PBDEs). The model can also be readily adapted to predict bioaccumulation of dioxin. However, implementing model simulations for these compounds would necessitate compiling inputs on water and sediment contamination to a level of spatial resolution that exists for PCBs. Thus, in order to establish inputs for emerging organic contaminants of concern, additional spatially comprehensive surveys of water and sediment quality would be necessary. Another contaminant of interest to the Detroit River is mercury. The Detroit River Fish Consumption Hazard Assessment model uses bioavailability, biomagnification and chemical elimination algorithms that are specific to hydrophobic organic contaminants that are not applicable to mercury. In order to model and predict fish consumption advisories due to mercury in the Detroit River, a mercury bioaccumulation model would have to be developed.

References

Anderson DJ, TB BLoem, RK Blankenbaker, TA Stanko. 1999. Concentrations of polychlorinated biphenyls in the water column of the Laurention Grat Lakes: spring 1993. *J. Great Lakes Res*. 25:160-170.

Arnot JA, FAPC Gobas. 2004. A food web bioaccumulation model for organic chemicals in aquatic ecosystems. *Environ. Toxicol. Chem*. 23:2343-2355.

Debruyn AMH, FAPC Gobas. 2007. The sorptive capacity of animal protein. *Environ. Toxicol. Chem*. 26:1803-1808.

Ditoro DM, CS Zarba, DJ Hansen, WJ Berry, RC Swartz, CE Cowan, SP Pavlou, HE Allen, NA Thomas, PR Paquin. 1991. Technical basis for establishing sediment quality criteria for non-ionic organic-chemicals using equilibrium partitioning. *Environ. Toxicol. Chem*. 10:1541-1583.

Drouillard, KG, JH Ciborowski, R Lazar, GD Haffner. 1996. Estimation of the uptake of organochlorines by the mayfly *Hexagenia limbata* (Ephemerotpera: Ephemidae). *J. Great Lakes Res. 22:26-35.*

Drouillard, KG, M Tomczak, S Reitsma, GD Haffner. 2006. A river wide survey of polychlorinated biphenyls (PCBs), polycyclic aromatic hydrocarbons (PAHs) and selected organochlorine pesticide residues in sediments of the Detroit River - 1999. *J. Great Lakes Res*. 32:209-226.

Fish and Wildlife Nutrition Project. 2000. *Communicating Fish Advisory Information: A Monograph*. Final report submitted to the Great Lakes 2000 Program, Health Canada, Ottawa, ON.

Frame GM, JW Cochran, SS Bowadt. 1996. Complete PCB congener distributions for 17 aroclor mixtures determined by 3 HRGC systems optimized for comprehensive, quantitative, congener-specific analysis. *HRC-Journal of High Resolution Chromatography*. 19:657-668.

Froese, K.L., D.A. Verbrugge, S.A. Snyder, F. Tilton, M. Tuchman, A. Ostaszewski and J.P. Giesy. 1997. “PCBs in the Detroit River water column.” *J. Great Lakes Res.* 23:440-449.

Gewurtz SB, KG Drouillard, R Lazar, GD Haffner. Quantitative biomonitoring of PAHs using the Barnes mussel (*Elliptio complanata*). *Arch. Environ. Contam. Toxciol.* 43:497-504.

Gewurtz SB, R Lazar, GD Haffner. 2003. Biomonitoring of bioavailabe PAH and PCB water concentrations in the Detroit River using the freshwater mussel, *Elliptio complanata*. *J. Great Lakes Res.* 29:242-255.

Gobas FAPC. 1983. A model for predicting the bioaccumulation of hydrophobic organic-chemicals in aquatic food webs – Application to Lake Ontario. *Ecological Modelling*. 69:1-17.

Gobas FAPCC, MN Agraggen, X Zhang. 1995. Time response of the Lake-Ontario ecosystem to virtual elimination of PCBs. *Environ. Sci. Technol.* 29:2038-2046.

Hawker DW, DW Connell. 1988. Octanol water partition coefficients for polychlorinated biphenyl congeners. *Environ. Sci. Technol*. 22:382-387.

Heidtke T, JH Hartig, MA Zarull, BN Yu. 2006. PCB levels and trends within the Detroit River-Western Lake Erie basin: A historical perspective of ecosystem monitoring. *Environ. Monitor. Assess*. 112:23-33.

Kaiser, KLE, ME Comba, H Hunter, RJ Maguire, RJ Tkacz, RF PLatford. 1985. Trace organic contaminants in the Detroit River. *J. Great Lakes Res*. 11:386-399.

Kannan, K., J.L. Kober, Y.-S. Kang, S. Masunaga, J. Nakanishi, A. Ostaszewski and J.P. Giesy. 2001. Polychlorinated naphthalenes, biphenyls, dibenzo-*p*-dioxins, and dibenzofurans as well as polycyclic aromatic hydrocarbons and alkylphenols in sediment from the Detroit and Rouge Rivers, Michigan, USA. *Environ. Toxicol. Chem.* 20(9):1878-1889.

Leblanc, GA. Trophic-level differences in the Bioconcentration of chemicals: implications in assessing environmental biomagnification. *Environ. Sci. Technol.* 29:154-160.

Morrison HA, T Yankovich, R. Lazar, GD Haffner. 1995. Elimination rate constants of 36 PCBs in zebra mussels (*Dreissena polymorpha*) and exposure dyanamics in the Lake St. Clair – Lake Erie corridor. *Can. J. Fish. Aquat. Sci.* 52:2574-2582.

Morrison HA, DM Whittle, GD Haffner. 2002. A comparison of the transport and fate of polychlorinated biphenyl congeners in three Great Lakes food webs. *Environ. Toxicol. Chem*. 21:683-692.

Morrison HA, FAPC Gobas, R Lazar, DM Whittle, GD Haffner. 1997. Development and verification of a benthic/pelagic food web bioaccumulation moel for PCB congeners in western Lake Erie. *Environ. Sci. Technol*. 31:3267-3273.

Morrison HA, Gobas FAPC, R Lazar, DM Whittle, GD Haffner. 1998. Projected changes to the trophodynamics of PCBs in the western Lake Erie ecosystem attributed to the presence of zebra mussels (*Dreissena polymora*). *Environ. Sci. Technol*. 32:3862-3867.

Morrison HA, FAPC Gobas, R Lazar, DM Whittle, GD Haffner. 2000. The relative importance of species invasions and sediment disturbance in regulating chemical dynamics in western Lake Erie. *Ecological Modelling*. 125:279-294.

OMOE (Ontario Ministry of the Environment). 2005. *Guide to eating Ontario Sport fish 2005-2006 Ed*. Queens Printer for Ontario, 282 pp.

O'Rourke S, KG Drouillard and GD Haffner. 2004. "Determination of laboratory and field elimination rates of polychlorinated biphenyls (PCBs) in the freshwater mussel, *Elliptio complanata*". *Arch. Environ. Contam. Toxicol. 47:74-83.*

O'Rourke SM. 2004. *Quantitative biomonitoring of polychlorinated biphenyls in the Detroit River using the freshwater mussel Elliptio complanata.* M.Sc. Thesis, University of Windsor, Windsor, ON, Canada.

Paterson G, KG Drouillard, TA Leadley, GD Haffner. 2007. Long term polychlorinated biphenyl elimination by three size classes of yellow perch (*Perca flavescens*). *Can. J. Fish. Aquat. Sci*. 64:1222-1233.

Pugsley, C.W., P.D.N. Hebert, G.W. Wood, G. Brotea and T.W. Obal. 1985. Distribution of contaminants in clams and sediments from the Huron-Erie corridor. I – PCBs and octachlorostyrene. *J. Great Lakes Res*. 11:275-289.Quinn, FH. Detroit River flow characteristics and their application to chemical loading estimates. *J. Great Lakes Res*. 2:71-77.

Raeside, AA, S O'Rourke, KG Drouillard. 2009. Determination of *in situ* PCB elimination rate coefficients in the freshwater mussel biomonitor *Elliptio complanata* deployed in the Huron-Erie corridor. *Environ. Toxicol. Chem.* 28:434-435.

Rantalainen AL, MG Idonomou, IH Rogers. 1998. Lipid-containing semipermeable membrane devices (SPMDs) as concentrators of toxic chemicals in the lower Fraser River, Vancouver, British Columbia. *Chemosphere* 37:1119-1138.

Russell, R.W. and F.A.P.C. Gobas. 1989. Calibration of the freshwater mussel, *Elliptio complanata*, for quantitative biomonitoring of hexachlorobenzene and octachlorostyrene in aquatic systems. *Bull. Environ. Contam. Toxicol.* 43:576-582.

Selck H, Forbes VE, Forbes TL. 1998. Toxicity and toxicokinetics of cadmium in Capitella sp. I: relative importance of water and sediment as routes of cadmium uptake. *Mar Ecol Prog Ser*. 164: 167-178

Thomann RV, JP Connolly. 1984. Model of PCB in the Lake-Michigan lake trout food chain. *Environ. Sci. Technol*. 18:65-71.

UGLCCS (Upper Great Lakes Connecting Channels Study). 1988b. *Upper Great Lakes Connecting Channels Study: Volume II, Executive Summary.* US Fish and Wildlife Service, Ontario Ministry of the Environment, National Oceanic and Atmospheric Administration, US Army Corps of Engineers, Detroit Water and Sewage Department, Michigan Department of Natural Resources, US Environmental Protection Agency, and Environment Canada.

Walker SL, FAPC Gobas. 1999. An investigation of the application of the Canadian water quality guidelines. *Environ. Toxicol. Chem*. 18:1323-1328.

CHAPTER 6:

SPATIAL MODIFICATION OF MODELLING PCB TRANSFER IN THE FOOD WEB OF DETROIT RIVER

ABSTRACT

Because of the high body burden of PCBs in sport fish, there has been the establishment of fish consumption advisories in the Detroit River. The primary sources of PCBs are legacy deposition in sediments and run-off deposition in water. These depositions have a direct affect on aquatic organisms that intake the contaminated sediments and water, but also have an indirect effect because PCBs accumulate in the higher trophic levels of food webs. The analyses presented in this chapter are the preliminary start in responding to a key issue identified by the River Food Web breakout group in Workshop 1: "What are transfer efficiencies for different levels in food web?" It will also help to answer one of the top five stakeholder issues "Where are the sources of contaminant in the basin that are high enough to translate into a FCA?" Our objective in this chapter is to improve Monte-Carlo predictions in PCB concentrations presented in the Chapter 5 single zone model by spatially connecting feeding interactions among the 37 taxa in the model. We found that the spatially connected model performance was good in terms of predicting PCB concentrations in Detroit River fish. The model has 94.5% of predictions within a factor of 10 and 78.5% of predictions within a factor of 4 of observed values. The predictions are an improvement over the single zone model by increasing the number of predictions within a factor of 4 of the observed values. The spatially connected model predictions were more conservative than the single zone model where 63% of the spatially connected model predictions were overestimates versus the 23% of the predictions from the single zone model. For the 29 fish types (taxa and zones) with at least 5 observations available, a total of 82.85% of fish groups had predicted PCB concentrations within a factor of 4 of the observed values.

Recommendations to Stakeholders for Next Steps

Because our preliminary results suggest that taking into account the movement ecology of the 37 taxa helped to improve predictions of PCB transfers in the Detroit River, we recommend that the stakeholders:

1. Continue to provide advice and suggestions to the researchers that will further refine the zone specific adjustments.
2. Support the sensitivity analysis, which will help in understanding how the model results respond to variations in transfer rates through diet percentages and zone specific adjustments.

INTRODUCTION

The Detroit River, as a highly industrialized and urbanized area, has been heavily and widely contaminated with Polychlorinated Biphenyls (PCBs) from upstream water, local point-source emission, and atmospheric deposition (Froese *et al*. 1997; Drouillard *et al*. 2006). PCBs, a class of persistent and highly accumulative organic pollutant, can exhibit a wide range of toxic effects on the health of fish, wildlife and humans (Rosiu *et al*.1989; Maccubbin *et al*. 1996; Leadly *et al*. 1998; Brown *et al*. 1994) and are probably carcinogenic to humans. PCBs have also been demonstrated to biomagnify through the food chains and accumulate to hazardous concentrations in high trophic level organisms in the Detroit River. Thus, the high body burden of PCBs in sport fish has been a particular concern of existing fish consumption advisories of Detroit River, which recommend that people limit or avoid eating certain species of fish caught in certain places due to the unsafe contaminant levels.

Our primary goal is to develop a risk assessment of PCB concentrations in fish in the Detroit River that are consumed by humans. In order to reach this goal, we need to understand how the aquatic organisms (phytoplankton, zooplankton, invertebrates, and fish) are exposed to PCBs in river water and sediment, and how the PCBs are transferred in complex food web system (Nfon *et al*. 2008; Rashleigh *et al*. 2008; Preziosi and Pastorok 2008). A simulation model of the Detroit River food web was developed to estimate the PCB concentrations in fish, where the food web contained 36 taxonomic groups (Morrison *et al*. 1997). The model quantifies PCB bioaccumulation through PCB dietary uptake and elimination in organisms at steady state where predictions are made for an individual adult of average size. Arnot and Gobas (2004) further improved this model by making it kinetic by including parameters that quantify the mechanism of bioaccumulation through gill ventilation rates and gastrointestinal magnification. The model has been validated and parameterized on the chemical and biological processes of PCB transfer (Chapter 5, Drouillard *et al*.). In this chapter, we report on an additional improvement to the model that takes into account the spatial variation of PCB residues in river water and sediments.

The primary sources of PCBs are legacy deposition in sediments and run-off deposition in water. These depositions have a direct affect on aquatic organisms that intake the contaminated sediments and water, but also have an indirect effect because PCBs accumulate in the higher trophic levels of food webs. Spatial distribution patterns of PCB accumulation in spottail shiners (Suns *et al*. 1993), burrowing mayfly (Corkum *et al*. 1997), zebra mussels (Metcalfe *et al*. 1997), and snapping turtles (de Solla and Fernie 2004) have demonstrated the site-specific bioavailability of PCB inputs at different locations of Detroit River and other Lake Erie areas. Furthermore, a series of model research on food web bioaccumulation have predicted that the PCB concentrations in fish are very sensitive to the PCB concentrations in sediments (Suns *et al*. 1993; Morrison *et al*. 1997; Gewurtz *et al*. 2009). Drouillard *et al*. (2006) found that the total PCB concentrations were significantly elevated at sample stations of U.S. side as compared to Canadian stations, where the sediment PCB concentrations in the upper and middle U.S. river are higher than those in the lower reach. The spatial distribution pattern of PCBs is shaped by source inputs from upstream (Lake St. Clair) and industrial and municipal run-off from U.S. and Canada. In addition, PCBs can be remobilized from sediments by river flow, sediment disturbance events, and shipping channels (Froese *et al*. 1997; Drouillard *et al*. 2006). There are "hot spots" in the river where concentrations of PCBs in sediments are very high and are strongly associated with legacy industrial activities, where the Trenton Channel is one such "hot spot" (Metcalfe *et al*. 2000; Marvin *et al*. 2002; Gewurtz *et al*. 2003).

Feeding interactions in food webs, as the pathways of matter and energy flow, play a crucial role in PCB transfer and biomagnification (Russell, 1999; Preziosi and Pastorok, 2008). To understand these transfers in the Detroit River, spatial heterogeneity should be accounted for in the feeding interactions (Ruiter *et al*. 2005; West *et al*. 2003). The food webs of the river ecosystem can be considered as a nested hierarchy of spatial scales from discrete habitats to the whole river (Winemiller and Jepsen, 1998; Woodward and Hildrew, 2002). Similar to the role of fish movement as a nutrient or energy transport systems in river ecosystems (Polis *et al*. 1997 ; Winemiller and Jepsen, 1998; Woodward and Hildrew, 2002; Vanni *et al*. 2005; Rooney *et al*. 2006), the movements of organisms (particularly fish) play an important role in PCB transport across local food webs. Furthermore, the roles played by the species in PCB transport are various due to their difference in movement distances and directions. These differences are related to body size, current velocity, foraging behavior, resources availability, or special needs of abiotic conditions for spawning (Winemiller and Jepsen, 1998; Railsback *et al*.1999; Albanese *et al*. 2004). Accordingly, the species with short movement distances are exposed to the constant PCB concentration present in their small ranges, while the more mobile predators are exposed to a large gradient of PCB concentrations and couple the pathways of PCB transfer because they forage a large home range. For example, a *Hexagenia* nymph will be exposed to a constant level of PCB because of limited mobility, and on the hand, a walleye will be exposed a range of PCB levels because the fish's range will cover areas of high and low PCB concentrations.

The purpose for this model research is to improve our understanding of factors controlling PCB concentrations in consumed fish by incorporating spatially connected information of PCB concentrations in sediment and water and feeding interactions. Our objective in this chapter is to improve Monte-Carlo predictions in PCB concentrations of an individual for select fish species at different spatial zones by spatially connecting PCB feeding interactions. Currently, we are exploring the sensitivity of the model predictions to the diet compositions and movements of organisms and identify dominant pathways of PCB transfers for the mostly consumed fish species. However, these analyses have yet to be completed but there is commitment to follow through on these analyses because they will be a part of Zhicai Liu's dissertation (University of Toledo). These analyses are a direct response to a key issue identified by the River Food Web breakout group in Workshop 1: "What are transfer efficiencies for different levels in food web?" It will also help to answer one of the top five stakeholder issues "Where are the sources of contaminant in the basin that are high enough to translate into a FCA?"

METHODS

Study Area

The Detroit River is a connecting channel flowing from southern Lake Saint Clair to western Lake Erie with a length of 51 km (Figure 1). The upper 21 km is 700 to 1000 wide, less than 15 m deep, and contains two islands. The lower 30 km is 1500 to 6000 m wide, less than 9 m deep and contain 10 islands. The Detroit River has an average discharge of about 5270 m^3/s and the water surface elevations fall about 1m within the river (Holtschlag *et al*. 2002). The mean annual water temperature is about 10^0C; monthly temperature vary from 0.5^0C to 22^0C (Muth *et al*. 1986). The river has been designated by the International Joint Commission (IJC) as an Area of Concern (AOC) due to impairments of the environmental health of the river, which includes the implementation of fish consumption advisories (Ontario Ministry of the Environment, 2001). The Detroit River provides habitat for at least 82 species of phytoplankton, 31 species of aquatic macrophytes, 300 species of macrozoobenthos, 65 species of fish, and 27 species of waterfowl (Manny *et al*. 1988; Manny *et al*. 1991). Habitat is provided for coldwater fish from September to June, but these fish migrate during the period of maximum water temperature from July to September (Manny *et al*. 1988; Manny *et al*. 1991).

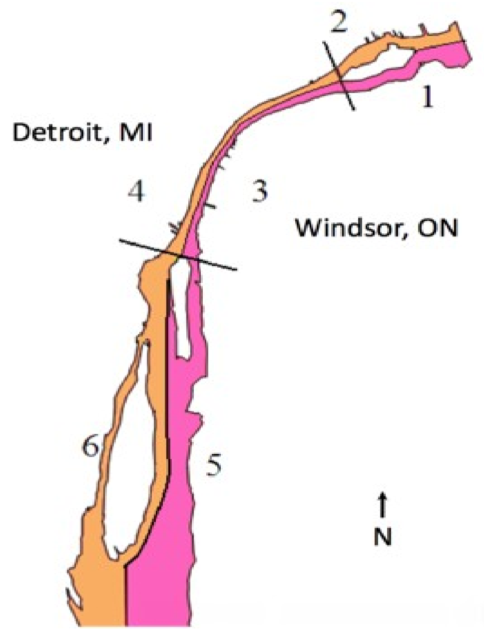


Figure 1. The six geostatistical zones of Detroit River and the sampling sites

Basic Details about the Food Web Model

As detailed in Chapter 5, PCBs are loaded to the food web system through sediment and water and then are transferred through feeding interactions from lower trophic levels to the higher trophic levels (Figure 2). The Chapter 5 food web model for simulating PCB transfer in the Detroit River was developed based on the methodology from Arnot and Gobas (2004), in which PCB concentrations are determined at steady-state for all 37 aquatic taxa in the food web Details of theory and methodology can be found in Chapter 5 as well as in Morrison *et al*. (1997) with updated parameters and equations from Arnot and Gobas (2004).

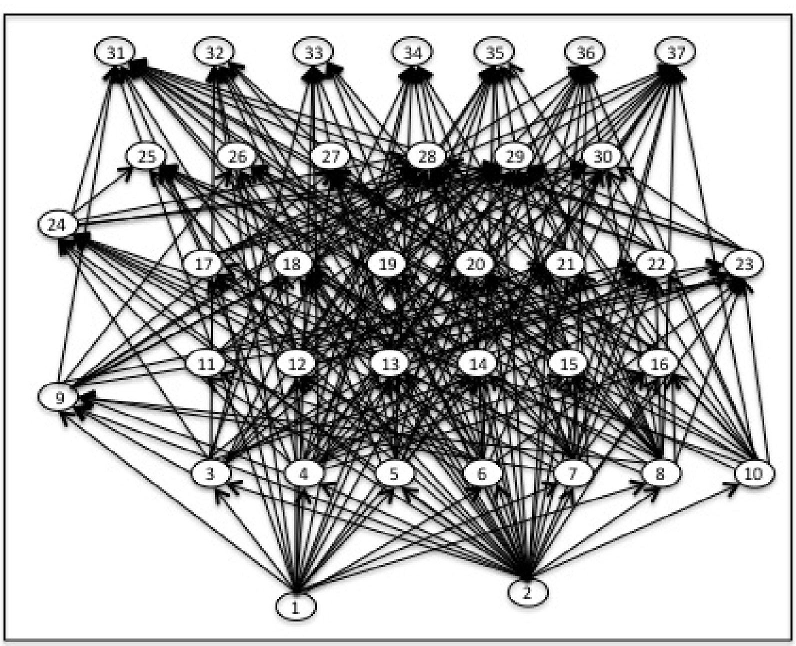


Figure 2. A schematic representation of the structure for the Detroit River food web model. Circles represent taxonomic groups. Lines with arrows represent PCB transfer

from a prey to a predator. Taxonomic groups correspond to: (1) Sediment; (2) Plankton (Phytoplankton, zooplankton); (3) Zebra Mussel; (4) Caddisfly; (5) Oligochaetes; (6) Chironomids; (7) Gammerus; (8) Mayfly; (9) Crayfish; (10) Young of the year fish; (11) Brook Silverside; (12) Emerald shiner; (13) Spottail shiner; (14) Round goby; (15) Alewife; (16) Smelt; (17) Small white sucker; (18) Bluegill; (19) Black crappie; (20) Gizzard shad; (21) White perch; (22) White bass; (23) Rock bass; (24) Yellow perch; (25) Walleye; (26) Smallmouth bass; (27) Largemouth bass; (28) Northern pike; (29) Gar pike; (30) Muskellunge; (31) Bowfin; (32) Redhorse sucker; (33) White sucker; (34) Carp; (35) Freshwater drum; (36) Brown bullhead; (37) Channel catfish.

In addition to the assumption of steady-state, there are several primary assumptions of the general food web model: (1) each taxon component in the food web represents an individual adult of average body size; (2) the size and spatial distributions of taxa populations are not considered; and (3) not all species that exist in the Detroit River are included. Additionally, we assume that the whole Detroit River aquatic community is a closed system without fish moved from the adjacent lakes and rivers. Although accounting for movement in and out of the system is beyond the scope of this modeling effort, stakeholders and modelers should revisit this assumption at a later time. Finally, the model shares all the assumptions of listed in the Theory section of Arnot and Gobas (2004).

There are two primary differences between the Chapter 5 model and the model presented in this chapter:

1. Modeling Platform: We transferred the model presented in Chapter 5 from Excel to MATLAB with Object Oriented Program (OOP). In comparison to modeling in Excel, MATLAB is more advanced in the whole process of model construction and implementation. First, it is more efficient to organize, integrate, and analyze heterogeneous arrays and matrices using OOP command language in MATLAB. Second, using OOP in MATLAB, connecting food webs for each zone together can be coherently integrated into one hierarchical system. It allows us to input water and sediment PCB data for all zones at the same time when running the model. The Excel version is limited to the analysis of one spatial zone at a time. Expanding the model to include input and connected food webs for all six zones in Excel would not be efficient in coding or in the length of time for a run. It may not even be possible with the limit Excel has in how much data and how many calculations it can handle. Third, MATLAB has also been very effective in debugging the food web models, including the Chapter 5 Excel model. Model development was concurrent between the Excel and MATLAB versions and output was compared to ensure correct transfer of the model to MATLAB.

2. Food Web Connections across Zones: We extended the food web model presented in Chapter 5 by incorporating inputs of PCB concentrations in water and sediments of all the six zones within the same model run (Figure 3). Thus, PCB inputs from all six zones can influence a taxon's PCB levels through feeding interactions where food webs across zones are connected via the diet compositions.

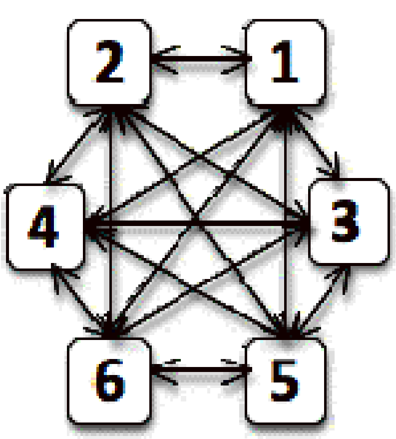


Figure 3. A schematic representation of the spatially connected food webs across 6 river zones. Boxes represent local food webs in the six zones. Arrows represent PCB flows among zone food webs.

Food web integration of PCB Inputs from all 6 Zones

In order to integrate the estimates of PCB concentrations in water and sediment from Chapter 5 across the six zones in the Detroit River, we developed zone specific adjustments (based on the ecology of all 37 taxonomic groups in the food web. We define zone specific adjustments as the probability of a taxonomic group's movement into a particular river zone where we account for the length and width of the zones themselves, their distance from each other, and what is known about a taxon's ecological behavior. For each of the 37 taxonomic groups, we went through the following protocol to estimate these zone specific probabilities. First, we collected literature from primary and secondary sources on the ecological movement behavior of taxon. We focused on literature about taxa in the Detroit River, however sources were scarce. Thus we expanded our search to adjacent water bodies (Lake St. Clair, St. Clair River, Lake Erie). If we were unable to find enough information from these locations, we expanded to remaining Great Lakes (Lake Michigan, Lake Huron, Lake Superior, Lake Ontario). Finally, if there were still data gaps, we examined sources from other aquatic ecosystems. We focused on the information that was most relevant to the Detroit River and used the less relevant sources as supplemental information. Second, we synthesized the collected literature into a document for each taxon component. In this synthesis, we developed a concise description of ecological movement behavior by documenting migration habits, home ranges, and movement rates. Third, based on the synthesis, we estimated the distances, direction, and frequency of the taxonomic group's migration or drifting taking into account the length, width, and depth of the zones to estimate a matrix of zone specific probabilities. These zone specific probabilities It is a 37x6x6 matrix where 37 is the number of taxa groups, 6 is the number of resident zones, and 6 is the number of zones that a taxonomic group either resides in or moves to (Table 1).

Table 1. An example of the 6x6 matrix of zone specific adjustments for smallmouth bass

Zone Adjustment	Taxon's Resident Zone 1	2	3	4	5	6
1	42%	26%	12%	12%	4%	4%
2	26%	42%	12%	12%	4%	4%
3	10%	10%	38%	22%	10%	10%
4	10%	10%	22%	38%	10%	10%
5	4%	4%	10%	10%	44%	28%
6	4%	4%	10%	10%	28%	44%

In the example for smallmouth bass in Table 1, a smallmouth bass that resides in Zone 1 will ingest 42% of its dietary intake from prey *i* in its resident zone, 26% of its dietary intake from prey *i* in Zone 2, 10% of its dietary intake from prey *i* in Zone 3, etc. The synthesized documents of how zone specific adjustments were calculated (including literature citations) for all 37 taxa components will be posted on the project website. Fourth, These zone specific adjustments are multiplied by the diet percentage of each prey item (P in the general predictive equation reported in Chapter 5).

Model Evaluation Comparison

We employed the same methods for evaluation as that in Chapter 5. We compared our simulated distributions to the same evaluation data set. The validation data set consisted of a total of 621 sample records distributed across 18 sport fish species and collected in 5 of 6 river zones. We also used Monte Carlo simulation to randomly generate 2000 sets values of PCB concentrations in sediment and water for each zone using the distributions estimated in Chapter 5. Both the pre-existing model and the spatially connected model were run 2000 times with an set of values of PCB concentrations in sediment and water for each iteration. Differences between the two models' performance were identified by comparing the maximum, minimum, mean, standard deviation, and shape of the distributions of simulated PCB concentrations for the dataset of sport fish by zone. Walleye, channel catfish, yellow perch, white (silver) bass, and largemouth bass are the main focus of this model application because there are mostly consumed by shoreline fisherpeople (Kalkirtz *et al*. 2008) as well as the availability of observed data.
For each sport fish species in a zone, the mean and standard deviation was calculated based on the $\log_{10}$ of empirically measured samples at specific locations across the zones. The observed and simulated means and standard deviations were compared to a 1:1 line, 4x line, and 10x line to determine model bias the same as the methods outlined in Chapter 5.

Results

The predicted and observed PCB concentrations were compared by means, standard deviations, frequency distributions for the fish groups with relevance to specific river zones.

Part 1. Comparison of Means and Standard deviations

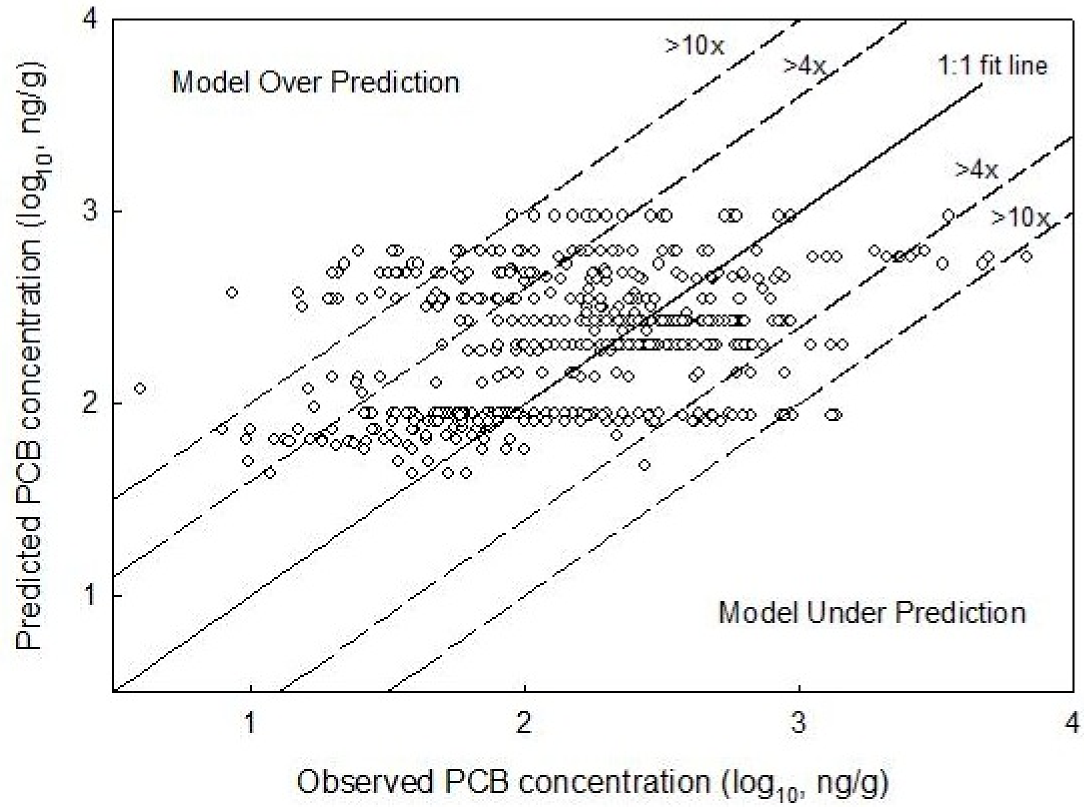


Figure 4. Observed versus predicted PCB concentrations in the fish groups of Detroit River

We present an overview of model predictions against observed PCB concentrations in fish groups with 619 individually sampled data from five river zones (Figure 4). The predicted PCB concentrations ($\log_{10}$ transformed) are significantly correlated to the observed PCB concentrations ($\log_{10}$ transformed, $p<0.01$ $R^2=0.131$). A total of 63% of observations were over-predicted and 37% were under-predicted. The overall mean model bias (observed/predicted PCB concentrations) was 0.95±0.20. A total of 94.5% (585 of 619) of model predictions were within a factor of 10 of observations and a total of 78.5% (486 of 619) of model predictions were within a factor of 4 of observations.

In comparison to the results reported in Chapter 5 (see Figure 14 in Chapter 5), the spatially connected model increased the potential to over predict PCB concentrations where the single zone model had only 23% of the observations over predicted compared to 63% in this model. When modeling PCBs, it is better to err on the side of over prediction because that is the more conservative approach. When related back to human health, we would rather be overly cautious and have higher predictions than observed than have lower predictions than observed. This approach is consistent with the fish consumption advisories themselves, which also err on the side of protecting human health. While we saw no loss in total predictive capabilities with the spatial model with a < 1% increase in those values greater than 10x the 1:1 line, we did see a 6%

increase in predicted values within the 4x the 1:1 line range (72% single zone model versus 78.5% spatially connected model).

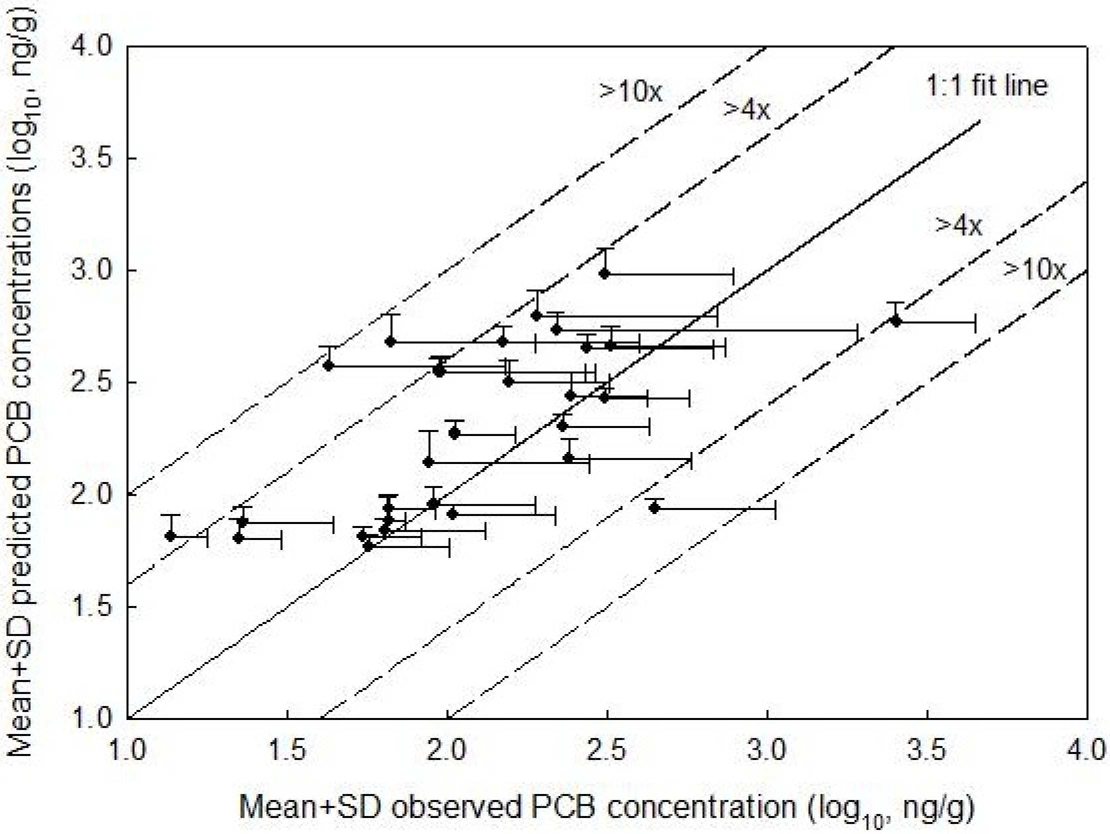


Figure 5. Means and standard deviations of observed and predicted PCB concentrations in the fish groups of Detroit River

We present the mean and positive standard deviations of observed versus predicted PCB concentrations (log_{10} transformed) for 29 fish types (taxa and zone combinations) of Detroit River (Figure 5). We chose these 29 fish types because they had at least 5 samples of observed PCB concentrations to represent their taxa and zone combination. The horizontal error bars refer to the standard deviations of observed PCB concentrations; the vertical error bars refer to the standard deviations of predicted PCB concentrations. Mean predictions were within a factor of 4 of the observed means for 82.8% (24/29) of fish combinations. 75.9% (22/29) of fish types were over-predicted and 24.1% (7/29) of fish groups were under-predicted.

Of the 29 fish types selected for Figure 5, 6 fish types represented the upper and middle Canadian river zones; 10 fish types represented the lower Canadian river zone; 6 fish types represented the middle and lower US river zones; 7 fish types represented the upper US river zone. We now go into greater detail about these fish types, especially focusing on the most consumed fish like yellow perch, walleye, channel catfish, white bass, and largemouth bass.

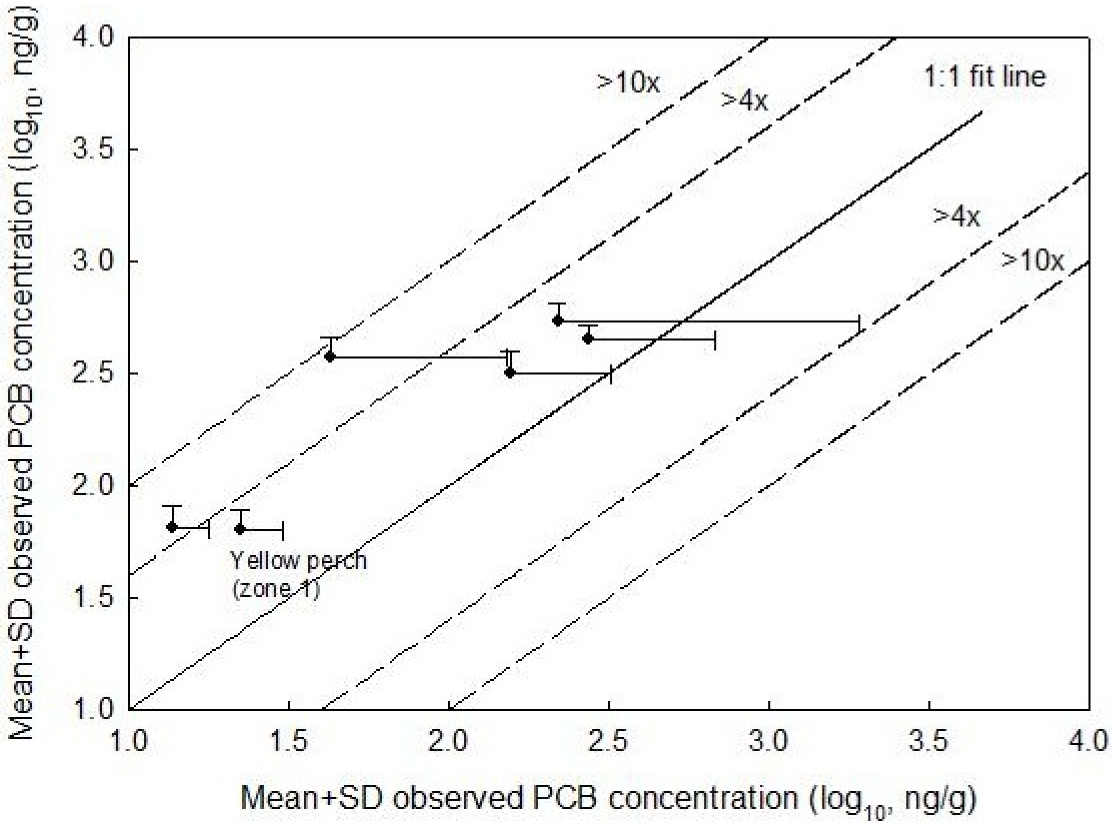


Figure 6. Means and standard deviations of observed and predicted PCB concentrations in fish groups from the upper and middle Canadian river zones 1 and 3.

The 6 fish types shown in Figure 7 are gizzard shad, white perch, yellow perch, northern pike from zone 1, and gar pike and carp from zone 3. For white perch, yellow perch in zone 1, and gar pike and carp in zone 3, the model overestimated their PCB concentrations within a factor of 4. The model overestimated PCB concentrations for gizzard shad and northern pike in zone 1 within a factor of 10.

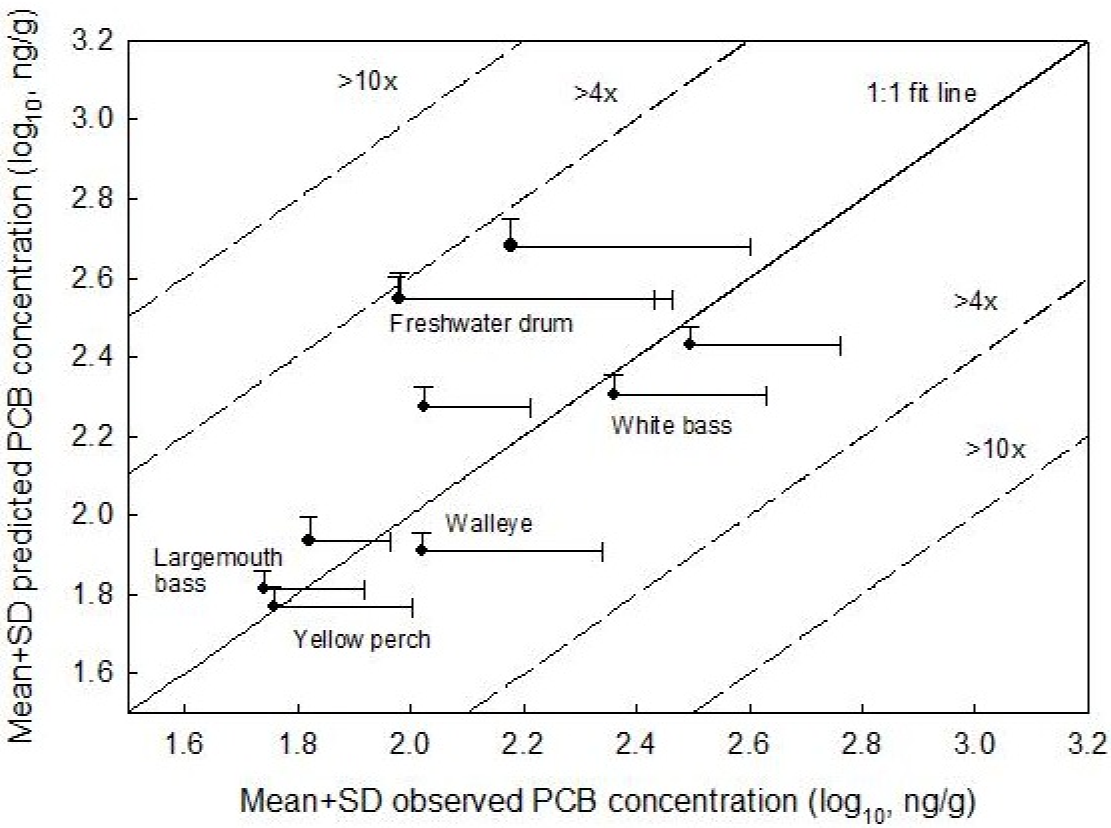


Figure 7. Means and standard deviations of observed and predicted PCB concentrations in fish groups from the lower reach of Canada river zone 5

The 10 fish taxa shown in Figure 7 are gizzard shad, white perch, white bass, rock bass, yellow perch, walleye, largemouth bass, muskellunge, carp and freshwater drum form the lower reach of Canadian river zone 5. All predicted means fall within a factor of 4 of the observed means.

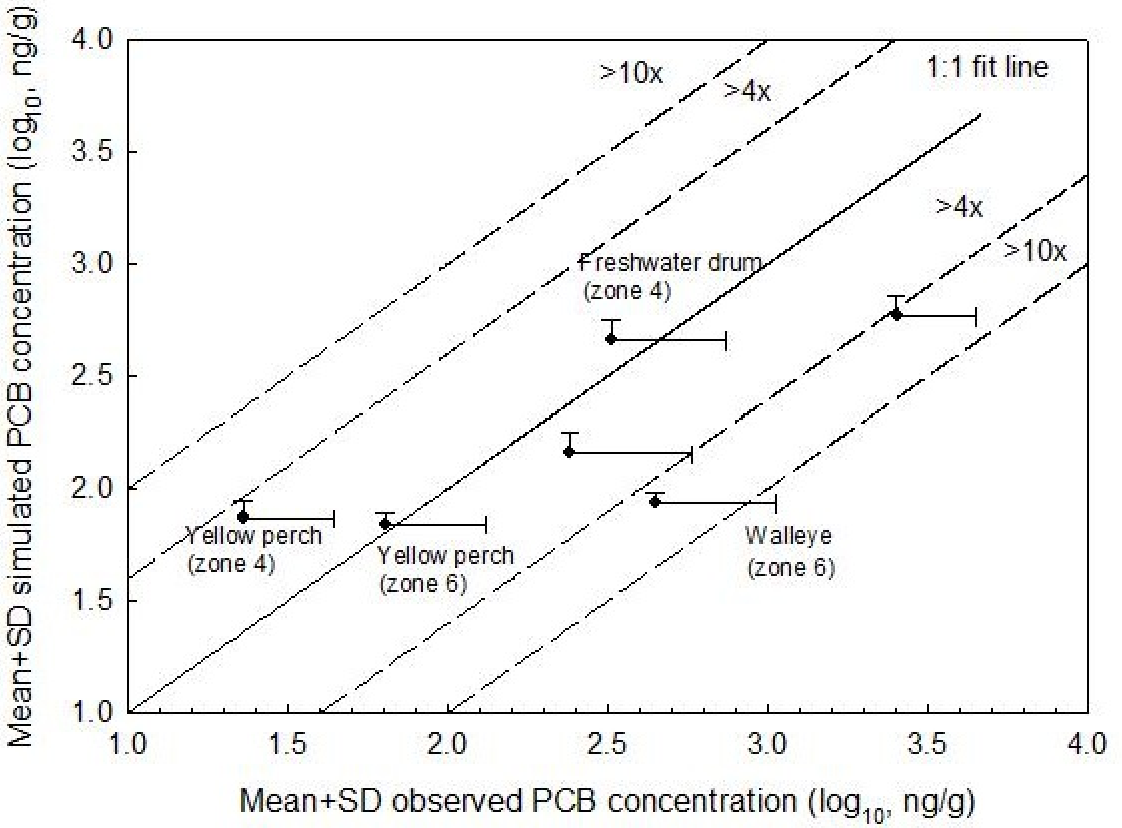


Figure 8. Means and standard deviations of observed and predicted PCB concentrations in fish groups from the middle and lower reach of US river zones 4 & 6

The 6 fish types shown in Figure 8 are Yellow perch, redhorse sucker, carp and freshwater drum in zone 4, and yellow perch and walleye in zone 6. The model over-predicted mean PCB concentrations in freshwater drum (zone 4), yellow perch (zone 4) and yellow perch (zone 6) within a factor of 4 of the observed means. The PCB concentrations in redhorse sucker (zone 4) were under-predicted within a factor of 4 of the observed means. The PCB concentrations in walleye (zone 6) and carp (zone 4) were underestimated within a factor of 10 of the observed means.

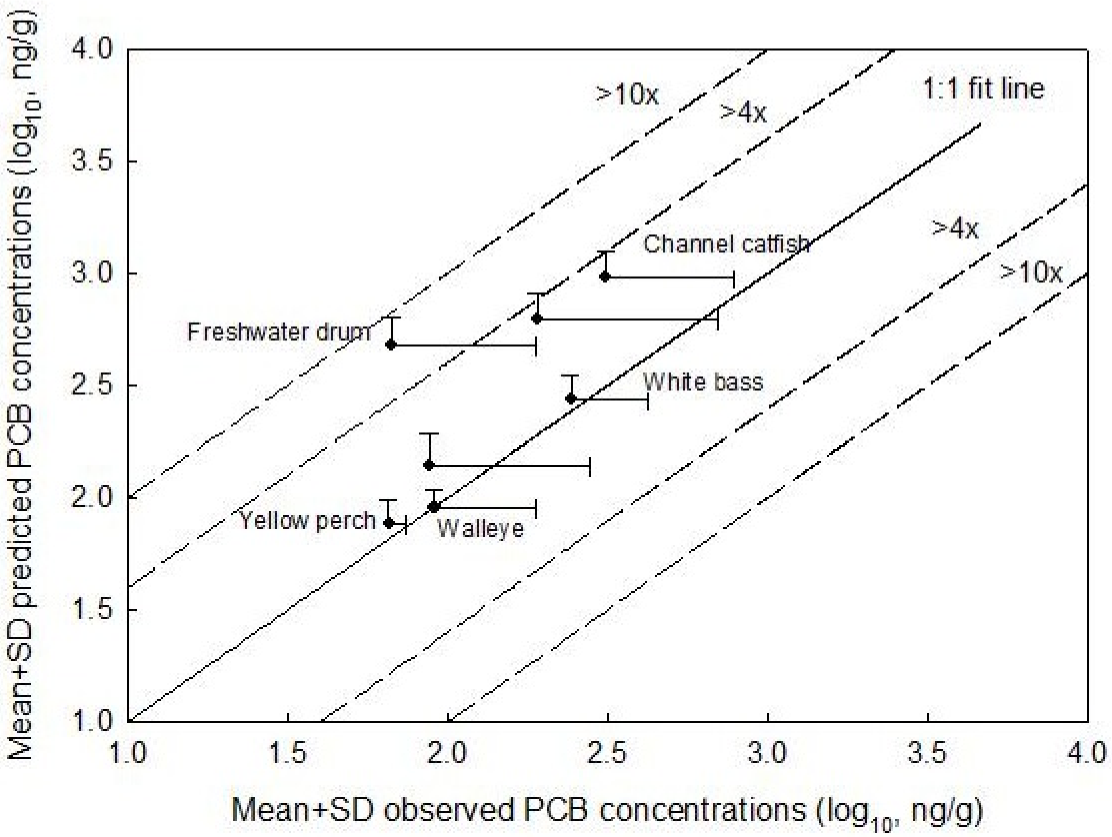


Figure 9. Means and standard deviations of observed and predicted PCB concentrations in fish groups from the upper reach of US river zone 2.

The 7 fish taxa shown in Figure 9 are white bass, rock bass, yellow perch, walleye, carp, freshwater drum, and channel catfish from the upper reach of US river zone 2. All predicted means except for freshwater drum were within a factor of 4 of the observed means where freshwater drum was within a factor of 10 of the observed means.

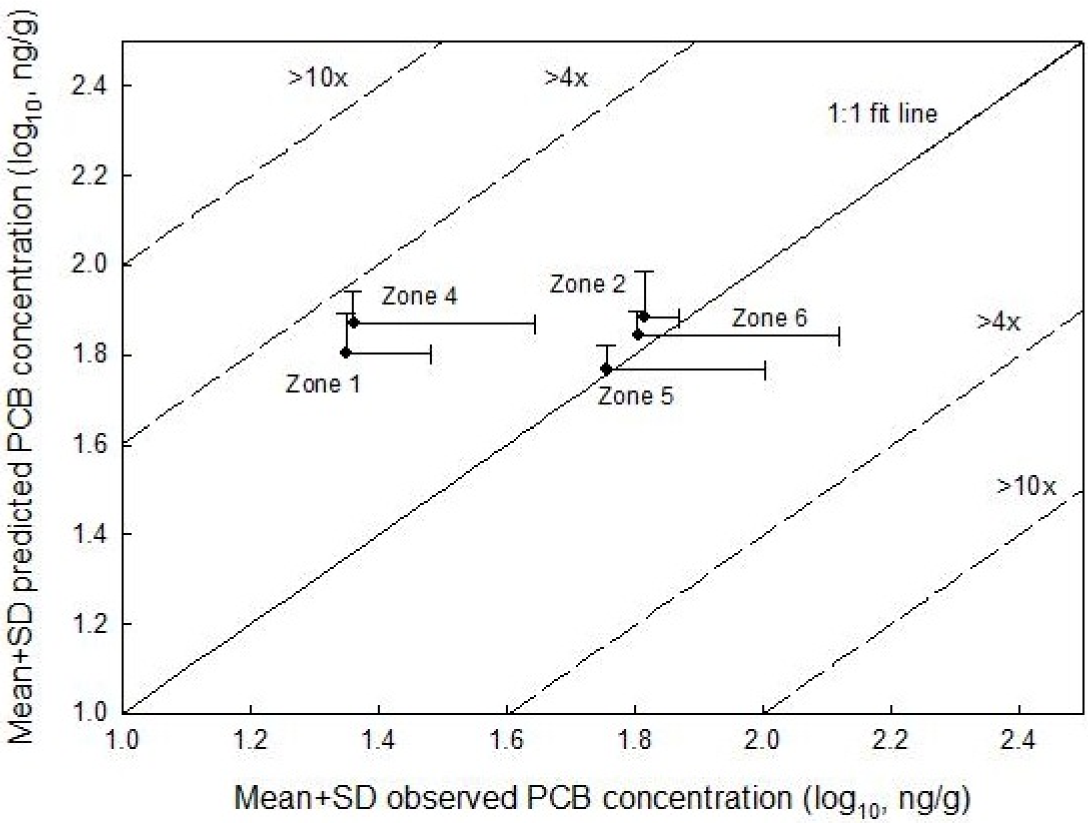


Figure 10. Means and standard deviations of observed and predicted PCB concentrations in yellow perch from different river zones

We provide a comparative view of model predictions for PCB concentrations in yellow perch in 5 river zones (Figure 10). All zones were overestimated within a factor of 4. The model made the best predictions for zones 2, 5, and 6.

Part 2. Comparison of Frequency Distribution

The white bass and walleye in zone 2 and zone 5 were used to further compare the frequency distribution of observed and predicted PCB concentrations for two reasons: 1. they are two of the important sport fish and 2. They have the largest number of observations in zone 2 and zone 5 of all 29 fish types. Note that the following frequency distributions are on the untransformed values.

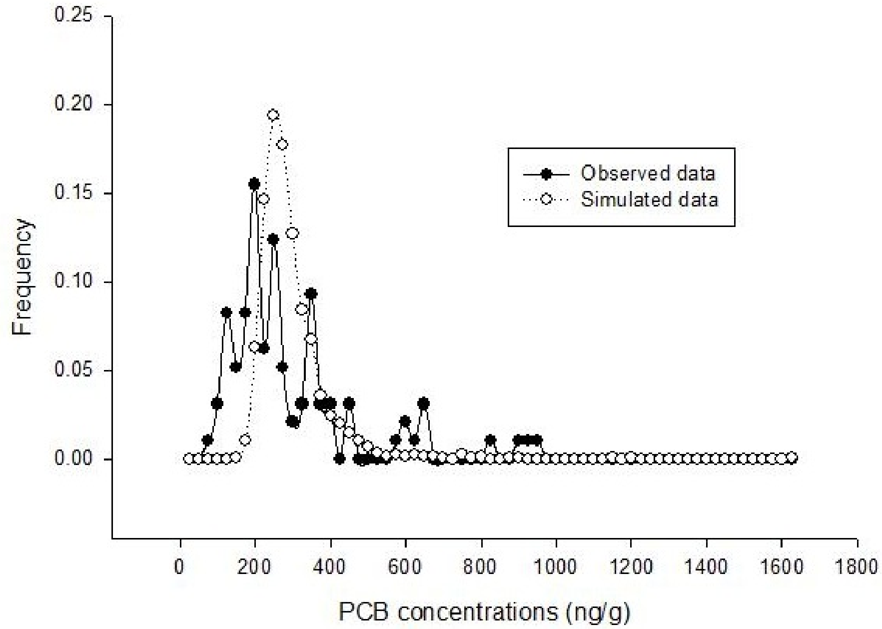


Figure 12. Frequency distribution of observed and predicted PCB concentrations of white bass from zone 2.

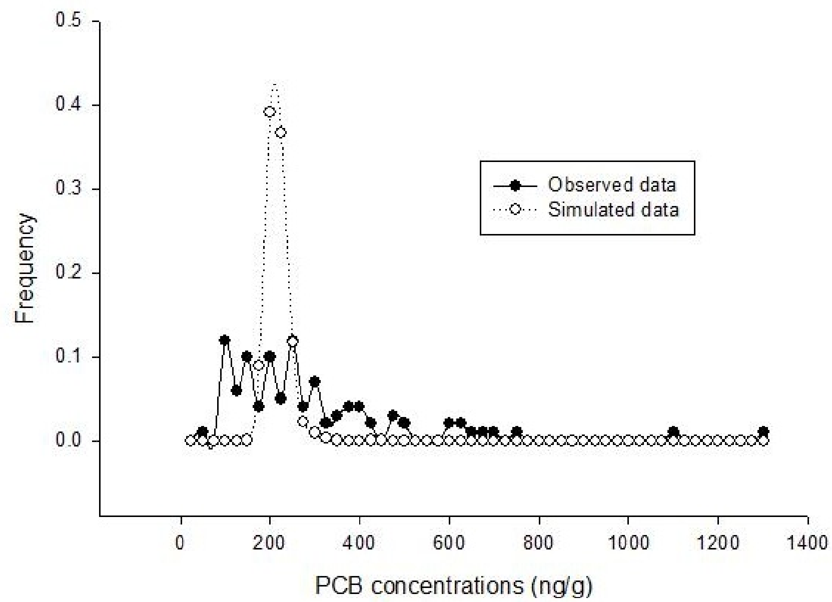


Figure 13. Frequency distribution of observed and predicted PCB concentrations of white bass from zone 5.

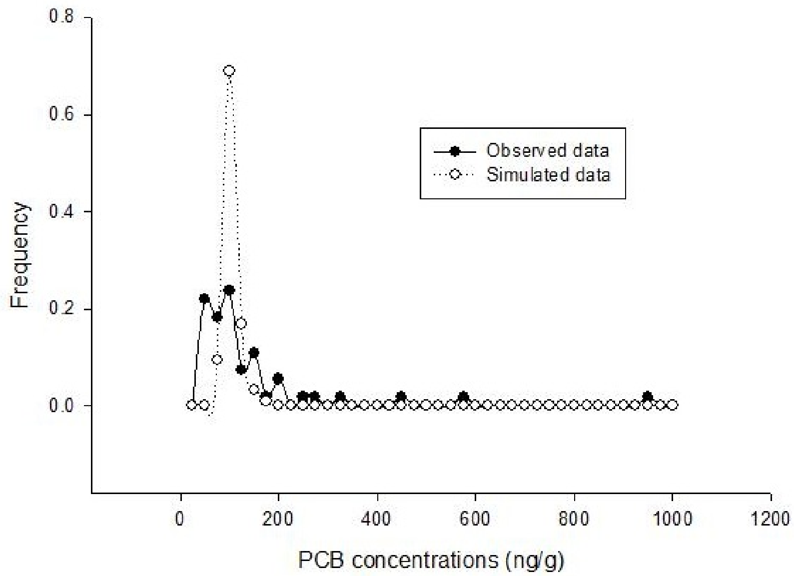


Figure 14. Frequency distribution of observed and predicted PCB concentrations of walleye from zone 2.

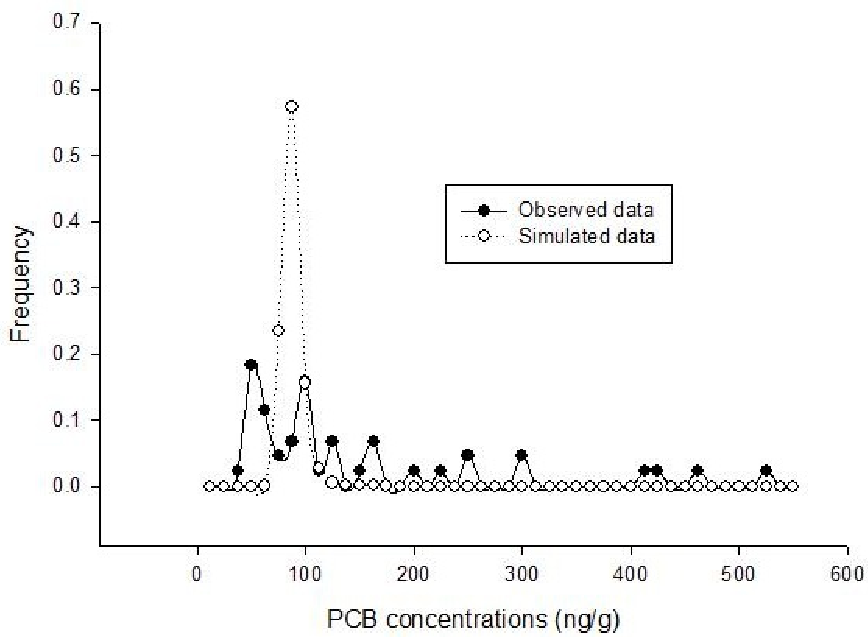


Figure 15. Frequency distribution of observed and predicted PCB concentrations of walleye from zone 5.

For the observed PCB concentrations of the two fish taxa in zone 2 and zone 5, a pattern of lognormal frequency distributions was shown in Figure 12 – 15. The predicted distributions were were more normal than the observed counterparts. The frequency peak of predicted values overlapped with the frequency peaks of the observed values, indicating that the model generally did a good job at predicting most of the values in the observed data. However, the model did not predict the high PCB concentrations in these fish. While these high concentrations had very low frequencies (< 10%), they do indicate that the model has not yet captured the mechanism for these high values.

Summary Statements

1. The spatially connected model performance was good in terms of predicting PCB concentrations in Detroit River fish. It is consistent with the single zone model (Chapter 5) and the original models (Morrison *et al*. 1997; Arnot and Gobas, 2004). The model has 94.5% of predictions within a factor of 10 and 78.5% of predictions within a factor of 4 in correspondence to the 619 observations (Figure 5). The predictions are an improvement over the single zone model by increasing the number of predictions within a factor of 4 of the observed values.

2. The spatially connected model predictions were more conservative than the single zone model where 63% of the spatially connected model predictions were overestimates versus the 23% of the predictions from the single zone model.

3. For the 29 fish types (taxa and zones) with at least 5 observations available, a total of 82.85% of fish groups had predicted PCB concentrations within a factor of 4 of the observed values.

4. The model did well for 12 of the 29 fish types with larger datasets (> 5 observations) where those 12 points were very close to the 1:1 line across multiple zones.

5. The model did well for yellow perch in zones 2, 5, and 6.

6. The model did a good job in predicting the peak frequencies for white bass and walleye in zones 2 and 5.

Overall, the spatially connected model showed promise as an update to the existing single zone model. Once the model is more refined through sensitivity analyses of the results to the diet matrix probabilities and the zone specific adjustments, it can be further developed into a useful interactive product to be used by stakeholders to identify hot zones in the Detroit River and determine likely impacts of clean up of the water or the sediments in those areas.

References

Albanese B, Angermeier PL, Dorai-Raj S. Ecological correlates of fish movement in a network of Virginia streams. Can J Fish Aquat Sci 2004;61:857-869.

Arnot JA, Gobas FAPC. A food web bioaccumulation model for organic chemicals in aquatic ecosystems. Environmental Toxicology and Chemistry 2004;23(10):2343-2355.

Brown JF, Lawton RW, Morgan CB. PCB metabolism, persistence, and health effects after occupational exposure: implications for risk assessment. Chemosphere 1994;29:2287-2294.

Corkum LD, Ciborowski JJH, Lazar R. The distribution and contaminant burdens of adults of the burrowing mayfly, Hexagenia, in Lake Erie. J Great Lakes Res 1997;23(4):383-390.

de Ruiter PC, Wolters V, Moore JC. 2006. *Dynamic food webs: multispecies assemblages, ecosystem development and environmental change.* Theoretical Ecology Series. Academic Press, San Diego.

de Solla SR, Fernie KJ. Characterization of contaminants in snapping turtles (*Chelydra serpentina*) from Candadian Lake Erie areas of concern: St. Clair River, Detroit River, and Wheatley Harbour. Environmental Pollution 2004;132:101-112.

Drouillard KG, Tomczak M, Reitsma S, Haffner GD. A river-wide survey of polychlorinated biphenyls (PCBs), polycylic aromatic hydrocarbons (PAHs), and selected organochlorine pesticide residues in sediments of the Detroit River – 1999. J Great Lakes Res 2006;32:209-226.

Froese KL, Verbrugge DA, Snyder SA, Tilton F, Tuchman M, Ostaszewski A, Giesy JP. PCBs in the Detroit River water column. J Great Lakes Res 1997;23(4):440-449.

Gewurtz SB, Gandhi N, Christensen GN, Evenset A, Gregor D, Diamond ML. Use of a food web model to evaluate the factors responsible for high PCB fish concentrations in Lake Ellasjoen, in a high Arctic Lake. Environmental Science and Pollution Research 2009;16:176-190.

Gewurtz SB, Lazar R, Haffner GD. Biomonitoring of bioavailable PAH and PCB water concentrations in the Detroit River using the Freshwater Mussel, *Elliptio complanata*. J Great Lakes Res 2003;29(2): 242-255.

Kalkirtz V, Martinez M, Teague A. 2008. Environmental Justice and Fish Consumption Advisories on the Detroit River Area of Concern.M.S. Thesis. University of Micghian, Ann Arbor, MI. U.S.

Leadly TA, Balch G, Metcalfe CD, Lazar R, Mazak E, Habowsky J, Haffner GD. Chemical accumulation and toxicological stress in three brown bullhead (Ameiurus nebulosus) populations in the Detroit River, Michigan, U.S.A. Environ Toxicol Chem 1998;17:1756-1766.

Maccubbin AE, Ersing N. Tumours in fish from the Detroit River. Hydrobiologia 1991;219:301-306.

Manny BA, Edsall TA, Jaworski E. The Detroit River, Michigan: an ecological profile. U.S. Fish and Wildlife Service. Biological Report. 1988; 85(7.17), 86pp.

Manny BA, Kenaga, D. The Detroit River: effects of contaminants and human activities on aquatic plants and animals and their habitats. Hydrobiologia1991; 219: 269-279.

Marvin C, Alaee M, Painter S, Charlton M, Kauss P, Kolic K, MacPerson K, Takeuchi D, Reiner E. Persistent organic pollutants in Detroit River suspended sediments: polychlorinated dibenzo-p-dioxins and dibenzofurans, dioxin-like polychlorinated biphenyls and polychlorinated naphthalenes. Chemosphere 2002; 49: 111-120.

Metcalfe CD, Metcalfe TL, Riddle G, Haffner GD. Aromatic hydrocarbons in biota from the Detroit River and Western Lake Erie. J Great Lakes Res 1997;23(2):160-168.

Metcalfe TL, Metcalfe CD, Bennett ER, Haffner GD. Distribution of toxic organic contaminants in water and sediments in the Detroit River. J Great Lakes Res 2000;26(1):55-64.

APPENDIX A:

Bibliography

Detroit River Fish Consumption Advisories: PCBs

Table of Contents

Assembled by: D.R. Kashian (Wayne State University), A.E. Krause (University of Toledo), Sander Robinson (Wayne State University), L. Sano (Marine Conservation Biology Institute), and Diane Wang (Ann Arbor Pioneer High School).

Last Updated: January, 2010

For more information, please contact Donna R. Kashian at dkashian@wayne.edu

This bibliography is part of an integrated assessment (IA) supported by a grant to D. Kashian from Michigan Sea Grant. The goal of the IA is to review the causes, consequences, and correctives for contamination on the Detroit River. More specifically, it looks at the reasons why fish contamination advisories are issued when they are. The project seeks to bring policy-makers, interested stakeholders, scientists, and governmental agencies together on both the Canadian and United States sides of the shore to talk about new information concerning PCB contamination and integrate historical elements to create new approaches to management of the River. We aim to help in protecting the health and safety of the people who fish on the Detroit River, the ecosystems that house them, and the economy that depends on fishing.

Fish Consumption Advisories for Polychlorinated Biphenyls (PCBs): Human Health

Abdelouahab, N., D. Mergler, L. Takser, C. Vanier, M. St-Jean, M. Baldwin, P. A. Spear, and H. M. Chan. 2008. Gender differences in the effects of organochlorines, mercury, and lead on thyroid hormone levels in lakeside communities of Quebec (Canada). *Environmental Research* 107 (3):380-392.

Agudo, A., F. Goni, A. Etxeandia, A. Vives, E. Millan, R. Lopez, P. Amiano, E. Ardanaz, A. Barricarte, M. D. Chirlaque, M. Dorronsoro, P. Jakszyn, N. Larranaga, C. Martinez, C. Navarro, L. Rodriguez, M. J. Sanchez, M. J. Tormo, and C. A. Gonzalez. 2009. Polychlorinated biphenyls in Spanish adults: Determinants of serum concentrations. *Environmental Research* 109 (5):620-628.

Anderson, H. A., Falk, C., Hanrahan, L., Olson, J., Burse, V.W., Needham, L., Paschal, D., Patterson, D. Jr., and Hill, R. Jr. 1998. Profiles of Great Lakes critical pollutants: A sentinel analysis of human blood and urine. *Environmental Health Perspectives.* 106(5): 279-28.

Angulo, R., Martinez P. and Jodral, M.L. 1999. PCB congeners transferred by human milk, with an estimate of their daily intake. *Food and Toxicology.* 37:1081-1088

Arulmozhiraja, S; Shiraishi, F; Okumura, T; Iida, M; Takigami, H; Edmonds, JS; Morita, M. 2005. Structural requirements for the interaction of 91 hydroxylated polychlorinated biphenyls with estrogen and thyroid hormone receptors. *Toxicological Sciences* 84 (1): 49-62.

Axmon, A., Rylander, L., Strömberg, U., Dyremark, E. and Hagmar, L. 2001. Polychlorinated biphenyls in blood plasma among Swedish female fish consumers in relation to time pregnancy. *Journal of Toxicology and Environmental Health A.* 64:6, 485-498.

Axmon, A., 2006. Menarche in women with high exposure to persistent organochlorine pollutants in utero and during childhoods. *Environmental Research.* 102:77-82.

Behrooz, R. D., A. E. Sari, N. Bahramifar, and S. M. Ghasempouri. 2009. Organochlorine pesticide and polychlorinated biphenyl residues in human milk from the Southern Coast of Caspian Sea, Iran. *Chemosphere* 74 (7):931-937.

Bilau, M., C. Matthys, W. Baeyens, L. Bruckers, G. De Backer, E. Den Hond, H. Keune, G. Koppen, V. Nelen, G. Schoeters, N. Van Larebeke, J. L. Willems, S. De Henauw, and Environm Flemish Ctr Expertise. 2008. Dietary exposure to dioxin-like compounds in three age groups: Results from the Flemish environment and health study. *Chemosphere* 70 (4):584-592.

Bloom, M.S., Weiner, J.M., Vena, J.E. and Beehler, G.P. 2003. Exploring associations between serum levels of select organochlorines and thyroxine in a sample of New York state sportsmen: the New York State Cohort Study. *Environmental Research.* 93:52-66.

Bloom, M. S., Vena, J. E., Swanson, M. K., Moysich, K. B. and Olson, J. R. 2005. Profile of ortho-polychlorinated biphenyl congeners, dichlorodiphenyldichloroethylene, hexachlorobenzene, and mirex among male Lake Ontario sportfish consumers: the New York state angler cohort study. *Environmental Research.* 97:178-194.

Breffle, W. S., and K. K. Maroney. 2009. The restoration of fishing services and the conveyance of risk information in the Southern California Bight. *Marine Policy* 33 (4):561-570.

Brustad, M., T. M. Sandanger, E. Nieboer, and E. Lund. 2008. 10th Anniversary Review: when healthy food becomes polluted - implications for public health and dietary advice. *Journal of Environmental Monitoring* 10 (4):422-427.

Buck Louis, G. M., J. Dmochowski, C. Lynch, P. Kostyniak, B. M. McGuinness, and J. E. Vena. 2009. Polychlorinated biphenyl serum concentrations, lifestyle and time-to-pregnancy. *Hum Reprod* 24 (2):451-8.

Buck, G. M., P. Mendola, J. E. Vena, L. E. Sever, P. Kostyniak, H. Greizerstein, J. Olson, and F. D. Stephen. 1999. Paternal Lake Ontario fish consumption and risk of conception delay, New York state angler cohort. *Environmental Research* 80 (2):S13-S18.

Buck, G. M., J. E. Vena, H. B. Greizerstein, J. M. Weiner, B. McGuinness, P. Mendola, P. J. Kostyniak, M. Swanson, M. S. Bloom, and J. R. Olson. 2002. PCB congeners and pesticides and female fecundity, New York State Angler Prospective Pregnancy Study. *Environmental Toxicology and Pharmacology* 12 (2):83-92.

Buck, G. M., J. E. Vena, E. F. Schisterman, J. Dmochowski, P. Mendola, L. E. Sever, E. Fitzgerald, P. Kostyniak, H. Greizerstein, and J. Olson. 2000. Parental consumption of contaminated sport fish from Lake Ontario and predicted fecundability. *Epidemiology* 11 (4):388-393.

Burger J. 2005. Fishing, fish consumption, and knowledge about advisories in college students and others in central New Jersey. *Environmental Research* 98(2):268-275.

Burger J. 2008. Fishing, fish consumption, and awareness about warnings in a university community in central New Jersey in 2007, and comparisons with 2004. *Environmental Research* 108(1):107-116.

Burger, Joanna. 2008. Perceptions as Indicators of Potential Risk from Fish Consumption and Health of Fish Populations. *Environmental Bioindicators* 3 (2):90-105.

Burger, J., and K. R. Campbell. 2008. Fishing and consumption patterns of anglers adjacent to the Oak Ridge Reservation, Tennessee: higher income anglers ate more fish and are more at risk. *Journal of Risk Research* 11 (3):335-350.

Burger J, Gochfeld M. 2006. A framework and information needs for the management of the risks from consumption of self-caught fish. *Environmental Research* 101(2):275-285.

Burger, J., and M. Gochfeld. 2008. Knowledge about fish consumption advisories: A risk communication failure within a university population. *Science of the Total Environment* 390 (2-3):346-354.

Burger, Joanna, and Michael Gochfeld. 2009. Perceptions of the risks and benefits of fish consumption: Individual choices to reduce risk and increase health benefits. *Environmental Research* 109 (3):343-349.

Burger J, Gochfeld M, Burke S, Jeitner CW, Jewett S, Snigaroff D, Snigaroff R, Stamm T, Harper S, Hoberg M and others. 2006. Do scientists and fishermen collect the same size fish? Possible implications for exposure assessment. *Environmental Research* 101(1):34-41.

Burger J, Harris S, Gochfeld M. Identifying High-End & Highly Impacted Fish Consumers: Methods for Assessing Exposure Risk for Populations with High Fish Consumption Rates; 2008 Oct 12-16; Pasadena, CA. p S18-S18.

Burger, J., S. Shukla, M. Fitzgerald, S. Flores, and C. Chess. 2008. Fish consumption: efficacy among fishermen of a brochure developed for pregnant women. *Journal of Risk Research* 11 (7):891-904.

Chess C, Burger J, McDermott MH. 2005. Speaking like a state: Environmental justice and fish consumption advisories. *Society & Natural Resources* 18(3):267-278.

Cooper, G. S., Klebanoff, M.A., Promislow J., Brock, J.W. and Longnecker, M. P. 2005. Polychlorinated biphenyls and menstrual cycle characteristics. *Epidemiology*. 16(2):191-200.

Costabeber, I., Emanuell, I., 2003. Influence of alimentary habits, age and occupation on polychlorinated biphenyl levels in adipose tissue. *Food and Chemical Toxicology.* 41:73-80

Craan, A.G., Haines, D.A. 1998. Twenty-five years of surveillance for contaminants in human breast milk. *Arch. Environ. Contam. Toxicol.* 35:702-710.

Dallaire, F., Dewailly, É., Muckle, G., Vézina, C., Jacobson, S.W., Jacobson, J. L. and Ayotte, P. 2004. Acute infections and environmental exposure to organochlorines in inuit infants from Nunavik. *Environmental Health Perspectives*. 112(14):1359-1364.

Darvill, T., Lonky, E., Reihman, J., Stewart P. and Pagano, J. 2000. Prenatal exposure to PCBs and infant performance on the Fagan test of infant intelligence. *Neurotoxicology*. 21(6)1029-38.

Dawson J, Sheeshka J, Cole DC, Kraft D, Waugh A. 2008. Fishers weigh in: benefits and risks of eating Great Lakes fish from the consumer's perspective. *Agriculture and Human Values* 25:349-364.

Dellinger, J.A. 2004. Exposure assessment and initial intervention regarding fish consumption of tribal members of the Upper Great Lakes Region in the United States. *Environmental Research.* 95(3):325-340.

De Mul, A., M. I. Bakker, M. J. Zeilmaker, W. A. Traag, S. P. J. van Leeuwen, Rlap Hoogenboom, P. E. Boon, and J. D. van Klaveren. 2008. Dietary exposure to dioxins and dioxin-like PCBs in The Netherlands anno 2004. *Regulatory Toxicology and Pharmacology* 51 (3):278-287.

DeWeese, A. D., N. E. Kmiecik, E. D. Chiriboga, and J. A. Foran. 2009. Efficacy of Risk-Based, Culturally Sensitive Ogaa (Walleye) Consumption Advice for Anishinaabe Tribal Members in the Great Lakes Region. *Risk Analysis* 29 (5):729-742.

Domingo JL, Bocio A, Falco G, Llobet JM. 2007. Benefits and risks of fish consumption Part I. A quantitative analysis of the intake of omega-3 fatty acids and chemical contaminants. *Toxicology* 230(2-3):219-226.

Domingo JL, Bocio A, Marti-Cid R, Llobet JM. 2007. Benefits and risks of fish consumption Part II. RIBEPEIX, a computer program to optimize the balance between the intake of omega-3 fatty acids and chemical contaminants. *Toxicology* 230(2-3):227-233.

Falk, C., Hanrahan, L, Anderson, H. A., Kanarek, M. S. and Draheim, L. 1999. Body burden levels of dioxin, furans, and PCBs among frequent consumers of Great Lakes Sport Fish. *Environmental Research A*. 80:19-25

Fangstrom, B., Athanasiaduo, M., Grandjean, P. Weihe, P. and Bergman, A. 2002. Hydrolated PCB metabolites and PCBs in serum from pregnant Faroese women. *Environmental Health Perspectives.* 110(9):895-899.

Fangstrom, B., Hovander, L., Bignert, A., Athanassiadis, I., Linderholm, L., Grandjean, P., Weihe, P. and, Bergman, A. 2005. Concentrations of polybrominated diphenyl ethers, polychlorinated biphenyls, and polychlorobiphenylols in serum from pregnant Faroese women and their children 7 years later. *Environ. Sci. Technol.* 39: 9457-9463

Feeley, M.M., Jordan, S.A. and Gilman, A.P. 1998. The health Canada Great Lakes multigeneration study-summary and regulatory considerations. *Regulatory Toxicology and Pharmacology*. 27:90-98.

Fitzgerald, E. F., E. E. Belanger, M. I. Gomez, M. Cayo, R. J. McCaffrey, R. F. Seegal, R. L. Jansing, S. A. Hwang, and H. E. Hicks. 2008. Polychlorinated biphenyl exposure and neuropsychological status among older residents of upper Hudson river communities. *Environmental Health Perspectives* 116 (2):209-215.

Fitzgerald, E.F., Brix, K.A., Deres, D.A., Hwang, S.A., Bush, B., Lambert, G. and Tarbell, A. 1996. Polychlorinated biphenyl (PCB) and dichlorodiphenyl dichloroethylene (DDE) exposure among Native American men from contaminated Great Lakes fish and wilflife. *Toxicol. Ind. Health.* 12(3-4):361-8.

Fitzgerald, E.F., Deres, D.A., Hwang, S., Bush, B., Yang, B. 1999. Local fish consumption and serum PCB concentrations among Mohawk men at Akwesasne. *Environmental Research* A. 80:97-103

Fitzgerald, E. F., Hwang S., Bush B., Cook K., and Worswick, P., 1998. Fish consumption and breast milk PCB concentrations among Mohawk woman at Akwesasne. *American Journal of Epidemiology.* 148(2)

Fitzgerald, E.F., Hwang, S., Lambert, G., Gomez, M., Tarbell, A., 2005. PCB exposure and in vivo CYP1A2 Activity among Native Americans. *Environmental Health Perspectives.* 113(3):272-277.

Fitzgerald, E.F.; Hwang, SA; Gomez, M; Bush, B; Yang, BZ; Tarbell, A. 2007. Environmental and occupational exposures and serum PCB concentrations and patterns among Mohawk men at Akwesasne. *Journal of Exposure Science and Environmental Epidemiology* 17 (3): 269-278.

Foran JA, Good DH, Carpenter DO, Hamilton MC, Knuth BA, Schwager SJ. 2005. Quantitative analysis of the benefits and risks of consuming farmed and wild salmon. *Journal of Nutrition* 135(11):2639-2643.

Frithsen, I., and W. Goodnight. 2009. Awareness and Implications of Fish Consumption Advisories in a Women's Health Setting. *Journal of Reproductive Medicine* 54 (5):267-272.

Garabrant, D. H., A. Franzblau, J. Lepkowski, B. W. Gillespie, P. Adriaens, A. Demond, E. Hedgeman, K. Knutson, L. Zwica, K. Olson, T. Towey, Q. X. Chen, B. L. Hong, C. W. Chang, S. Y. Lee, B. Ward, K. LaDronka, W. Luksemburg, and M. Maier. 2009. The University of Michigan Dioxin Exposure Study: Predictors of Human Serum Dioxin Concentrations in Midland and Saginaw, Michigan. *Environmental Health Perspectives* 117 (5):818-824.

Gerstenberger, S.L. and Dellinger, J.A. 2002. PCBs, mercury, and organochlorines concentrations in lake trout, walleye, and whitefish from selected tribal fisheries in the Upper Great Lakes region. *Environmental Toxicology*. 17(6):513-519.

Glynn, A.W., Granath, F., Aune, M., Atuma, S., Bjerselius, R., Darnerud, P.O., Vainio, H., Weiderpass, E. 2003. Organochlorines in Swedish women: Determinants of serum concentrations. *Environmental Health Perspectives*. 111(3): 349-355.

Gochfeld M, Burger J. Good fish/bad fish: A composite benefit-risk by dose curve; 2004 Feb 10-14; Honolulu, HI. p 511-520.

Goncharov, A., Haase, R.F., Santiago-Rivera, A., Morse, G., Akwesasne Task Force on the Environment, McCaffrey, R.J., Rej, R. and Carpenter, D.O. 2008. High serum PCBs are associated with elevation of serum lipids and cardiovascular disease in a Native American population. *Environmental Research.* 106:226-239.

Gonzales, G.J. and Fresquez, P.R. 2005. Polychlorinated biphenyls (PCBs) in predator and botton-feeding fish from Abiquiu and Cochiti reservoirs in North-Central New Mexico. Edited by Hector Hinojosa. Group IM-1. Los Alamos National Laboratory. U.S., Dept. of Energy. LA-14289. pages: 1-16.

Haase, R. F., R. J. McCaffrey, A. L. Santiago-Rivera, G. S. Morse, and A. Tarbell. 2009. Evidence of an age-related threshold effect of polychlorinated biphenyls (PCBs) on neuropsychological functioning in a Native American population. *Environmental Research* 109 (1):73-85.

Habron, G., M. Barbier, and R. Kinnunen. 2008. Local understanding of fish consumption advisory risks in Michigan's Upper Peninsula: The role of structure, culture, and agency. *Rural Sociology* 73 (2):275-299.

Hagmar, L., Wallin, E., Vessby, B., Jonsson, B. AG, Bergman A. and, Rylander L. 2006. Intra-individual variations and time trends 1991-2001 in human serum levels of PCB, DDE and hexachlorobenzene. *Chemosphere*. 64:1507-1513.

Halldorsson, T. I., I. Thorsdottir, H. M. Meltzer, F. Nielsen, and S. F. Olsen. 2008. Linking Exposure to Polychlorinated Biphenyls With Fatty Fish Consumption and Reduced Fetal Growth Among Danish Pregnant Women: A Cause for Concern? *American Journal of Epidemiology* 168 (8):958-965.

Hanrahan, L.P., Falk, C., Anderson, H.A., Draheim, L., Kanarek, M.S., Olson, J. and The Great Lakes Consortium. 1999. Serum PCB and DDE levels of frequent Great Lakes sport fish consumers – a first look. *Environmental Research Section A*. 80:26-37.

Harris, S. A., and J. L. Jones. 2008. Fish consumption and PCB-associated health risks in recreational fishermen on the James River, Virginia. *Environmental Research* 107 (2):254-263.

He, J-P, Stein, A.D., Humphrey, H.E.B., Paneth, N. and Courval, J.M. 2001. Time trends in sport-caught Great Lakes fish consumption and serum polychlorinated biphenyl levels among Michigan Anglers, 1973-1993. *Environmental Science and Technology*. 35(3):435-439.

Hedgeman, Elizabeth, Qixuan Chen, Biling Hong, Chiung-Wen Chang, Kristen Olson, Kathleen LaDronka, Barbara Ward, Peter Adriaens, Avery Demond, Brenda W. Gillespie, James Lepkowski, Alfred Franzblau, and David H. Garabrant. 2009. The University of Michigan Dioxin Exposure Study: Population Survey Results and Serum Concentrations for Polychlorinated Dioxins, Furans, and Biphenyls. *Environmental Health Perspectives* 117 (5):811-817.

Hertz-Picciotto, I., Charles, M.J., James, R.A., Keller, J.A., Willman, E. and Teplin, S. 2005. In utero polychlorinated biphenyl exposures in relation to fetal and early childhood growth. *Epidemiology*. 16(5):648-656.

Hotchkiss, A. K., C. V. Rider, C. R. Blystone, V. S. Wilson, P. C. Hartig, G. T. Ankley, P. M. Foster, C. L. Gray, and L. E. Gray. 2008. Fifteen years after "Wingspread" - Environmental endocrine disrupters and human and wildlife health: Where we are today and where we need to go. *Toxicological Sciences* 105 (2):235-259.

Huang, X., Hites, R.A., Foran, J.A., Hamilton, C., Knuthe, B.A., Schwager, S.J. and Carpenter, D.O. 2006. Consumption advisories for salmon based on risk of cancer and noncancer health effects. *Environmental Research*. 101:263-274.

Humphrey, H.E.B., Gardiner, J.C., Pandya, J.R., Sweeney, A.M., Gasior, D.M., McCaffrey, R.J. and Schantz, S.L. 2000. PCB congener profile in the serum of humans consuming Great Lakes fish. *Environmental Health Perspectives*. 108(2):167-172.

Jacobson, J.L., and Jacobson, S.W. 1996. Intellectual impairment in children exposed to polychlorinated biphenyls in utero. *The New England Journal of Medicine.* 335(11):783-789.

Jacobson, J.L. and Jacobson, S.W. 2002. Breast-feeding and gender as moderators of teratogenic effects on cognitive development. *Neurotoxicology and Teratology.* 24:349-358.

Jacobson, J.L. and Jacobson, S.W. 2003. Prenatal exposure to polychlorinated biphenyls and attention at school age. *The Journal of Pediatrics.* 780-788.

Jan, J., and K. Reinert. 2008. Dental caries in Faroese children exposed to polychlorinated biphenyls. *Environmental Toxicology and Pharmacology* 25 (2):188-191.

Johansen HR, Alexander J, Rossland OJ, Planting S, Lovik M, Gaarder PI, Gdynia W, Bjerve KS, Becher G. 1996. PCDDs, PCDFs, and PCBs in human blood in relation to consumption of crabs from a contaminated Fjord area in Norway. *Environmental Health Perspectives* 104(7):756-764.

Johansen, P., Muin, D., Asmund, G. and Riget, F. 2004. Human exposure to contaminants in the traditional Greenland diet. *Science of the Total Environment.* 331:189-206.

Judd, N.L., Griffith, W.C., Kalman, D.A. and Faustman, E.M. 2003. Assessment of PCB congener analytical methods: do they meet risk assessment needs? *Arch. Environ. Contam. Toxicology.* 44:132-130.

Judd, N., Griffith, W.C. and Faustman, E.M. 2004. Contribution of PCB exposure from fish consumption to total dioxin-like dietary exposure. *Regulatory Toxicology and Pharmacology.* 40:125-135.

Kamrin, M.A. and Fishcer, L.J. 1999. Current status of sport fish consumption advisories for PCBs in the Great Lakes. *Regulatory Toxicology and Pharmacology.* 29:175-181.

Kearney, J.P., Cole, D.C., Ferron, L.A. and Weber, J-P. 1999. Blood PCB, p,p'-DDE, and mirex levels in the Great Lakes fish and waterfowl consumers in two Ontario communitites. *Environmental Research A*. 80:138-149.

Kelly BC, Ikonomou MG, Higgs DA, Oakes J, Dubetz C. 2008. Mercury and other trace elements in farmed and wild salmon from British Columbia, Canada. *Environmental Toxicology and Chemistry* 27:1361-1370.

Khanjani, N. and Sim, M.S. 2007. Maternal contamination with PCBs and reproductive outcomes in an Australian population. *Journal of Exposure Science and Environmental Epidemiology.* 17:191-195.

Kiviranta H, Vartiainen T, Tuomisto J. 2002. Polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls in fishermen in Finland. *Environmental Health Perspectives* 110(4):355-361.

Kiviranta, H., Ovaskainen, M-L. and Vartiainen, T. 2004. Market basket study on dietary intake of PCDD/Fs, PCBs, and PBDEs in Finland. *Environmental International*. 30:923-932.

Kiviranta, H., Tuomisto, J.T., Tuomisto J., Tukiainen E. and Vartiainen, T. 2005. Polychlorinated dibenzo-p-dioxins, dibenzofurans, and biphenyls in the general population in Finland. *Chemosphere*. 60:854-869.

Knobeloch, L., M. Turyk, P. Imm, C. Schrank, and H. Anderson. 2009. Temporal changes in PCB and DDE levels among a cohort of frequent and infrequent consumers of Great Lakes sportfish. *Environmental Research* 109 (1):66-72.

Knuth, B. A., C. McOliver, E. K. Silbergeld, N. A. Connelly, and A. Faulds. 2008. Contaminant and Pathogen Considerations in Urban Fisheries: Balancing the Fishing Experience with the Need to Protect Human Health. *Urban and Community Fisheries Programms: Development, Management, and Evaluation* 67:143-164.

Kosatsky, T., Przybysz, R., Shatenstein, B, Weber, J-P and Armstrong, B. 1999. Fish consumption and contaminant exposure among Montreal-area sportfishers: pilot study. *Environmental Research Section A*. 80:150-158.

Lee, K.T., Lee, J.H., Lee., J.S., Park, K.H., Kim, S.K., Shim, W.J., Hong, S.H., Im, U.H., Giesy, J.P., Oh, J.R. 2007. Human exposure to dioxin-like compounds in fish and shellfish consumed in South Korea. *Human and Ecological Risk Assessment*. 13(1):223-235.

Leng, Jun-Hong, Fujio Kayama, Pei-Yu Wang, Masafumi Nakamura, Toshiyoshi Nakata, and Yan Wang. 2009. Levels of persistent organic pollutants in human milk in two Chinese coastal cities, Tianjin and Yantai: Influence of fish consumption. *Chemosphere* 75 (5):634-639.

Llobet, J. M., R. Marti-Cid, V. Castell, and J. L. Domingo. 2008. Significant decreasing trend in human dietary exposure to PCDD/PCDFs and PCBs in Catalonia, Spain. *Toxicology Letters* 178 (2):117-126.

Longnecker, M.O., Wolff, M.S., Gladen, B.C., Brock, J.W., Grandjean, P., Jacobson, J.L., Korrick, S.A., Rogan, W.J., Weisglas-Kuperus, N., Hertz-Picciotto, I., Ayotte, P., Stewart, P., Winneke, G., Charles, M.J., Jacobson, S.W., Dewailly, E., Boersma, E.R., Altshul, L.M., Heinzow, B., Pagano, J.J. and Jensen, A.A., 2003. Comparison of polychlorinated biphenyl levels across studies of human neurodevelopment. *Environmental Health Perspectives.* 111(1)65-70.

Louis, G. M. B., J. Dmochowski, C. Lynch, P. Kostyniak, B. M. McGuinness, and J. E. Vena. 2009. Polychlorinated biphenyl serum concentrations, lifestyle and time-to-pregnancy. *Human Reproduction* 24 (2):451-458.

Lurig, L., and K. K. Pflugh. 2008. Development and Evolution of the New Jersey Department of Environmental Protection's Urban Fishing Program. *Urban and Community Fisheries Programms: Development, Management, and Evaluation* 67:271-279.

Madeddu, A., and S. Sciacca. 2008. Biological tracking on the presence of Hg, PCB and HCG in milk and hair of women resident in a region with high incidence of children born with malformation (Augusta). *Ann Ig* 20 (3 Suppl 1):59-64.

Mahaffey KR, Clickner RP, Jeffries RA. 2008. Methylmercury and omega-3 fatty acids: Co-occurrence of dietary sources with emphasis on fish and shellfish. *Environmental Research* 107:20-29.

McGraw, J. E., and D. P. Waller. 2009. Fish ingestion and congener specific polychlorinated biphenyl and p,p '-dichlorodiphenyldichloroethylene serum concentrations in a great lakes cohort of pregnant African American women. *Environment International* 35 (3):557-565.

Mikoczy, Z., and L. Rylander. 2009. Mortality and cancer incidence in cohorts of Swedish fishermen and fishermen's wives: Updated findings. *Chemosphere* 74 (7):938-943.

Moon, H. B., and H. G. Choi. 2009. Human exposure to PCDDs, PCDFs and dioxin-like PCBs associated with seafood consumption in Korea from 2005 to 2007. *Environment International* 35 (2):279-284.

Moon, H. B., H. S. Kim, M. Choi, J. Yu, and H. G. Choi. 2009. Human health risk of polychlorinated biphenyls and organochlorine pesticides resulting from seafood consumption in South Korea, 2005-2007. *Food and Chemical Toxicology* 47 (8):1819-1825.

Morland, K., M. Wolff, R. Bopp, J. Godbold, and P. Landrigan. 2008. Fish consumption and body burden of organochlorines among lower Hudson urban anglers. *American Journal of Industrial Medicine* 51 (8):587-594.

Moya, J., C. Itkin, S. G. Selevan, J. W. Rogers, and R. P. Clickner. 2008. Estimates of fish consumption rates for consumers of bought and self-caught fish in Connecticut, Florida, Minnesota, and North Dakota. *Science of the Total Environment* 403 (1-3):89-98.

Nadon, S., Kosatsky, T. and Przybysz, R. 2002. Contaminant exposure among women of childbearing age who eat St. Lawrence River sport fish. *Archives Environmental Health.* 57(5):473-481.

Naert, C., Piette, M., Bruneel, N. and Van Petegham, C. 2006. Occurrence of polychlorinated biphenyls and polybrominated diphenyl ethers in Belgian human adipose tissue samples. *Archives Environmental. Contam. Toxicology.* 50:290-296.

Newsome, W.H., Davies, D. and Doucet, J. 1995. PCB and organochlorine pesticides in Canadian human milk-1992. *Chemosphere*. 30(11):2143-2153.

Ney, J. J., and J. P. Ney. 2008. Risky Business: Evaluation of US Consumption Advisories for Freshwater Sport Fish. *Balancing Fisheries Management and Water Uses for Impounded River Systems* 62:559-569.

Paris-Pombo, A., Aronson, K.J., Woolcott, C.G. and King, W.D. 2003. Dietary predictors of concentrations of polychlorinated biphenyls in breast adipose tissue of women living in Ontario, Canada. *Archives of Environmental Health*. 58(1):48-54.

Phillips, L.J. and Birchard, G.F. 1991. Regional variations in human toxics exposure in the USA: An analysis based on the National Human Adipose Tissue Survey. *Arch. Environ. Contain. Toxicol.* 21:159-168.

Pompa, G., Caloni, F. and Fracchiolla, M.L. 2003. Dioxin and PCB contamination of fish and shellfish: assessment of human exposure. Review of the international situation. *Veterinary Research Communications*. 27(Suppl. 1):159-167.

Ravoori, S., P. Ayotte, C. Srinivasan, D. Pereg, L. W. Robertson, G. K. Russell, J. Jeyabalan, and R. C. Gupta. 2008. DNA damage associated with PCBs in the whole blood cells of Inuit. *Environmental Toxicology and Pharmacology* 25 (2):273-276.

Ritchie, J.M., Vial, S.L., Fuortes, L.J., Robertson, L.W., Guo, H., Reedy, V.E. and Smith, E.M. 2005. Comparison of proposed frameworks for grouping polychlorinated biphenyl congener data applied to a case-control pilot study of prostate cancer. *Environmental Research*. 98:104-113.

Rozati, R. 2002. Role of environmental estrogens in the deterioration of male factor fertility. *Fertility and Sterility*. 78(6):1187-1194.

Rylander, C., T. M. Sandanger, and M. Brustad. 2009. Associations between marine food consumption and plasma concentrations of POPs in a Norwegian coastal population. *Journal of Environmental Monitoring* 11 (2):370-376.

Saint-Amour, D., Roy, M-S., Bastian, C., Ayotte, P., Dewailly, E., Despres, C., Gingras, S. and Muckle, G. 2006. Alterations of visual evoked potentials in preschool Inuit children exposed to methylmercury and polychlorinated biphenyls from a marine diet. *NeuroToxicology.* 27:567-578.

Sandanger, T.M., Brustad, M., Lund, E. and Burkow, I.C. 2003. Change in levels of persistent organic pollutants in human plasma after consumption of a traditional northern Norwegian fish dish-Molje (cod, cod liver, cod liver oil and hard roe). *J. Environ. Monit.* 5:160-165.

Sandanger, T.M., Brustad, M., Odland, J.O., Doudarev, A.A., Miretsky, G.I., Chaschin, V., Burkow, I.C. and Lund, E. 2003. Human plasma levels of POPs, and diet among native people from Uelen, Chukotka. *The Royal Society of Chemistry.* 5:689-696

Schaeffer, D.J., Dellinger, J.A., Needham, L.L. and Hansen, L.G. 2006. Serum PCB profiles in Native Americans from Wisconsin based on region, diet, age, and gender: implications for epidemiology studies. *Science of Total Environment.* 357:74-87.

Schecter, A., Pavuk, M., Malisch, R. and Ryan, J.J. 2003. Dioxin, dibenzofuran, and polychlorinated biphenyl (PCB) levels in food from agent. *Journal of Toxicology and Environmental Health A*. 66:2165-2186.

Schell, L. M., M. V. Gallo, J. Ravenscroft, and A. P. DeCaprio. 2009. Persistent organic pollutants and anti-thyroid peroxidase levels in Akwesasne Mohawk young adults. *Environmental Research* 109 (1):86-92.

Scherer, A. C., A. Tsuchiya, L. R. Younglove, T. M. Burbacher, and E. M. Faustman. 2008. Comparative Analysis of State Fish Consumption Advisories Targeting Sensitive Populations. *Environmental Health Perspectives* 116 (12):1598-1606.

Senn, K. M., B. M. McGuinness, G. M. Buck, J. E. Vena, S. Anderson, and B. T. Rogers. 2005. Longitudinal study of babies born to mothers enrolled in a preconception prospective pregnancy study: study design and methodology, New York State Angler Cohort Study. *Environmental Research* 97 (2):163-169.

Stewart, P., Darvill, T., Lonky, E., Reihman, J., Pagano, J. and Bush, B. 1999. Assessment of prenatal exposure to PCBs from maternal consumption of Great Lakes fish: An analysis of PCB pattern and concentration. *Environmental Research A*. 80:87-96.

Stewart, P., Reihman, J., Lonky, E., Darvill, T. and Pagano, J. 2004. Prenatal PCB exposure and neurobehavioral development in infants and children: Can the Oswego study inform the current debate? *Psychology in the Schools*. 41(6)639-653.

Stewart, P.W., Sargent, D.M., Reihamn, J., Gump, B.B., Lonky, E., Darvill, T., Hicks, H. and Pagano, J. 2006. Response inhibition during differential reinforcement of low rates (DRL). Schedules may be sensitive to low-level polychlorinated biphenyl, methylmercury, and lead exposure in children. *Environmental Health Perspectives.* 114(12):1923-1929.

Stewart, P.W., Lonky, E., Reihamn, J., Pagano, J., Gump, B.B. and Darvill, T. 2008. The relationship between prenatal PCB exposure and intelligence (IQ) in 9-year-old children. *Environmental Health Perspectives*. Doi: 10.1289/ehp.11058 (http://dx.doi.org/)

Storelli, M. M. 2008. Potential human health risks from metals (Hg, Cd, and Pb) and polychlorinated biphenyls (PCBs) via seafood consumption: Estimation of target hazard quotients (THQs) and toxic equivalents (TEQs). *Food and Chemical Toxicology* 46 (8):2782-2788.

Sun, S-J., Zhao, J-H., Liu, H-J., Liu, D-W., Ma, Y-X., Li, L., Horiguchi, H., Uno, H., Lida, T., Koga, M., Kiyonari, Y., Nakamura, M., Sasako, S., Fukatu, H., Clark. G.C. and Kayama, F. 2006. Dioxin concentration in human milk in Hebei province in China and Tokyo, Japan: potential dietary risk factors and determination of possible sources. *Chemosphere*. 62:1879-1888.

Surgan, M. H., J. Davis, T. Congdon, and L. Kellerman. 2008. Fish consumption advisories: One agency's focus on families. *Society & Natural Resources* 21 (3):266-270.

Tan, J., Q. Q. Li, A. Loganath, Y. S. Chong, M. Xiao, and J. P. Obbard. 2008. Multivariate data analyses of persistent organic pollutants in maternal adipose tissue in Singapore. *Environmental Science & Technology* 42 (7):2681-2687.

Taylor, K.C., Jackson, L.W>, Lynch, C.D., Kostyniak, P.J. and Louis, G.M.B. 2007. Preconception maternal polychlorinated biphenyl concentrations and the secondary sex ratio. *Environmental Research*. 103:99-105.

Tee, P.G., Sweeney, A.M., Symanski, E., Gardiner, J.C., Gasior, D.M. and Schantz, S.L. 2003. A longitudinal examination of factors related to changes in serum polychlorinated biphenyl levels. *Environmental Health Perspectives*. 111(5):702-707.

Tiido, T., Rignell-Hydbom, A., Jonsseon, B.A.G., Giwercman, Y.L., Pedersen, H.S., Wojtyniak, B., Ludwicki, J.K., Lesovoy, V., Zvyezday, V., Spano, M., Manicardi, G-C., Bizzaro, D., Bonefeld-Jorgensen, E.C., Toft, G., Bonde, J.P., Rylander, L., Hagmar, L. and Giwercman, A. 2006. Impact of PCB and p,p'-DDE contaminants on human sperm Y:X chromosome ratio: studies in three European populations and the Inuit population in Greenland. *Environmental Health Perspectives.* 114(5):718-724.

Tsuchiya, A., J. Hardy, T. M. Burbacher, E. M. Faustman, and K. Marien. 2008. Fish intake guidelines: incorporating n-3 fatty acid intake and contaminant exposure in the Korean and Japanese communities. *American Journal of Clinical Nutrition* 87 (6):1867-1875.

Turyk, M.E., Anderson, H.A., Freels, S., Chatterton, R. Jr., Needham, L.L., Patterson, D.G. Jr., Steenport, D.N., Knobeloch, L., Imm, P., Persky, V.W. and the Great Lakes Consortium., 2006. Associations of organochlorines with endogenous hormones in male Great Lakes fish consumers and nonconsumers. *Environmental Research*. 102:299-307.

Turyk, M., Anderson, H.A., Hanrahan, L.P., Falk, C., Steenport, D.N., Needham, L.L., Patterson, D.G. Jr., Freels, S., Persky, V. and the Great Lakes Consortium., 2006. Relationship of serum levels of individual PCB, dioxin and furan congeners and DDE with Great Lakes sport-caught fish consumptions. *Environmental Research.* 100:173-183.

Turyk, Mary, Henry Anderson, Lynda Knobeloch, Pamela Imm, and Victoria Persky. 2009. Organochlorine Exposure and Incidence of Diabetes in a Cohort of Great Lakes Sport Fish Consumers. *Environmental Health Perspectives* 117 (7):1076-1082.

Turyk, Mary, Henry A. Anderson, Lynda Knobeloch, Pamela Imm, and Victoria W. Persky. 2009. Prevalence of diabetes and body burdens of polychlorinated biphenyls, polybrominated diphenyl ethers, and p,p '-diphenyldichloroethene in Great Lakes sport fish consumers. *Chemosphere* 75 (5):674-679.

Turyk ME, Persky VW, Imm P, Knobeloch L, Chatterton R, Anderson HA. 2008. Hormone Disruption by PBDEs in Adult Male Sport Fish Consumers. *Environmental Health Perspectives* 116:1635-1641.

Uemura, H., K. Arisawa, M. Hiyoshi, H. Satoh, Y. Sumiyoshi, K. Morinaga, K. Kodama, T. Suzuki, and M. Nagai. 2008. PCDDs/PCDFs and dioxin-like PCBs: Recent body burden levels and their determinants among general inhabitants in Japan. *Chemosphere* 73 (1):30-37.

Urban, J. D., J. A. Tachovsky, L. C. Haws, D. Wikoff Staskal, and M. A. Harris. 2009. Assessment of human health risks posed by consumption of fish from the Lower Passaic River, New Jersey. *Science of the Total Environment* 408 (2):209-224

Usydus, Z., J. Szlinder-Richert, L. Polak-Juszczak, K. Komar, M. Adamczyk, M. Malesa-Ciecwierz, and W. Ruczynska. 2009. Fish products available in Polish market - Assessment of the nutritive value and human exposure to dioxins and other contaminants. *Chemosphere* 74 (11):1420-1428.

Vaclavik, E., Tjonneland, A., Stripp, C., Overvad, K., Weber, J.P. and Rasschou-Nielsen, O. 2006. Organochlorines in Danish women: Predictors of adipose tissue concentrations. *Environmental Research*. 100:362-379

van der Voet H, de Mul A, van Klaveren JD. 2007. A probabilistic model for simultaneous exposure to multiple compounds from food and its use for risk-benefit assessment. *Food and Chemical Toxicology* 45(8):1496-1506.

Vardeman, J. E., and L. Aldoory. 2008. A qualitative study of how women make meaning of contradictory media messages about the risks of eating fish. *Health Communication* 23 (3):282-291.

Vasiliu, O., Muttineni, J. and Karmaus, W. 2004. In utero exposure to organochlorines and age at menarche. *Human Reproduction*. 19(7):1506-1512.

Vena, J. E., G. M. Buck, P. Kostyniak, P. Mendola, E. Fitzgerald, L. Sever, J. Freudenheim, H. Greizerstein, M. Zielezny, J. McReynolds, and J. Olson. 1996. The New York Angler Cohort

Study: Exposure characterization and reproductive and developmental health. *Toxicology and Industrial Health* 12 (3-4):327-334.

Verger, P., N. Khalfi, C. Roy, S. Blanchemanche, S. Marette, and J. Roosen. 2008. Balancing the risk of dioxins and polychlorinated biphenyls (PCBs) and the benefit of long-chain polyunsaturated fatty acids of the n-3 variety for French fish consumers in western coastal areas. *Food Additives and Contaminants* 25 (6):765-771.

Weintraub M, Birnbaum LS. 2008. Catfish consumption as a contributor to elevated PCB levels in a non-Hispanic black subpopulation. *Environmental Research* 107(3):412-417.

Weis, P. and Ashley, J.T.F. 2007. Contaminants in fish of the Hackensack Meadowlands, New Jersey: size, sex, and seasonal relatipnships as related to health risks. *Arch. Environ. Contam. Toxicol.* 52:80-89.

Westphal, L. M., M. Longoni, C. L. LeBlanc, and A. Wali. 2008. Anglers' appraisals of the risks of eating sport-caught fish from industrial areas: Lessons from Chicago's Calumet region. *Human Ecology Review* 15 (1):46-62.

Williams, L.L., Glesy, J.P., DeGalan, N., Verbrugge, D.A., Tillit, D.E., Ankley, G.T. and Welch, R.L. 1992. Prediction of concentrations of 2,3,4,8-Tetrachlorodibenzo-p-dioxin equivalents from total concentrations of polychlorinated biphenyls in fish fillets. *Environ. Sci. Technol.* 26:1151-1159.

Wolff, M.S., Britton, J.A., Teitelbaum, S.L., Eng, S., Deych, E., Ireland, K., Liu, Z., Neugut, A.I., Santella, R.M. and Gammon, M.D. 2005. Improving organochlorine biomarker models for cancer research. *Cancer Epidemiol Biomarkers Prev.* 14(9):2224-2236.

Wolff, M.S., Deych, E., Ojo, F. and Berkowitz, G.S. 2005. Predictors of organochlorines in New York City pregnant women, 1998-2001. *Environmental Research.* 97:170-177.

Wong, C.K.C., Leung, K.M., Poon, B.H.T., Lan, C.Y., and Wong, M.H. 2002. Organochlorines hydrocarbons in human breast milk collected in Hong Kong and Guangzhou. *Arch. Environ. Contam. Toxicol.* 43:364-372.

Yang, C. Y., Y. J. Wang, P. C. Chen, S. J. Tsai, and Y. L. Guo. 2008. Exposure to a mixture of polychlorinated biphenyls and polychlorinated dibenzofurans resulted in a prolonged time to pregnancy in women. *Environmental Health Perspectives* 116 (5):599-604.

Yim, U.H., Hong, S.H., Shim, J. and Oh. J.R. 2005. Levels of persistent organochlorine contaminants in fish from Korea and their potential health risk. *Arch. Environ. Contam. Toxicol.* 48:358-366.

Zhang, J. Q., Y. S. Jiang, R. Zhou, D. K. Fang, J. Jiang, G. H. Liu, H. Y. Zhang, J. B. Xie, W. Huang, J. Z. Zhang, H. Li, Z. Wang, and L. Pan. 2008. Concentrations of PCDD/PCDFs and

PCBs in retail foods and an assessment of dietary intake for local population of Shenzhen in China. *Environment International* 34 (6):799-803.

Fish Consumption Advisories for Polychlorinated Biphenyls (PCBs): PCBs in Fish

Ackerman, L. K., A. R. Schwindt, S. L. M. Simonich, D. C. Koch, T. F. Blett, C. B. Schreck, M. L. Kent, and D. H. Landers. 2008. Atmospherically deposited PBDEs, pesticides, PCBs, and PAHs in Western US National Park fish: Concentrations and consumption guidelines. *Environmental Science & Technology* 42 (7):2334-2341.

Antunes P, Amado J, Vale C, Gil O. 2007. Influence of the chemical structure on mobility of PCB congeners in female and male sardine (Sardina pilchardus) from Portuguese coast. *Chemosphere* 69(3):395-402.

Baeyens, W., Leermakers, M., Elskens, M., Van Larebeke, N., De Bont, R., Vanderperren, H., Fontaine, A., Degroodt, J.-M., Goeyens, L., Hanot, V. and Windal, I. 2007. PCBs and PCDD/FS in fish and fish products and their impact on the human body burden in Belgium. *Archives of Environmental Contamination and Toxicology*. 52(4):563-571.

Bayarri, S., Baldassarri, L.T., Iacovella, N., Ferrara, F. and Domenico, A. 2001. PCDDs, PCDFs, PCBs and DDE in edible marine species from the Adriatic Sea. *Chemosphere*. 43(4-7):601-610.

Binelli, A. and Provini, A. 2004. Risk for human health of some POPs due to fish from Lake Iseo. *Ecotoxicology and Environmental Safety*. 58(1):139-145.

Brown, F.R., Winkler, J., Visita, P., Dhaliwal, J. and Petreas, M. 2006. Levels of PBDEs, PCDDs, PCDFs, and coplanar PCBs in edible fish from California coastal waters. *Chemosphere.* 64(2):276-286.

Buckman, AH; Brown, SB; Hoekstra, PF; Solomon, KR; Fisk, AT. 2004. Toxicokinetics of three polychlorinated biphenyl technical mixtures in rainbow trout (Oncorhynchus mykiss). *Environmental Toxicology and Chemistry* 23 (7): 1725-1736.

Buckman, AH; Wong, CS; Chow, EA; Brown, SB; Solomon, KR; Fisk, AT. 2006. Biotransformation of polychlorinated biphenyls (PCBs) and bioformation of hydroxylated PCBs in fish. *Aquatic Toxicology* 78 (2): 176-185.

Buckman, AH; Brown, SB; Small, J; Muir, DCG; Parrott, J; Solomon, KR; Fisk, AT. 2007. Role of temperature and enzyme induction in the biotransformation of polychlorinated biphenyls and bioformation of hydroxylated polychlorinated biphenyls by rainbow trout (Oncorhynchus mykiss). *Environmental Science and Technology* 41 (11): 3856-3863.

Burkhard, LP; Cook, PM; Lukasewycz, MT. 2004. Biota-sediment accumulation factors for polychlorinated biphenyls, dibenzo-p-dioxins, and dibenzofurans in southern Lake Michigan lake trout (Salvelinus namaycush). *Environmental Science and Technology* 38 (20): 5297-5305.

Campbell, LM; Muir, DCG; Whittle, DM; Backus, S; Norstrom, RJ; Fisk, AT. 2003. Hydroxylated PCBs and other chlorinated phenolic compounds in lake trout (Salvelinus namaycush) blood plasma from the Great Lakes Region. *Environmental Science and Technology* 37 (9): 1720-1725.

Connor, K.T., Eversen, M., Su, S.H. and Finley, B.L. 2005. Quantitation of polychlorinated biphenyls in fish for human cancer risk assessment: a comparative case study. *Environmental Toxicology and Chemistry*. 24(1):17-24.

Corsolini, S., Ademollo, N., Romeo, T., Greco, S. and Focardi, S. 2005. Persistent organic pollutants in edible fish: a human and environmental health problem. *Microchemical Journal*. 79(1-2):115-123.

Domingo, JL; Bocio, A. 2007. Levels of PCDD/PCDFs and PCBs in edible marine species and human intake: A literature review. *Environment International* 33 (3): 397-405.

Dorea, J. G. 2008. Persistent, bioaccumulative and toxic substances in fish: Human health considerations. *Science of the Total Environment* 400 (1-3):93-114.

Elia, AC; Dorr, AJM; Galarini, R. 2007. Comparison of organochlorine pesticides, PCBs, and heavy metal contamination and of detoxifying response in tissues of Ameiurus melas from corbara, alviano, and trasimeno lakes, italy. *Bulletin of Environmental Contamination and Toxicology* 78 (6): 463-468.

Fairey, R., Taberski, K., Lamerdin, S., Johnson, E., Clark, R.P., Downing, J.W., Newman, J. and Petreas M. 1997. Organochlorines and other envnrionmental contaminants in muscle tissues of sportfish collected from San Francisco Bay. *Marine Pollution Bulletin*. 34(12):1058-1071.

Fernandes, A., P. Dicks, D. Mortimer, M. Gem, F. Smith, M. D. Ield, S. White, and M. Rose. 2008. Brominated and chlorinated dioxins, PCBs and brominated flame retardants in Scottish shellfish: Methodology, occurrence and human dietary exposure. *Molecular Nutrition & Food Research* 52 (2):238-249.

Ferrante, MC; Cirillo, T; Naso, B; Clausi, MT; Lucisano, A; Cocchieri, RA. 2007. Polychlorinated biphenyls and organochlorine pesticides in seafood from the Gulf of Naples (Italy). *Journal of Food Protection* 70 (3): 706-715.

Gomara, B; Bordajandi, LR; Fernandez, MA; Herrero, L; Abad, E; Abalos, M; Rivera, J; Gonzalez, MJ. 2005. Levels and trends of polychlorinated dibenzo-p-dioxins/furans (PCDD/Fs) and dioxin-like polychlorinated biphenyls (PCBs) in Spanish commercial fish and shellfish products, 1995-2003. *Journal of Agricultural and Food Chemistry* 53 (21): 8406-8413.

Greenfield, B.K., Davis, J.A., Fairey, R., Roberts, C., Crane, D. and Ichikawa, G. 2005. Seasonal, interannual, and long-term variation in sport fish contamination, San Francisco Bay. *Science of Total Environment.* 336(1-3):25-43.

Leondiadis, L., D. Costopoulou, I. Vassiliadou, and A. Papadopoulos. 2008. Monitoring of dioxins and dioxin-like PCBs in food, feed, and biological samples in Greece. *Fate of Persistent Organic Pollutants in the Environment*: 83-98.

Li, H., Drouillard, K.G., Bennet, E., Haffner, G.D. and Letcher, R.J. 2003. Plasma-associated halogenated phenolic contaminants in benthic and pelagic fish species from the Detroit River. *Environ. Sci. Technol.* 37(5):832-839.

Li, XM; Gan, YP; Yang, XP; Zhou, J; Dai, JY; Xu, MQ. 2008. Human health risk of organochlorine pesticides (OCPs) and polychlorinated biphenyls (PCBs) in edible fish from Huairou Reservoir and Gaobeidian Lake in Beijing, China. *Food Chemistry* 109 (2): 348-354.

Mazet, A; Keck, G; Berny, P. 2005. Concentrations of PCBs, organochlorine pesticides and heavy metals (lead, cadmium, and copper) in fish from the Drome river: Potential effects on otters (Lutra lutra). *Chemosphere* 61 (6): 810-816.

Parnell, PE; Groce, AK; Stebbins, TD; Dayton, PK. 2008. Discriminating sources of PCB contamination in fish on the coastal shelf off San Diego, California (USA). *Marine Pollution Bulletin* 56 (12): 1992-2002.

Perugini, M., Cavalier, M., Giammarino, A., Mazzone, P., Olivieri, V. and Amorena, M. 2004. Levels of polychlorinated biphenyls and organochlorine pesticides in some edible marine organisms from the Central Adriatic Sea. *Chemosphere*. 57(5):391-400.

Perugini, M; Giammarino, A; Olivieri, V; Di Nardo, W; Amorena, M. 2006. Assessment of edible marine species in the Adriatic Sea for contamination from polychlorinated biphenyls and organochlorine insecticides. *Journal of Food Protection* 69 (5): 1144-1149.

Pinto, B., S. L. Garritano, R. Cristofani, G. Ortaggi, A. Giuliano, R. Amodio-Cocchieri, T. Cirillo, M. De Giusti, A. Boccia, and D. Reali. 2008. Monitoring of polychlorinated biphenyl contamination and estrogenic activity in water, commercial feed and farmed seafood. *Environmental Monitoring and Assessment* 144 (1-3):445-453.

Rawn, D. F. K., K. Breakell, V. Verigin, H. Nicolidakis, D. Sit, and M. Feeley. 2009. Persistent Organic Pollutants in Fish Oil Supplements on the Canadian Market: Polychlorinated Biphenyls and Organochlorine Insecticides. *Journal of Food Science* 74 (1):T14-T19.

Roosens, L., A. C. Dirtu, G. Goemans, C. Belpaire, A. Gheorghe, H. Neels, R. Blust, and A. Covaci. 2008. Brominated flame retardants and polychlorinated biphenyls in fish from the river Scheldt, Belgium. *Environment International* 34 (7):976-983.

Sagratini, G; Buccioni, M; Ciccarelli, C; Conti, P; Cristalli, G; Giardina, D; Lambertucci, C; Marucci, G; Volpini, R; Vittori, S. 2008. Levels of polychlorinated biphenyls in fish and shellfish from the Adriatic Sea. *Food Additives and Contaminants Part B-Surveillance* 1 (1): 69-77.

Salama, A.A., Mohamed, M.A.M., Duval, B., Potter, T.L. and Levin, R.E. 1998. Polychlorinated biphenyl concentration in raw and cooked North Atlantic Bluefish (*Pomatomus saltatrix)* fillets. *J. Agric. Food Chem.* 46(4):1359-1362.

Simmonds, M.P., Johnston, P.A., French, M.C., Reeve, R. and Hutchinson, J.D. 1994. Organochlorines and mercury in pilot whale blubber consumed by Faroe islanders. *The Science of the Total Environment*. 149:97-111.

Stahl, L. L., B. D. Snyder, A. R. Olsen, and J. L. Pitt. 2009. Contaminants in fish tissue from US lakes and reservoirs: a national probabilistic study. *Environmental Monitoring and Assessment* 150 (1-4):3-19.

Storelli, M.M. and Marcotrigiano, G.O. 2003. Levels and congener pattern of polychlorinated biphenyls in the blubber of the Mediterranean bottlenose dolphins *Tursiops truncates*. *Environmental International*. 28(7):559-565.

Storelli, M.M, Perrone, V.G. and Marcotrigiano, G.O. 2007. Organochlorine contamination (PCBs and DDTs) in deep-sea fish from the Mediterranean Sea. *Marine Pollution Bulletin*. 54(12):1968-1971.

Storelli MM, Barone G, Giacominelli-Stuffler R, Marcotrigianoa GO. 2008. Levels and profiles of DDTs and PCBs in a gadiform fish (Phycis blennoides) from Mediterranean Sea. *Marine Pollution Bulletin* 56(7):1367-1370.

Storelli, M.M., Casalino, E., Barone, G. and Marcotrigiano, G.O. 2008. Persistent organic pollutants (PCBs and DDTs) in small size specimens of bluefin tuna (*Thunnus thynnus*) from the Mediterranean Sea (Ionian Sea). *Environmental International*. 34(4):509-513.

Valters, K; Li, HX; Alaee, M; D'Sa, I; Marsh, G; Bergman, A; Letcher, RJ. 2005. Polybrominated diphenyl ethers and hydroxylated and methoxylated brominated and chlorinated analogues in the plasma of fish from the Detroit River. *Environmental Science and Technology* 39 (15): 5612-5619.

van Leeuwen, S. P. J., M. J. M. van Velzen, C. P. Swart, I. van der Veen, W. A. Traag, and J. de Boer. 2009. Halogenated Contaminants in Farmed Salmon, Trout, Tilapia, Pangasius, and Shrimp. *Environmental Science & Technology* 43 (11):4009-4015.

Wang, W., S. Batterman, S. Chernyak, and J. Nriagu. 2008. Concentrations and risks of organic and metal contaminants in Eurasian caviar. *Ecotoxicology and Environmental Safety* 71 (1):138-148.

Yang, FX; Xu, Y. 2005. Hydroxylated metabolites of polychlorinated biphenyls and their endocrine disrupting mechanism. *Progress in Chemistry* 17 (4): 740-748.

Zuccato, E., P. Grassi, E. Davoli, L. Valdicelli, D. Wood, G. Reitano, and R. Fanelli. 2008. PCB concentrations in some foods from four European countries. *Food and Chemical Toxicology* 46 (3):1062-1067.

Acknowledgments:

We thank project collaborators, including Ken Drouillard and Doug Haffner (University of Windsor). A special thanks to Kory Groetsch (Michigan Department of Public Health) and Dale Honeyfield (Northern Appalachian Research Laboratory-USGS) for providing several citations. This project would not be possible without the contribution of the Canadian and United States stakeholder groups. Funding for this project was provided by Michigan Sea Grant. Thanks to the summer internship program, Partners for Excellent supported through NOAA/Great Lakes Environmental Research Laboratory for funding Diane Wang.

APPENDIX B: Project Fact Sheet

Detroit River Fish Consumption Guides: Navigating the Issues

Workshops negotiating Fish Consumption Guides on the Detroit River Area of Concern

Detroit River Fish Consumption Advisories:

Are developed both by Ontario and Michigan to advise consumption limits to sport fish anglers. Are beneficial use impairments that impact human health and affect economic revenue. Restrict general population and sensitive sub-groups separately. Refer to multiple species at different size levels. Advise based on fish tissue sampling and generalized body weights and meal sizes. Use varying "trigger-levels" set by multiple agencies. Refer to a variety of different chemicals from PCBs, to dioxin and mercury

Background to a Complex Issue

The basic mechanism for PCB body burdens of fish species utilized by humans is understood to be bioaccumulation from the food the fish eat, what is not clearly understood is the relative role of the food web in creating these burdens. Another important consideration in identifying the causes of consumption advisories in the Detroit River is the relative role of sediment contaminant (i.e., legacy contaminants and hot spots) compared to water concentrations. Deciphering between these two contaminant sources is further compounded by the mobility of the sport fish populations most of concern. Currently no standard protocol exists across international borders that captures the complexities for fish sampling, collection, analysis, data processing and risk communication. This suggests that multiple aspects of sampling procedures are necessary in compiling an advisory that is a risk-based approach to trigger-levels that examines elevated fish body burdens.

Why Fish Consumption Advisories in 2007?

Many uncertainties remain regarding the primary drivers of these advisories, with key uncertainties including the relative contribution of sediment hot spots, the role of point versus non-point contaminant sources, and the appropriateness of tissue trigger-levels in identifying threshold action levels for consumption advisories. Despite the critical importance of these advisories, little progress has been made in developing effective management strategies.

USING AN INTEGRATED ASSESSMENT MODEL

Brings together devoted parties together to make informed decisions
Closes the gap between scientific information and policy governing the Detroit River
Overcomes international, state, and municipal and other institutional barriers
Strengthens stakeholder communication and collaboration
Identifies common goals and helps to achieve desired outcomes

CONTACT INFORMATION AND RELEVANT INFORMATION CAN BE FOUND AT: http://ciler.snre.umich.edu/fca/

Project Goals and Action Plan

1. Document the status and trends of environmental, social, and economic conditions related to fish consumption advisories in the Detroit River.
2. Describe the environmental, social, and economic causes and consequences of the fish consumption advisories
3. Provide forecasts of conditions under various policy options andtechnical guidance for implementing each option
4. Provide an assessment of the levels of certainty associated with the information provided in each of the steps

Potential stakeholders

This is a short list of just a few of the invites to the workshop.

Canada:

Health Canada
Ontario Ministry of the Environment
Department of Fisheries and Oceans
Environment Canada
Detroit River Canadian Cleanup Committee
Essex Region Conservation Authority
City of Windsor

United States:

US EPA
National Wildlife Federation
Detroiters Working for Environmental Justice
Michigan Dept. of Environmental Quality
Michigan Dept. of Community Health
Detroit Water and Sewage Department
Friends of the Detroit River
City of Detroit

INVESTIGATORS:

Donna Kashian
Larissa Sano
Ann Krause
Ken Drouillard
Doug Haffner
Jonathan Bulkley
Roseanne Ellison
Branda Nowell

Graduate Students:

Victoria Kalkirtz
Michelle Martinez
Ivan Jezdic
Alexandra Teague
Justin Selden

Workshops

There will be a total of four workshops. The goal of the workshops are to utilize information on the causes and consequences of consumption advisories for providing technical guidance in implementing policy and management options.

Workshop 1:
November 13, 2007
Belle Isle Nature Center
Detroit, Michigan

Introduce stakeholders and bring forward information regarding fish contamination and corresponding advisories, including: the roles and relationships of stakeholders, scientific datasets, and historical documentation of contaminants.

Workshop 2:
TBA
Work to summarize and incorporate multiple sources and types of information. Compile multiple datasets, and summarize status and trends of contaminant sources and consequences for fish and water quality.

Workshop 3:
TBA
Receive information regarding trends via explanatory analysis and model simulation. Collaboratively identify key uncertainties with human and non - human biological health factors leading to fish consumption advisories.

Workshop 4:
TBA
Develop technical guidance with stakeholders to help guide effective management initiatives. Incorporate new information into management and policy suggestions for the future.

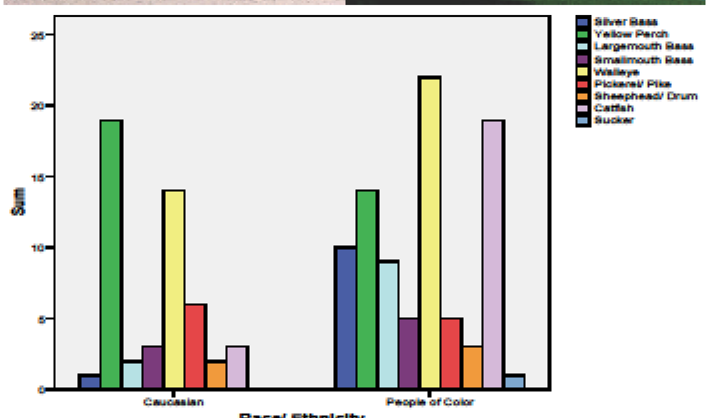
Contact:

Donna Kashian
Phone: (734) 741-2291
Fax: (734) 7412055
E-mail: dkashian@wayne.edu

APPENDIX C: Environmental Justice Fact Sheet

EJ and Fish Consumption on the Detroit River Area of Concern

We surveyed anglers on the Detroit River from June–September, 2008 to understand who is fishing on the Detroit River Area of Concern, who of them is consuming fish, and attitudes, knowledge and beliefs about fish contamination and fish contaminant advisories. Interviews took place in public access areas on the Michigan and Ontario shores. A summary of our findings are provided here for the purpose of developing a targeted fish consumption advisory for Detroit River fish consumers.



Major findings on fishing behavior and consumption by race and income

- People of Color in the United States report taking home fish at a significantly higher rate than their Caucasian and Canadian counterparts
- Even when controlling for income, People of Color are fishing more often, and low-income People of Color represent the greatest proportion of take home.
- People of Color report taking home a larger variety of species more often than Caucasians

Table 1: Demographics of those that report taking fish home

Demographic	Catch & Release (%)	Take home (%)
Race/Ethnicity		
Caucasian	53.3	46.7
People of Color	34.4	65.6
Country		
Canada	55.6	44.4
USA	35.6	64.4
Income		
$0-24,999	46.2	53.8
$25,000-49,999	42.4	57.6
$50,000-74,999	38.5	61.5
$75,000-100,000+	50	50
Gender		
Male	44.6	55.4
Female	31.3	68.8
Education		
High school & less	45.5	54.5
Higher education	40	60
Location		
Detroit	28.6	71.4
Downriver	40	60
Age		
18 to 40	39.4	60.6
41 to 65	44.1	55.9
Greater than 66	16.7	83.3

Table 2: Race/Ethnicity and Income intersections and fishing behavior

Race and Income Intersection	Fish > once / week (%)	Take Home (%)
Low Income Caucasian	68.4	35
High Income Caucasian	57.9	55
Low Income People of Color	81.5	73.1
High Income People of Color	81.5	56

Environmental Justice and Fish Consumption Advisories on the Detroit River Area of Concern

By:

Victoria Kalkirtz
University of Michigan

Michelle Martinez
University of Michigan

Alexandria Teague
University of Michigan

A practicum submitted
in partial fulfillment of the requirements
for the degree of
Masters of Science

University of Michigan
School of Natural Resources and Environment
May 2008

Faculty Advisors:
Professor Bunyan Bryant
Professor Elaine Hockman

TABLE OF CONTENTS

LIST OF ACRONYMS

ACCESS: Arab Community Center for Economic and Social Services
AOCs: Great Lakes' Area of Concerns
CILER: The Cooperative Institute for Limnology and Ecosystems Research
CSOs: combined sewer overflows
DWEJ: Detroiters Working for Environmental Justice
EPA: Environmental Protection Agency
PCBs: Polychlorinated biphenyls
MDCH: Michigan Department of Community Health
MDEQ: Michigan Department of Environmental Quality
MDNR: Michigan Department of Natural Resources
RAP: Remedial Action Plan
SDEV: Southwest Detroit Environmental Vision
SSOs: sanitary sewer overflows
USDA: United States Department of Agriculture
USFWS: United States Fish and Wildlife Service
WIC: Women, Infant and Children program

ABSTRACT

The Detroit River serves as a source of recreation, food, transportation and is an international demarcation. Decades of industrial and municipal pollution have threatened this valuable resource, particularly for those that are dependent on it for a food source. As Detroit, MI and Windsor, Ontario jointly govern this waterway, both communities were examined as a part of this study. The demographics of these communities are varied, with those living in Detroit predominantly African American. We sought to determine if fish consumption advisories are indeed an environmental justice issue; whether the most vulnerable populations receive and utilize this information; if contaminated fish consumption contributes to food insecurity; and how public information provided by institutions influences anglers. To accomplish this, we conducted creel surveys of anglers on the Canadian and US sides of the Detroit River to look at comparative aspects of jurisdictional boundaries affecting the attitudes, knowledge and beliefs of risks of fish consumption and contamination. Our results and conclusions reflect and highlight the environmental injustice surrounding fish consumption and the status of fish advisories.

ACKNOWLEDGEMENTS

We would like to thank our advisors Dr. Bunyan Bryant and Dr. Elaine Hockman for their guidance, patience, and endurance. We would like to thank our client and the Principal Investigators of the Integrated Assessment, Dr. Donna Kashian and Dr. Larissa Sano. We also would like to thank Dr. Michaela Zint and Dr. Jonathan Bulkley for their time and effort in guiding our study, and Dean David Allan, Darlene Ray-Johnson, and Sondra Auerbach for their counsel. Lastly, we would like to thank Joe "the fish guy" Nohner, Mike Yun, and our friends and families.

This research was supported by the Environmental Justice Initiative, Office of Academic Programs Office Staff, The Dean's Office Staff, the School of Natural Resources & Environment, Rackham Graduate School, and Cooperative Institute for Limnology and Ecosystem Research.

CHAPTER 1: INTRODUCTION

CHAPTER 1: INTRODUCTION

Fish consumption advisories are created by governments to inform anglers and fish consumers about potential health concerns regarding contaminants in fish. They are not regulations but rather guidelines with the objective of helping those who intend to consume fish make informed decisions regarding the consumption of fish. State issued consumption advisories are problematic for those that do not receive the information or distrust its source. Those that are most affected by fish contaminants, sensitive populations of fish consumers such as women of child-bearing age and children, often do not or cannot receive this information. Issues of environmental justice further exacerbate information flows and in respect to sources of contamination, particularly in urban waters. Many subsistence anglers fish in contaminated urban waters such as the Detroit River.

The Detroit River is a connecting channel between Lake St. Clair and Lake Erie that spans 32-miles, 11 municipalities, two counties, one state, one province, and two countries. It is home to numerous industries and a variety of ethnic neighborhoods and multiple social groups which aid in its conservation as a recreation point and a historical site. As a part of the Great Lakes ecosystem, it is under the jurisdiction of several agencies at the local, state, federal, and international levels, and under the control of multiple policy initiatives. In 1986, Canada and the United States signed the Great Lakes Water Quality Agreement, designating the Detroit River an Area of Concern. This created yet another layer of policy in which international cooperation is a necessary component to delist the Detroit River from the Areas of Concern. Beyond this complex web of governmental institutions and policy, there is a vibrant community of anglers. Anglers arrive to fish at the waters of the Detroit River because of its proximity to their homes, the pleasure it brings them, and the fish which inhabit it. In many cases fish in the river are used as a food resource. Subsistence anglers on the Detroit River represent a subset of the Great Lakes angler population who are at risk of contamination due to the presence of potentially harmful contaminants.

Fish contamination in the Detroit River is a result of a long history of heavy industrial development, non-point source pollution, and storm-water runoff. While aquatic ecosystems in an industrialized Michigan have seen a peak of contaminants, the problems associated with polluted sediment still persist. Contamination problems in the Detroit River are further exacerbated by emerging chemical inputs like pharmaceutical bi-products, everyday household detergents from stormwater runoff, and combined sewer overflows. As our waterways are being inundated by toxins, further degradation may entail potentially serious health risks to Canadian and American fish consumers. There is a particular threat to those anglers that rely on fish for a healthy and well-balanced diet.

The purpose of this study was to identify angler groups on the Detroit River and assess which among them rely on the Detroit River as a food extractive resource. We sought to engage in a dialogue with anglers on their perception, knowledge, and attitudes towards fishing and fish consumption on the Detroit River Area of Concern. Based on these issues, we developed the hypothesis that there is an environmental justice issue regarding fish consumption on the Detroit River Area of Concern. We believe that fish consumption is an environmental justice issue that stems from inadequate risk communication through fish consumption advisories which compound issues of food security. We feel that people of color and those with low-incomes are differentially impacted by the risks of contaminated fish because fish consumption advisories fail to take into consideration cultural, social and economic needs. Because of cultural, economic, and food security reasons, they are forced out of habit to fish the Detroit River, contaminated by point and non-point source pollution. This becomes an environmental injustice issue when the State fails to protect its citizens by relying on ineffective fish advisories rather than reclaim the river to a more acceptable and healthy resource for multiple use.

Three questions guided our research:

1. Is there an environmental justice issue regarding fish consumption on the Detroit River exist?
2. Is the current fish consumption advisory information effective for all populations?
3. How do public information resources report or frame Detroit River governmental institutions?
4. How does food insecurity compound these issues of environmental justice and fish consumption advisories on the Detroit River?

Using this framework and our research questions to guide our practicum, we interviewed anglers on the Detroit River and investigated the media's reporting of institutional stakeholders.

We interviewed anglers from June through September of 2008 on the Michigan and Canadian sides of the Detroit River Area of Concern to assess the knowledge, attitudes, and beliefs about contamination and fish consumption. Closed and open-ended questions were utilized to investigate the behavior of anglers, perception of water quality and fish quality, and anglers' knowledge associated with state-issued fish consumption advisories. The second part of our study included an external survey of public media sources. We searched websites, newspapers, and online sources to gauge the strength of association between those organizations that govern the Detroit River and terms associated with contamination, fishing, and environmental justice. This two-pronged approach allowed us not only to understand anglers' perspectives, but also the messages they are receiving outside of the advisory itself.

In partnership with The Cooperative Institute for Limnology and Ecosystems

Research (CILER) and the University of Michigan's Environmental Justice Initiative, this practicum contributed to the integrated assessment, "What are the Causes, Consequences and Correctives of Fish Consumption Advisories on the Detroit River Area of Concern?" This assessment includes major governmental, private, and non-governmental institutions on both the Canadian and U.S. side of the river working to understand fish consumption advisories. The surveys conducted with anglers aided in assessing the effectiveness of fish consumption advisories as a mechanism to address risk for those most affected by the risk of contamination. Through speaking with anglers directly, we hope to offer correctives that incorporate environmental justice principles of equity, increased food security, and appropriate policy suggestions to make fishing a safe and healthy endeavor for all who catch and consume fish from the Detroit River.

Why Environmental Justice Now?

Certain aspects of Michigan's environmental situation as pertains to class and race are known. Low-income communities and people of color suffer a disproportionate burden of toxic waste in their neighborhoods.[1] Low-income African-Americans have less access to healthy food resources than other ethnicities.[2] This is particularly true in Detroit where there is a severe lack of access to grocery stores that carry fresh foods. Throughout Michigan, African-American and Latino populations have been disproportionately burdened by a lack of health care coverage, obesity, and diabetes.[3] Mohai and Bryant find that race as a category of environmental quality assessment is especially valid in Detroit, not because

[1]Bryant, B. & Hockman, E. (1994). *Hazardous Waste and Spatial Relations According to Race and Income in the State of Michigan*. (R) in progress.
[2] Zenk, S., Schultz, A., Israel, B., James, S., Bao, S., & Mark Wilson. (2006). Fruit and vegetable access differs by community racial composition and socioeconomic position in Detroit, Michigan. *Ethnicity and Disease, 16*, 275-280.
[3] Center for Disease Control's National Center for Chronic Disease Prevention and Health Promotion (2005). Behavioral risk factor surveillance system. Retrieved February 28, 2008 from http://apps.nccd.cdc.gov/brfss/

different people of color do not value the environment, but rather that the nature of that valuation relies on more immediate concerns of the pollution of air, water, and land derived from cultural differences and environmental deprivation.[4] This is separate and qualitatively different than conservation efforts in the predominantly white environmental movement. For this reason, it is crucial to explore how urban inhabitants understand and interact with their physical and natural resources.

Despite recent findings that little has changed as far as environmental conditions for people of color over the past 20 years, significant political momentum has gained in Detroit.[5] Over the last 20 years, Detroit has seen different non-profit social justice groups focus their attention on environmental issues. Detroiters Working for Environmental Justice (DWEJ) has been organizing communities in Detroit since 1994 on issues that range from lead in homes to youth education and metropolitan air quality.[6] The Arab Community Center for Economic and Social Services (ACCESS) has provided research and advocacy in community public health since 1988.[7] Southwest Detroit Environmental Vision (SDEV) has worked to build a business and community health connection through environmental programs since 1991.[8] In turn, larger national and state level non-profit environmental groups have turned towards urban environmentalism, rather than solely focusing on conservation.[9] For example, The Sierra Club's Environmental Justice national chapter is

---

[4] Mohai, Paul & Bunyan Bryant (1998). "Is There a 'Race' Effect on Concern for Environmental Quality?" *Public Opinion Quarterly.* Vol. 62.
[5] Bullard, R., Mohai, P., Saha, R., & Wright, B. (2007). "Toxic wastes and race at twenty 1987-2007: Grassroots Struggles to Dismantle Environmental Racism in the United States." *United Church of Christ Justice and Witness Ministries.* Cleveland, OH.
[6] Detroiters Working for Environmental Justice. Retrieved March 1, 2008 from http://www.dwej.org/.
[7] ACCESS. Retrieved March 4, 2008 from http://www.accesscommunity.org/site/PageServer?pagename=Community_Health_and_Research
[8] Southwest Environemental Vi
sion. Retrieved March 4, 2008 from http://www.sdevonline.org/
[9] See Sierra Club, http://www.sierraclub.org/environmental_justice/ National Wildlife Federation internship opportunities explicitly list environmental justice, and have created partnerships with DWEJ towards this goal. Also East Michigan Environmental Action Council has worked with Michigan Welfare Rights of water shut-offs in Highland Park, http://www.emeac.org/

located in Detroit, and has partnered with DWEJ and others. Other organizations like Michigan Environmental Council or East Michigan Environmental Action Council have also begun to initiate projects and dialogues in Detroit. The very meaning of environmentalism has begun to change, and is doing so at a rapid rate in Detroit.

Environmental Justice, the idea that environmental externalities are disproportionately distributed onto communities of color and those living in poverty, is the frame for discussing fish consumption and fish consumption advisories. The study focuses on aspects of race and income on the Detroit River because of the historical role race has played in the way resources have been distributed around the river. The study's aim is to determine exactly who the subsistence anglers are on the Detroit River, elucidate their attitudes, knowledge, and beliefs regarding contamination, and investigate how or why subsistence anglers continue to fish regardless of governmental risk communication efforts.

We also sought to examine the role of community food security, or access to healthy foods at the neighborhood level that are safe, culturally acceptable, nutritious, of high quality, and affordable. In trying to contextualize the traditions of fishing, we also looked at the cultural value of fishing for anglers. For these reasons, the Detroit River is understood as a neighborhood where information is exchanged, a food resource is yielded, and cultural activities are practiced. On the Detroit River and the Great Lakes, fish consumption advisories are distributed, assessed and incorporated into knowledge, attitudes and beliefs. What role does fishing play in anglers' lives, and how do fish consumption advisories limit or change those attitudes, knowledge, or beliefs?

From anglers' vantage point, we also investigate how those institutions that govern the Detroit River in Michigan approach the disproportionate burden of toxins on people of color and low-income communities. Specifically, we look at how successes and failures of fish consumption advisories as a tool to protect marginalized populations are shaped by those institutions. The question posed to these institutions is: How has race and/or income been utilized as metrics in assessing at-risk populations and understanding the way in which risk communication is effective for Detroit River anglers? We ask this question with the ultimate goal of understanding at-risk, fish consuming populations on the Detroit River, and the ways in which we can approach fish consumption advisories.

Detroit organically became the focus of this study because of the body of literature associated with the historical frame of race and urban Detroit. However, our study also examines the Canadian side of the Detroit River to compare and contrast a separate set of political tools used for risk communication, and public policies that vastly differ from Michigan and U.S. federal policies. This is no way infers that there are no environmental justice issues on the Canadian side of the Detroit River, but redirects the focus of institutional approaches to environmental justice issues to Michigan.

CHAPTER 2: STUDY AREA

CHAPTER 2: STUDY AREA

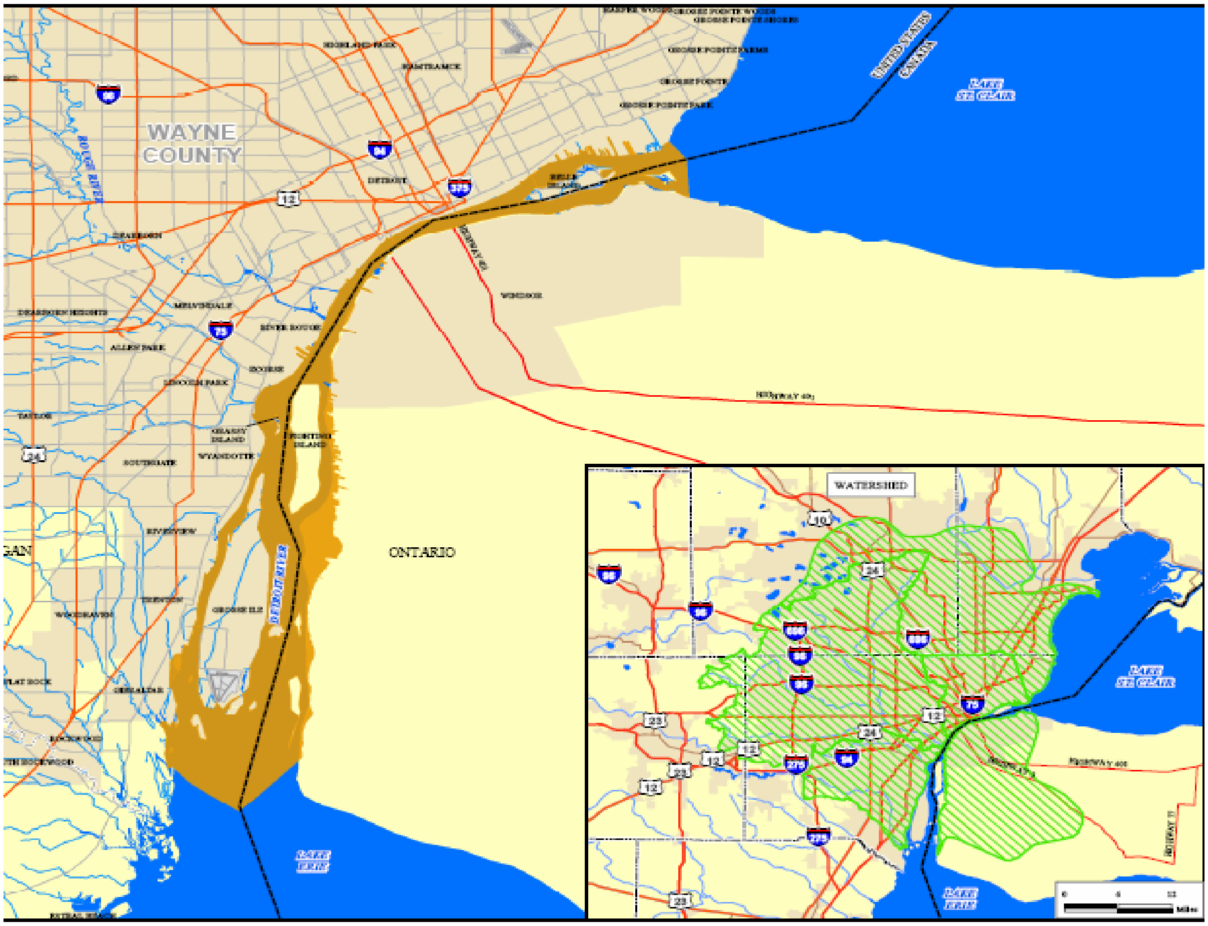


Figure 2.1 Detroit River Area of Concern
Source: EPA: Detroit River Area of Concern http://www.epa.gov/glnpo/aoc/detroit.html

The Detroit River Area of Concern

In 1987 the United States and Canada's Great Lakes Water Quality Agreement spearheaded efforts to recover the Great Lakes region, creating the Great Lakes' Remedial Action Plans for all 43 Area of Concerns (AOCs). AOCs are defined as "geographic areas that fail to meet the general or specific objectives of the agreement where such failure has caused or is likely to cause impairment of beneficial use of the area's ability to support aquatic life." [10] The U.S. and Canadian governments have identified 43 such areas; 26 in U.S. waters, 17 in Canadian waters, with 5 shared between the United States and Canada on

[10] EPA (2007). *Great Lakes Areas of Concern.* http://epa.gov/greatlakes/aoc/detroit.html

connecting river systems.[11] Of the 14 beneficial use impairments, those that most greatly affect the Detroit River include: restrictions on fish and wildlife consumption; tainting of fish and wildlife flavor; restrictions on drinking water consumption, or taste and odor; degradation of fish and wildlife populations; fish tumors or other deformities; degradation of aesthetics; and loss of fish and wildlife habitat.[12] According to the agreement, both countries must make efforts to improve the impaired waters so they may once again be suitably clean for beneficial use.

The Great Lakes Water Quality Agreement led to the creation of the Remedial Action Plan (RAP) with the goal to jointly assign responsibilities to recover and delist the Detroit River as an AOC. The Detroit River RAP priorities include control of combined sewer overflows (CSOs), control of sanitary sewer overflows (SSOs), point/nonpoint source pollution controls, remediation of contaminated sediments, habitat restoration, and pollution prevention. A gamut of activities, involving private and public actors, has taken place since the creation of RAPs that include, but are not limited to, efforts addressing SSOs and CSO's, biodiversity surveys, stakeholder workshops, and comprehensive remediation.[13] In May of 2004, President Bush signed Executive Order 13340 calling for a Regional Collaboration of National Significance to facilitate the Great Lakes communities—local, state, federal, Tribal, and Canadian—to convene on the protection and restoration of the Great Lakes.[14]

These efforts inspired the creation of the Detroit River International Refuge that spans from the lower Detroit Metro Area to near Toledo, Ohio. The U.S. Fish and Wildlife Services have provisioned a 15-year plan that includes multi-sector and bi-national efforts

---

[11] For more information on Great Lakes Area of Concerns see GLIN Website: http://www.greatlakes.net/envt/pollution/aoc.html

[12] EPA (2007). *Great Lakes Areas of Concern.* http://epa.gov/greatlakes/aoc/detroit.html

[13] Great Lakes Commission (2002). *An overview of the U.S. Great Lakes AOCs*. U.S. EPA Great Lakes National Program Office and the Great Lakes Commission Report, March 2002.

[14] EPA Great Lakes National Program Office (2004). *Framework for the Great Lakes Regional Collaboration*. Retrieved March 5, 2008 from http://www.epa.gov/glnpo/

for management.[15] The City of Detroit was not included in the refuge due to concerns over the city's ability to meet the stringent clean-up requirements. However, international cooperation regarding the Detroit River AOC indicates the magnitude and concern of both the ecological and human health. The study area includes two large metropolitan areas with unique characteristics on each bank of the Detroit River.

Detroit and Wayne County, Michigan

The largest metropolitan area in both the Detroit River AOC and the southeast Michigan region is Detroit/Wayne County. The most recent census figures report that Wayne County has been losing population at a rapid rate, second only to Louisiana's Orleans Parish in the wake of Hurricane Katrina. By 2006, a city of almost 2 million people in 1950 had fallen to 871,121 residents (see table 2.1).[16] There are many reasons for the decrease in population, several of which stem from the decline of southeast Michigan's main economic force, the automotive industry. The decrease in population was accelerated by "white flight" and urban sprawl. The State of Michigan's population also suffers from slow economic growth and high unemployment rates. The result has been blight and abandoned property, which have plagued the city for years as the population dwindled. The number of vacant lots in the city is double the number of lots with structures. The vacant lot numbers are estimated at 80,000 with taxable parcels with structures reaching only 40,000.[17] Currently, in the City of Detroit, 31.4 % of all people, and 27% of families, are below the poverty level, while 20.5% of Detroit's population is unemployed. With few job prospects, lack of a solid tax

[15] Hartig, John (2007). Detroit River International Wildlife Refuge. U.S. Fish and Wildlife Refuge. Retrieved March 06, 2008 from http://www.fws.gov/Midwest/DetroitRiver/
[16] United States Census Bureau. Retrieved March 07, 2008 from www.census.gov
[17] The Kirwan Institute for the Study of Race and Ethnicity (2007). Land banking in Detroit. Retrieved March 05, 2008, from http://kirwaninstitute.org/news/news_landbankdetroit.html

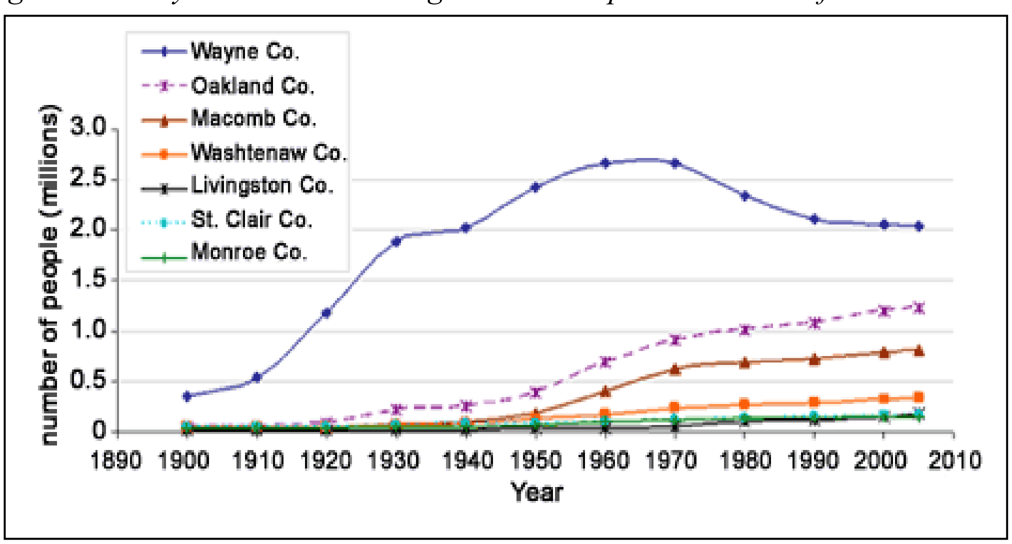
base, and poor public transportation, many find it difficult to thrive in their daily life. These figures demonstrate the dire situation with which many Detroit residents must contend.

Table 2.1 Detroit and Wayne County MI, Select Demographics

	Detroit 2000	Wayne County 2000	US Avg 2000	Detroit 2006	Wayne County 2006	US Avg 2006
Population						
Total Population	951,270	2,061,162		834,116	1,266,432	
Caucasian	12.3%	51.7%	75.1%	10.0%	51.6%	73.9%
African American	81.6%	42.2%	12.3%	83.1%	41.5%	12.4%
Housing						
Vacant Housing	10.3%	7.0%	9.0%	23%	14.8	11.6%
Med. Value of home	$63,600	$99,400	$119,600	$91,700	$139,500	$185,200
Income						
Median HH Income	$29,526	$40,776	$41,994	$28,364	$41,784	$48,451
Families Below Poverty	21.7%	12.7%	9.2%	27%	14.8%	9.8%
Individuals Below Poverty	26.1%	16.4%	12.4%	32.5%	19.6%	13.3%
Families Below Poverty – Female Householder	21.7%		26.5%	38.1%		28.6%
Unemployment – Families with children	28.6%	18..5%		36.4%	21.7%	
Unemployment Families with female householder	39.5%	35.8%		45.4%	39.2%	
Unemployment – Individuals	26.1%	16.4%	3.7%	32.5%	19.6%	6.4%

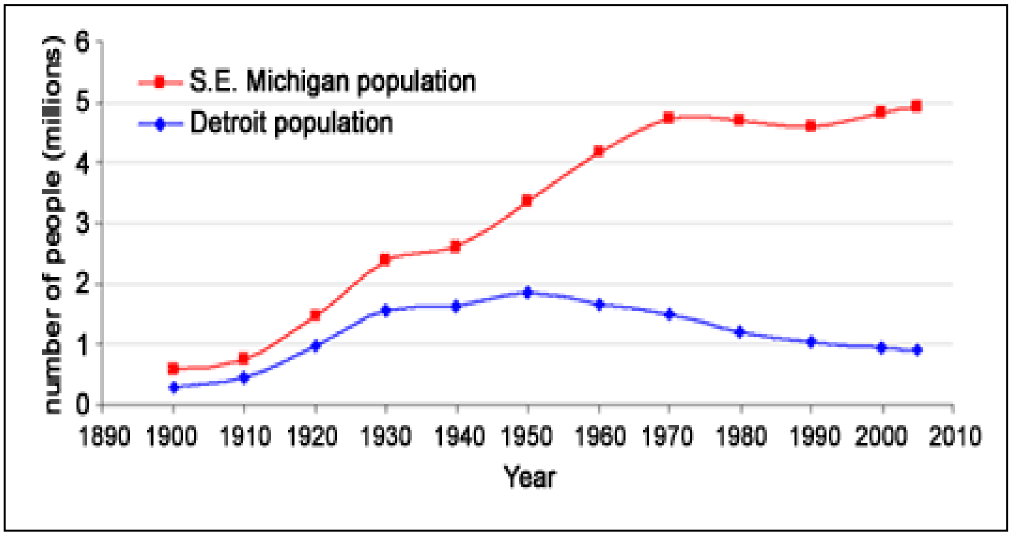
Source: U.S. Census, 2007

Figure 2.2 Wayne and Surrounding Counties Population Trends from 1890-2010



Source: EPA, http://www.epa.gov/med/grosseile_site/indicators/population.html

Figure 2.3 Detroit and SE Michigan Population Trends from 1890-2010



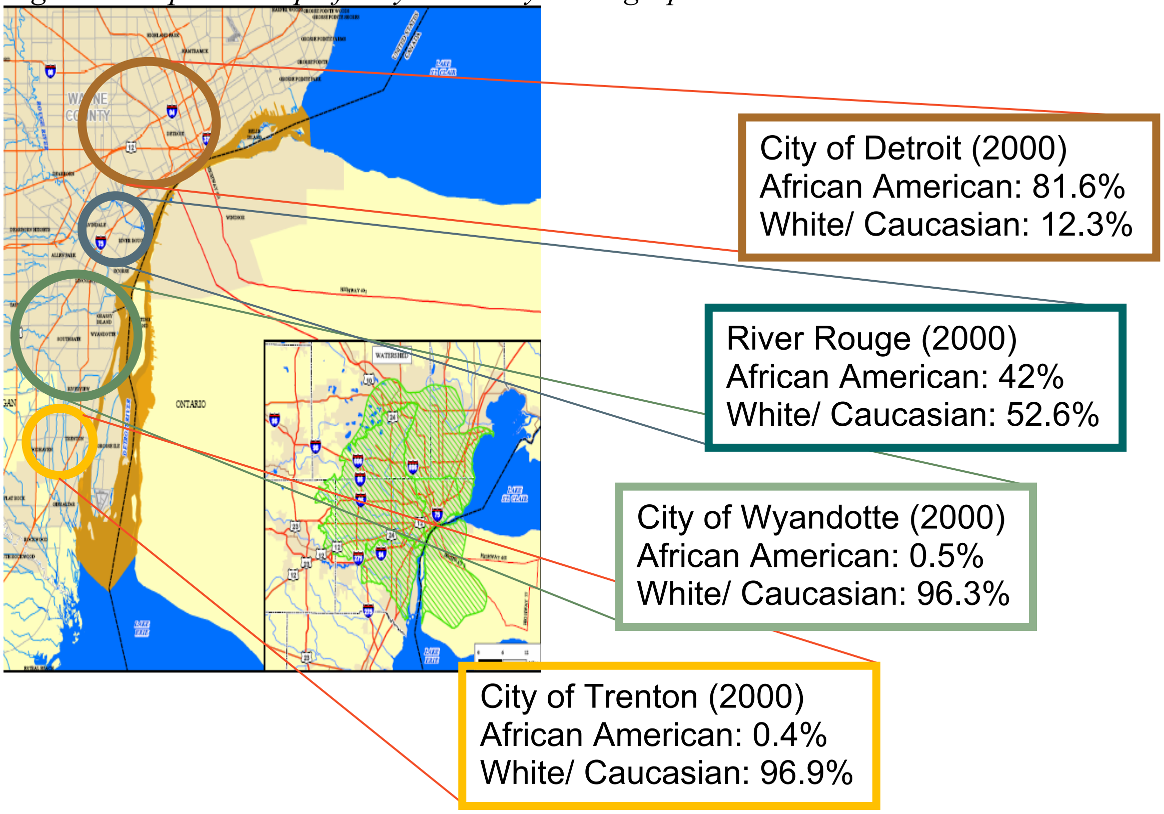
Source: EPA, http://www.epa.gov/med/grosseile_site/indicators/population.html

It is well-known that the extreme decrease in population in the second half of the twentieth century was highly racialized. Segregation indicators for the Detroit Metropolitan Area report that African Americans in the Detroit Metro area experience very high levels of segregation and isolation (see figure 2.4).[18] The extreme population segregation stems from historical and socio-structural discrimination that was found in hiring practices, housing segregation, police violence, income disparity, and access to social services and physical resources.[19]

[18] Lewis Mumford Center (2000). *Metropolitan racial and ethnic change—Census 2000.* Retrieved March 09, 2008 from http://www.albany.edu/mumford/census.

[19] Sugrue, T. (1996). *The origins of urban crisis: Race and inequality in postwar Detroit.* Princeton, NJ: Princeton University Press.

Figure 2.4 Spatial Map of Wayne County Demographics



Source: U.S. Census, 2000

This sort of extreme segregation and historical racism has had a direct effect on the distribution of resources, and indirectly, on various effects of human health.[20] Schultz et al. eloquently mapped the direct and indirect consequences of racial bias in the distribution of resources as present in Detroit throughout the twentieth century.[21] We used this model to focus on how industrial pollutants (e.g., PCBs, mercury and dioxin) have compounded environmental stressors on subsistence anglers and their food resources. Because Detroit River fish provide access to a healthy dietary supplement, contamination modifies and limits consistent access to healthy resources. Industrial pollutants, and those who control and monitor them, are therefore charged with the responsibility of communicating the risks associated with contaminated fish consumption. The inability to access the riverfront for

[20] Schultz, A. J., Williams, D., Israel, B., Lempert, L. B. (2002). "Racial and spatial relations as fundamental determinants of health in Detroit. *The Milbank Quarterly*, (*80*)4, 677-707.
[21] Ibid.

food extraction because of development or private property can also act as an environmental stressor that affect residents' diet, much like pollution. An inability to access the riverfront also carries long-lasting social consequences as there is also a social value of fishing on the riverfront. Therefore, stressors such as contamination, the state, and riverfront development, in the context of a highly segregated environment can compound risk for urban consumers of fish, threatening one form of livelihood for an already vulnerable population.

The City of Detroit has experienced a re-growth of sorts as the Downtown district has become an entertainment and sports hub with the addition of Ford Field, Comerica Park, and several casinos. For the first time in 20 years hotels are coming back to the area along with a surge of restaurants, night clubs, and upscale housing. While Detroit appears to be a livelier and interesting place to be, its residents continue to suffer an increase in poverty levels, unemployment, and vacant properties, as well as a dwindling population. Southeastern Michigan population continues to increase, while Wayne County and the City of Detroit are rapidly losing residents to the outlying areas (see table 2.3). This demographics shift further increased racial and economic segregation. The loss of population also has negative repercussions for county and city funding as the tax base shrinks. This combined with the economic situation and budgetary issues facing the State of Michigan creates a difficult political situation for Detroit and the allocation of scarce resources.

Yet these grim statistics in Detroit have not hampered efforts to clean up and increase riverfront development in Detroit. A primary component of this redevelopment capitalizes on the Detroit River and its real estate potential. In this vein, Mayor Coleman Young worked throughout the 1980s to establish public access through Chene and other parks under the leadership of Dan Krichbaum.[22] Since 2000, millions of investment dollars have poured

[22] Staff writer. (2007, Dec. 15-21). Granholm names Dan Krichbaum chief operating officer. *Arab American News.*

into the revitalization of the Detroit Riverfront. Coined the Detroit RiverWalk, these efforts have brought together old and new partnerships to transform the formerly industrial space to one used primarily for leisure, tourism, and high-end real estate.

The Detroit Riverfront Conservancy, established in 2002 by Mayor Kwame Kilpatrick, continues to renovate and create access points along the river. The Detroit Riverfront Conservancy represents comprehensive efforts from the private and public sector to raise money to make the Detroit Riverfront a viable market for real estate investment and entertainment. The Conservancy, headed by several major businesses, is charged with collaborating investments towards developing the RiverWalk. It has raised roughly $93 million to achieve its goals of long-term development of parks and green spaces, facilitating community understanding of the Conservancy's vision, and implementation of improvements and programming activities, among other things.[23] The redevelopment of the riverfront has paved the way for reinvestment and revitalization of downtown Detroit while much of the city continues to suffer from declining populations and subsequent economic issues.

Windsor and Ontario, Canada

With only the Detroit River separating the two cities, Windsor Ontario has a much different cultural, economic, and environmental outlook than Detroit. As noted in table 2.2, the average income of Canadians in the Windsor area is much higher than those of Detroit residents. Another marked difference lies in the demographics, where only 2-3% of the population identifies as "black" while in Detroit, this number is 85%. While these numbers are from 2001, they are likely not much different today. The different cultural groups and

[23] The Riverfront Conservancy. (2003-2005). Mission statement. Retrieved February 3, 2008 from http://detroitriverfront.org/index.asp?item=321&name=Mission+Statement&site=5

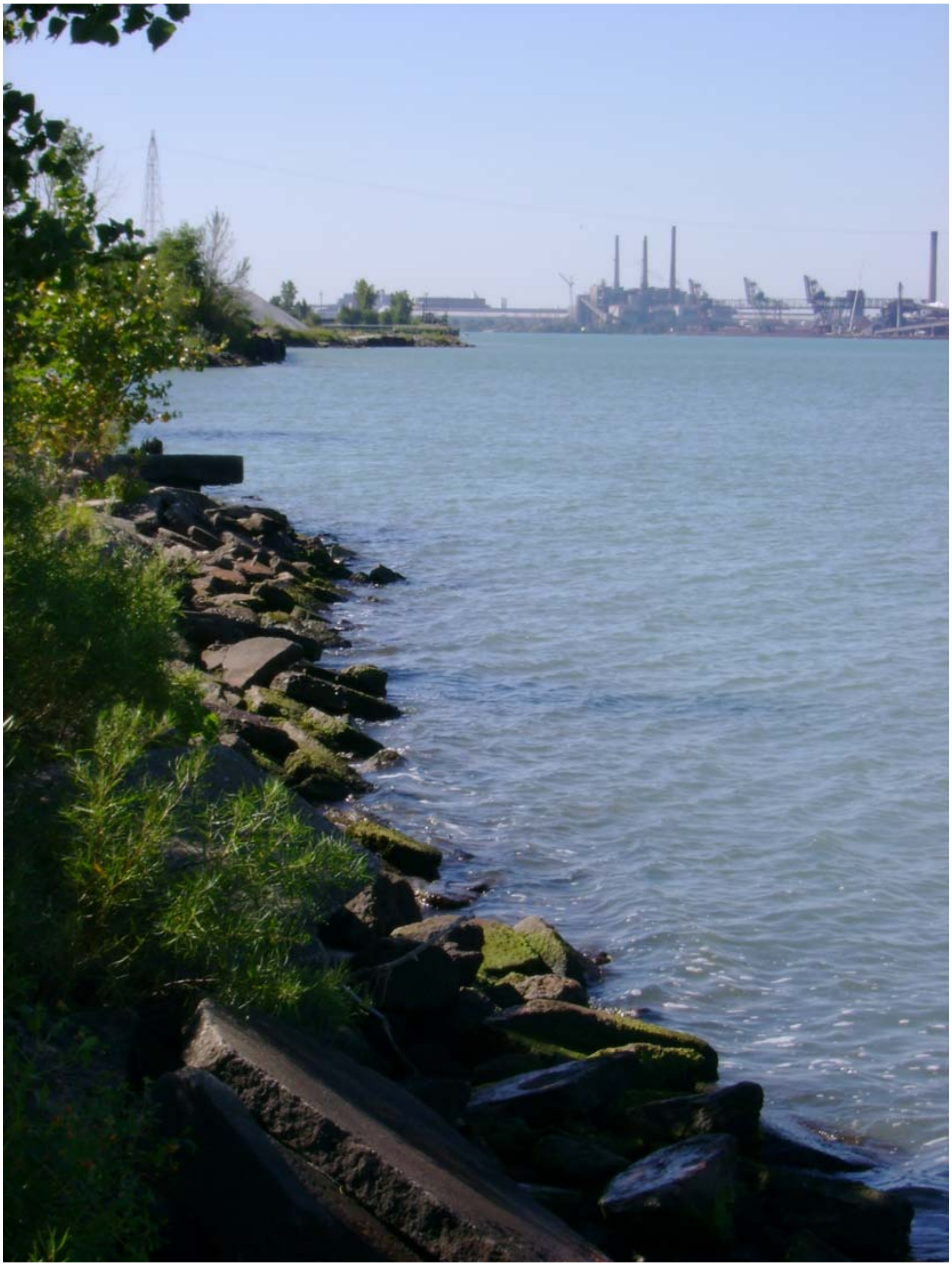
income levels and the smaller population on the Canadian side of the Detroit River indicate a different approach to issuing and distributing fish consumption advisories.

Table 2.2 2001 Canadian Census Data (Canadian Dollars)[21]

	Total Population	Chinese	S. Asian	Black	Filipino	Avg Family Income	Avg Individual Income	Low Income Families	Low Income Ind.
Amherstburg	20,339	0%	0%	1%	0%	$ 85,790.00	$ 29,987.00	6.1%	26.5%
Lasalle	25,285	1%	1%	2%	1%	$ 96,946.00	$ 38,486.00	2.9%	20%
Windsor	209,218	2%	3%	3%	1%	$ 66,490.00	$ 29,915.00	13.2%	34.9%

[21] Statistics Canada, (2001). 2001 Census. Retrieved March 30, 2008. http://www12.statcan.ca/english/census01/home/index.cfm

CHAPTER 3: BACKGROUND



CHAPTER 3: BACKGROUND

Environmental Justice

Environmental Justice refers to a social movement based on environmental, and economic equity for people of color and low-income individuals. It is an extension of the civil rights movement that focuses on health and environmental impacts that disproportionately affect people based on their income and color. Its roots began in Warren County, North Carolina when residents protested the dumping of Polychlorinated biphenyl (PCBs) in a landfill in a predominantly black township. This sparked the seminal 1987 report *Toxic Waste and Race in the United States* by the United Church of Christ. This research demonstrated that people of color and low-income individuals were more likely to live near toxic waste sites.[24] With this report, the environmental justice movement gained a certain amount of legitimacy and sparked a proliferation of research in academia. In 2007, an updated version of this report, *Toxic Waste and Race at Twenty 1987-2007*, discussed that while attention had been brought to this issue in 1987, little had changed in the present day lives of those living in the shadows of environmental disparities.[25] In the 1990s, fish consumption studies on the Detroit River have brought to light the issue of environmental injustice, however, we contend that little has changed.[26]

In January of 1990, Bunyan Bryant and Paul Mohai of the University of Michigan organized a working conference to bring scholars and activists together to work on the issue

---

[24] United Church of Christ. (1987). *Toxic wastes and race in the United States: A national report on the racial and socio-economic characteristics of communities with hazardous waste sites*. Commission for Racial Justice United Church of Christ. Cleveland, OH.

[25] Bullard, R., Mohai, P., Saha, R., & Wright, B. (2007). "Toxic wastes and race at twenty 1987-2007: Grassroots Struggles to Dismantle Environmental Racism in the United States." *United Church of Christ Justice and Witness Ministries.* Cleveland, OH.

[26] West, P., Fly, M., Larkin, F., & Marans, R. W. (1994). Minority anglers and toxic fish consumption: Evidence from a statewide survey of Michigan. In B. Bryant & P. Mohai (Eds.), *Race and the incidence of environmental hazards: A time for discourse.* Boulder, CO: Westview Press.

of environmental justice.[27] The majority of presenters at this conference were people of color. One of the conference's outcomes was a series of meetings with high-level government officials and legislators, during which they were urged to take the necessary actions to protect communities against environmental harm.[28] These officials and legislators brought the issue to President Bill Clinton and on February 11, 1994, President Clinton signed Executive Order 12898 creating "federal actions to address environmental justice in minority populations and low-income populations," further legitimizing the movement and bringing additional attention to the many research agendas that required attention.[29] One of the highlighted areas of concern was contaminated fish consumption and sensitive populations of color and low income. Michigan's Governor Jennifer Granholm signed a similar initiative on November 21, 2007. Executive Directive 2007-23 mandates that "the Department of Environmental Quality shall develop and implement a state environmental justice plan to promote environmental justice in Michigan."[30] It includes several components to measure the impact on environmental justice communities as well as suggested solutions.

Fish Advisories and Environmental Justice

Many scholars have pursued important research in the field of fish advisories, risk communication, and environmental justice. Researchers in other locations have found that fishing behavior,[31] i.e., the type and amount of fish,[32] cooking styles of local fish,[33] the

---

[27] Bryant, B., & Mohai, P. (1992). The Michigan conference: A turning point. *EPA Journal*, *18*(1).
[28] Ibid.
[29] Environmental Protection Agency (2008). Environmental justice. Retrieved February 20, 2008 from http://www.epa.gov/compliance/basics/ejbackground.html.
[30] Office of the Governor. 2007. Executive Directive 2007-23. Retrieved March 5, 2008. http://www.michigan.gov/gov/0,1607,7-168-36898-180696--,00.html
[31] Floyd, M., & Johnson, C. (2002). Coming to terms with environmental justice in outdoor recreation: A conceptual discussion with research implications. *Leisure Sciences*, *29*, 57-77.
[32] Burger, J. (2002). Consumption patterns and why people fish. *Environmental Research*. 90, pp. 125-135.

frequency of fishing,[34] have varied by race, income, age, education, and gender. The vast heterogeneity of fishing behavior further depends on geographic location, racial identity,[35] the awareness of contamination advisories,[36,37] and the knowledge of health effects caused by consuming contaminated fish.[38] In this section we provide a synthesized analysis of several empirical studies that focus specifically on fish consumption advisories and fish consumption. We find that although authors do not refer to the disproportionate burden of health risks from consumption of contaminated fish as environmental justice, race and income are major indicators in addressing fish consumption rates, and fish consumption advisory knowledge.

Authors looking at race and income as predictive factors for exposure to contaminated fish through consumption patterns and/or fish consumption advisory awareness found that there are substantial differences between racial and ethnic groups in different regions. Joanna Burger et al. reported on the Savannah River in 1999, where they found that low-income, black anglers consume more fish, more often than white anglers, thus putting them in a higher risk category. This lead the researchers to conclude that, "the use of general demographics (white, middle-class angler, between the ages of 30-40) to determine potential risk of fish consumption patterns for specific waters may seriously miss

---

[33] Burger, J., Stephens, W., Boring, C., Kuklinski, M., Gibbons, W. J., & Gochfield, M. (1999). Factors in exposure assessment: Ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River. *Risk Analysis*, *19*(3).

[34] Hunt, K., & Ditton, R. (2002). Freshwater fishing participation patterns of racial and ethnic groups in Texas. *North American Journal of Fisheries Management*, *22*, pp. 52-65.

[35] Beehler, G., McGuiness, B., & Vena, J. (2001). Polluted fish, sources of knowledge, and the perception of risk: Contextualizing African American anglers' sport fishing practices. *Human Organization*, *60*(3).

[36] Imm, P., Knobeloch, L., Anderson, H., & the Great Lakes Sport Fish Consortium (2005). Fish consumption advisory awareness in the Great Lakes Basin. *Environmental Health Perspectives*, *111*(10).

[37] Silver, E., Kaslow, J., Lee, D., Sun, L., Lynn, T. M., Weis, E. et al. (2007). Fish consumption and advisory awareness among low-income women in California's Sacramento–San Joaquin Delta. *Environmental Research*, *104*.

[38] Corburn, J. (2002). Combining community-based research and local knowledge to confront asthma and subsistence-fishing hazards in Greenpoint/Williamsburg, Brooklyn, New York. *Environmental Health Perspectives*, *110*(2).

the mark."[39] Since then, Burger has published over 35 articles on the topic, highlighting the need for targeted risk communication.

A series of studies have followed Burger's work, pointing to the different approaches to risk management, one that explicitly highlights race and ethnicity within the fish consumption issue. Beehler et al. found that African American anglers in Buffalo, New York were either unaware or tended to utilize local knowledge rather than state-based knowledge to direct fishing practices.[40] Corburn found that, not only are anglers in Brooklyn unaware of the risks of consuming contaminated fish, but also that risk management institutions were unaware of the high-risk population on the East River. [41] Hunt and Ditton found that different ethnic groups in Texas exhibited significant behavioral differences in outdoor recreation preferences including species of fish preferred and frequency of fishing. [42] Dellinger worked with Native Americans of the upper Great Lakes region finding that tribes consume a considerably larger amount of fish than the average fish consumer, and this varies with specie even amongst tribes. [43] Steenport et al. found that although a majority of anglers on the Fox River in Wisconsin practiced catch and release, many anglers were unaware of the fish consumption advisory or the risks of eating contaminated fish. Many fish consumers on the Fox River were also non-English speaking.

Other researchers have looked into the intersections of race, gender and income when considering exposure to risk of contaminated fish consumption. Bienenfeld et al. surveyed

---

[39] Burger, J., Warren, S., Boring, C., Kuklinski, M., Gibbons, W. J., & Michael Gochfield (1999). Factors in exposure assessment: Ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River. *Risk Analysis, 19*(3).

[40] Beehler, Gregory, McGuiness, Bridget, and John Vena (2001). Polluted fish, sources of knowledge, and the perception of risk: Contextualizing African American anglers' sport fishing practices." *Human Organization, 60(3).*

[41] Corburn, Jason (2002). Combining Community-based Research and Local Knowledge to Confront Asthma and Subsistence-Fishing Hazards in Greenpoint/Williamsburg, Brooklyn, New York. *Environmental Health Perspectives.* 10 (Supplement 2).

[42] Hunt, Kevin and Robert, Ditton (2002). Freshwater fishing participation patterns of racial and ethnic groups in Texas. *North American Journal of Fisheries Management,* 22(1).

[43] Dellinger, John (2004). Exposure Assessment and initial intervention regarding fish consumption of tribal members of the Upper Great Lakes Region in the United States. *Environmental Research,* 95, pp 325-340.

Women, Infant and Children (WIC) participants in East Harlem finding that 10% of women were eating non-commercial fish from contaminated waters. Those who were aware of the advisory were statistically significantly associated with consumption of such fish.[44] Similarly, researchers associated with the California Department of Health Services in the Sacramento-San Joaquin Delta, found that Hmong and Cambodian women consumed a higher proportion of sports fish on average than other ethnic groups who also varied in overall consumption rates. Generally, African-American women were found to consume the most fish overall. This study was particularly alarming given that the sample population was taken from the Women, Infant and Children (WIC) program. This study explicitly shows low-income, women of color are in an elevated risk category during child-bearing years.[45]

---

[44] Bienenfeld, LA, Golden, Anne, and Elizabeth Garland (2003). Consumption of fish from polluted waters by WIC participants in East Harlem." *Journal of Urban Health,* 80(2).

[45] Silver, Elana, Kaslow, Jessica, Lee, Diana, Lee, Sun, Tan, Lynn May, Weis, Erica, and Alyce Ujihara (2007). Fish Consumption and advisory awareness among low-income women in California's Sacramento-SanJoaquin Delta. *Environmental Research,* 103(3), pp 410-419.

Table 3.1 Studies of Fish Consumption as an Environmental Justice Issue

Studies of fish consumption as an environmental justice issue

Author	Region	Is fish consumption an environmental justice issue?		
		Race/ethnicity	Socioeconomic status	Secondary factors
Beehler, Gregory (2001)	Great Lakes, New York	yes	n/a	Motivation for fishing, knowledge, tradition
Burger, Joanna (1999)	Georgia	yes	yes	Age, education
Burger, Joanna (2001)	New Jersey	yes	yes	Age, education, frequency of consumption, and reasons for fishing
Corburn, Jason (2004)	Brooklyn, New York	yes	yes	Age, language
Dellinger, John (2004)	Upper Great Lakes	yes	n/a	Tribe
Hornbarger, Katherine et al (1994)	Detroit River	yes	yes	Cultural practices
Hunt, Kevin (2002)	Texas	yes	n/a	Gender, language
Imm et al (2005)	Great Lakes	yes	yes	Age, gender, education, state of residence
Silver, Elana (2007)	Sacramento, California	yes	yes	Age, education, pregnancy
Steenport, Dyan M. (2000)	Fox River, Wisconsin	yes	n/a	Knowledge of health risks, language
Tilden, John (1997)	Great Lakes	yes	n/a	Age, gender, education, state of residence
West et al (1992)	Michigan	yes	yes	Age, size of location, education, years of residence in MI

These studies show remarkable evidence that race and income are significant factors in analyzing the risk of consuming fish and the compounded nature of that risk. Yet several studies show that Michigan is no different in its risk communication abilities, nor different in its disproportionate burden of environmental risks to people of color. In 1992, Patrick West found that low-income Native Americans and middle-income black anglers consumed more fish, and more types of fish, than white anglers.[46] In 1997, an overall study in the Great Lakes area assessed fish consumption advisory awareness.[47] A telephone survey of over 8,000 people found that women and "non-whites" were less likely to know about fish consumption advisories than their white male counterparts.[48] Imm et al. found similar results in 2001 and 2002. Michigan's population, the greatest consumer of Great Lakes sport fish of all Great Lakes states, is uneven in fish consumption advisory awareness. According to the study, only half of all Great Lakes sport fish consumers were aware of the advisory, and only 15% of black sport fish consumers were aware of the advisory. The situation surrounding race and ethnicity is especially pertinent in the Saginaw River Basin where a 2007 study reported that minority anglers were less aware of current advisories and were consuming high-risk species of fish at a higher rate than whites.[49] While no studies before 1993 reported on fish consumption or advisory awareness, we know fish consumption in Michigan has been an Environmental Justice issue since 1992.

We also examined other factors beyond race and income in many of these articles. While we do not want to discount the importance of such factors as education, age, language, and culture, we do want to highlight the importance of considering race and income as factors. Each of these factors varies greatly by location and study. For example, while education may be a predictive factor in Burger et al.'s 1999 study, results are not determinative for education in Imm et al.'s 2005 study. Language is also another area that is highly variable dependent on the demographics on the locus studied. The California study of

---

[46] West, P., Fly, M., Larkin, F., & Marans, R. W. (1994). Minority anglers and toxic fish consumption: Evidence from a statewide survey of Michigan. In B. Bryant & P. Mohai (Eds.), *Race and the incidence of environmental hazards: A time for discourse.* Boulder, CO: Westview Press.
[47] Tilden, J., Hanrahan, L P., Anderson, H., Palit, C., Olson, J., Kenzie, W.M. (1997). Health advisories for consumers of Great Lakes sport fish: Is the message being received? *Environmental Health Perspectives*, *105*(12).
[48] Ibid.
[49] Michigan Department of Community Health (June, 2007). Fish consumption survey of people fishing and harvesting fish from the Saginaw Bay Watershed. Saginaw Bay Watershed Initiative Network. Retrieved March 20, 2008, from www.twwatch.org.

risk exposure relied heavily on language differences because of the high variety of ethnicities in the area, while Beehler's study looked primarily at English-speaking African Americans.[50] Similarly, the issue of age is also less of a direct determinant in risk exposure because of the high variability of age grouping among studies, and also regional differences. Lastly, cultural variation is very important in the assessment of risk exposure because of the qualitative relationship anglers have with the environment, fishing, and other anglers. Yet not all studies qualitatively examine angler behavior, and therefore, are more difficult to compare across studies. These variations are still important in the study, and push researchers to understand the dynamic relationship of various factors within their specific region.

In 1994, a group of graduate students from the School of Natural Resources and Environment at the University of Michigan conducted a study on the Detroit River concerning risk exposure, fish consumption, and its implications of environmental injustice. The students specifically interviewed African-Americans concerning fishing behavior: how often and what types of fish they caught; how black anglers prepared fish; gift culture versus catch and release; and their willingness to change their behavior. Anglers were also asked to assess the state's efforts in warning them of risks, their general awareness of risks, and what the state could improve its risk communications. The report was an interesting springboard for our study as the results gave us some direction in approaching our analysis. Their findings suggested that African American anglers in the 1990s selected high-risk benthic fish (such as drum and catfish) for consumption as well as more popular sport fish. The study also indicated that most of the anglers held fishing licenses and were aware of risks but did not change their behavior according to the fish consumption guidelines. Three quarters of

---

[50] Beehler, G., McGuiness, B., & Vena, J. (2001). Polluted fish, sources of knowledge, and the perception of risk: Contextualizing African American anglers' sport fishing practices. *Human Organization*, *60*(3).

our interviewees criticized the State of Michigan for not doing enough; there was a general feeling of distrust of the state, the Michigan Department of Natural Resources (MDNR), and Governor Engler. They were also skeptical of the state's efforts to control anglers' behavior rather than pollution.[51]

With this study in mind, we positioned ourselves to understand fish consumption on the Detroit River within a larger socio-historical context. Our study, in contrast to the 1994 perspective, is more balanced by interviews from Canada and the United States, specifically Detroit and other cities along the Detroit River. The demographics are markedly different within each of the areas along the Detroit River, and as the literature review suggests, understanding heterogeneity of angler populations on a particular body of water is necessary in addressing risk exposure. Furthermore, the literature is clear that not all populations use nor perceive natural resources in the same way. For this reason we aim to assess the Detroit River fishing communities by using the variables of race, income, education, age, and gender. This involves a holistic view of the area, its history, resource distribution, and demographics. We have included an explanation of food security, and its importance in the area where people live and fish. As stated previously, fishing is an activity that yields food for some anglers. In the absence of fresh food alternatives, the nutrients that fish provides become ever more important.

Compounding Factors

1. Food Security

Food security, as defined by the United States Department of Agriculture (USDA), refers to the "access by all people at all times to enough nutritious food for an active, healthy

[51] Hornbarger, K., MacFarlene, C., & Pompa, C. R. (1994). Target audience analysis: Recommendations for effectively communicating toxic fish consumption advisories to anglers on the Detroit River. In *Natural Resources Sociology Lab Technical Report #11*. Ann Arbor, MI: Natural Resource Sociology Research Lab, University of Michigan.

life."[52] Yet, there are 13 million children and 23 million adults living in food-insecure households within the United States. In addition, the stress that this places on families has multiple psychological, physiological, and social implications.[53] Simple measures of economic provisioning for food cannot adequately predict the extent to which a family, or individual, has food-security.[54] More recent scholars of food security have focused on the diverse and complex nature of food insecurity, looking towards ways to disaggregate and holistically analyze the issue.[55] In addition to relative cost and access to healthy food sources, it is essential that food sources must be socially and culturally acceptable for those who are suffering from food insecurity. For example, those dealing with hunger must also deal with additional stressors like familial isolation and social stigma when going to food banks or shelters.[56] It is understood that cultural and societal pressures, networks, and knowledge play a role in food security. When social organizations fails to provide secure food sources, hunger ensues, and hunger in turn affects social networks and the functioning of institutional resources.[57]

In Detroit, much attention has been paid to the issue of food security, particularly to the role of grocery stores and fresh food access and quality, as well as the role of urban agriculture. A 2006 study of fresh fruit and vegetable access in the Detroit area reported that the quality and quantity of fresh produce at food stores was significantly less in low-income, African-American communities as compared to middle-income, racially heterogeneous

---

[52] U.S. Department of Agriculture. (2008). Food and nutrition service. Retrieved March 04, 2008 from http://www.fns.usda.gov/fsec/.
[53] Alaimo, K. (2005). Food insecurity in the United States: An overview. *Top Clinical Nutrician*, *20*(4), 281-298.
[54] Rose, D. (1999). Economic determinants and dietary consequences of food insecurity in the United States. *American Society for Nutritional Sciences.* 129:517-520.
[55] Maxwell, S. (1996). Food security: A post-modern perspective. *Food Policy*, *21*(2), 155-170.
[56] Hamelin, A., Habicht, J., & Beaudry, M. (1999). Food insecurity: Consequences for the household and broader social implications. *American Society for Nutritional Sciences.* 129:525-528.
[57] Molnar, J. (1999). Sound policies for food security: The role of culture and social organization. *Review of Agricultural Economics*, *21*(2) 489-498..

neighborhoods in Detroit.[58] Another report in 2006 rearticulated the food-security debate, stating that of 1,073 total grocery stores in Detroit, most were fringe locations (convenience stores) that specialized in alcohol, money orders, cigarettes, lottery tickets, and other non-food products. Furthermore, the study states that over half of Detroit residents live in areas defined as a food desert, areas that require residents to travel twice as far or farther, to reach main stream grocery stores than a fringe location.[59] This is staggering considering that neither African-American, nor racially heterogeneous low-income neighborhoods contain at least one chain grocery store.[60]

Food security research has neglected to incorporate angling as an aspect of food access and security for those members who use it as a food resource. Perhaps the most significant statistic is that 34% of Great Lakes angling in Michigan occur in Lake St. Clair and the Detroit River. Also, the total amount of fishing activity on the Detroit River has actually increased by 30% from 1984 to 2003.[61] For this reason we have incorporated what we know about food security into our questions on subsistence fishing on the Detroit River and ask what elements make fishing in the Detroit River a secure food resource? Access and availability are two factors that determine whether or not a person has the physical resources or means to fish. However, there are limitations on the quantity of fish permissible to a consumer because of the listed persistent contaminants. Those limitations are contingent on the quality of water that flows down the straight. Anglers, both men and women, depend on the state of Michigan and the Province of Ontario to communicate which fish are acceptable and which are not.

[58] Zenk, S., Schultz, A., Israel, B., James, S., Bao, S., & Mark Wilson. (2006). Fruit and vegetable access differs by community racial composition and socioeconomic position in Detroit, Michigan. *Ethnicity and Disease, 16*, 275-280.
[59] Gallagher, M. (2006). Examining the impact of food deserts on public health in Detroit. *La Salle Bank Midwest Report..*
[60] Ibid.
[61] Sharp, E. (April 10, 2003). Fewer anglers find fish at the end of the lines. *Detroit Free Press*.

2. Health Benefits of Fish Consumption

In the late 1970s it was found that Native Alaskans' diets, high in fresh fish consumption, had possibly resulted in longer life expectancies and healthier hearts, sparking much interest and research in the medical and public health fields about the benefits of consuming fish.[62] Through many years of research, it has been discovered that Omega-3 fatty acids are essential for a healthy circulatory system, specifically assisting in lowering blood pressure and the risk of coronary heart disease. Omega-3 fatty acids have also been shown to provide other benefits such as relief from arthritis and maintaining a healthy neurological system.[63]

Fish are high in Omega-3 nutrients and lean proteins, making them a particularly healthy choice in that they provide both nutrients and a low fat protein source.[64] The American Heart Association has since recommended the daily intake of Omega-3 fatty acids for heart and circulatory health, but limits intakes for women and children, indicating the importance of fish consumption while considering the risks.[65]

The many health benefits of consuming fish create a dilemma for those concerned with potential contaminants. Toxicants often enter the human body through the ingestion of fish and other food sources, so that attempts to eat a healthy diet complete with the lean proteins found in fish can be harmful to human health. The contaminants can be especially detrimental to women of childbearing age, developing fetuses and children, as some

---

[62] Harris, W. (2004). Fish oil supplementation: Evidence for health benefits. *Cleveland Clinic Journal of Medicine*, 71(3).
[63] Ibid.
[64] Sidhu, K. S. (2003). Health benefits and potential risks related to consumption of fish or fish oil. *Regulatory Toxicology and Pharmacology*, *38*, 336-344.
[65] Kris-Etherton, P. M., Harris, W. S., & Appel, L. J. (2003). Omega-3 fatty acids and cardiovascular disease: New recommendations from the American Heart Association. *Arteriosclerosis, Thrombosis and Vascular Biology*, *23*(151).

contaminants can be transferred through breast milk.[66] Balancing a healthy diet with concerns of toxicants in food sources creates confusion and sometimes fear, particularly for those with the least access to clear information.

3. Contaminants in Fish

While there are many potential contaminants in fish, the focus of this study are those contaminants included in fish consumption advisories: mercury, PCBs, and dioxins. Concerns over these contaminants stem from years of scientific and medical research on their human health effects, often most problematic for women of childbearing age, developing fetuses and children. Mercury, PCBs, and dioxin are the three chemicals listed in the Fish Consumption Advisory issued by the Michigan Department of Community Health (MDCH) that are found in the Detroit River. The advisory suggests restricted consumption of several types of fish. Each contaminant is discussed in depth below.

A. Mercury

One of the most commonly cited contaminants in fish is mercury which is typically found in the form methylmercury in the environment. While naturally occurring in small doses, anthropomorphic sources of mercury are typically released into the atmosphere through the burning of fossil fuels and into terrestrial and aquatic environments through mining and other industrial practices.[67,68] Mercury is also found in thermometers, dental amalgam, batteries, and fluorescent light bulbs. In the environment, mercury finds it way into sediments in aquatic ecosystems where it bioaccumulates in fish through the food chain

[66] Ponce, R. A, Bartell, S. M., Wong, E. Y., LaFlamme, D., Carrington, C., Lee, R. C. et al. (2000). Use of quality-adjusted life year weights with dose-response models for public health decisions: A case study of the risks and benefits of fish consumption. *Risk Analysis*, *20*(4).
[67] Environmental Protection Agency Fact Sheet: "Mercury Update: Impact of Fish Advisories" June 2001.
[68] Egeland, G. M., & Middaugh, J. P. (1997). Balancing fish consumption benefits with mercury exposure. *Science, New Series*, *278*(5345).

and direct exposure to the contaminants.[69] Exposure to mercury has been widely studied and shown to cause neurological problems, vision and hearing loss in adults. High doses of methylmercury have been known to be fatal, such as in Minamata, Japan in the 1950s.[70] The most severe effects are seen on developing fetuses with health issues ranging from mild developmental delays to more severe issues such as cerebral palsy.[71] Great Lakes fish consumers have been found to have a larger amount of mercury in blood samples than normal, but not to any great clinical concern.[72] Fish consumption was first restricted in the Detroit River because of high levels of mercury in 1970.[73]

B. PCBs

Polychlorinated biphenyls, commonly referred to as PCBs are a mix of 209 possible organic and synthetic compounds previously used in a wide range of industrial products because of their diverse properties.[74] These include oil, waxy, non-flammable, chemically stable, high boiling point, and electrical insulating properties.[75] PCBs have been introduced into the environment through industrial processes and waste disposal. These chemicals have been associated with several toxic health effects including cancer, skin rashes and negative effects on the immune, reproductive, nervous, and endocrine systems skin rashes.[76] Human exposure to PCBs typically occurs through the ingestion of contaminated food sources.

---

[69] Environmental Protection Agency Fact Sheet: "Mercury Update: Impact of Fish Advisories" June 2001.
[70] Ratcliffe, H. E., & Swanson, G. M. (1996). Human exposure to mercury: A critical assessment of the evidence of adverse health effect. *Journal of Toxicology and Environmental Health*, *49*, 221-270.
[71] Clarkson, T. W. (1992). Mercury: Major issues in environmental health. *Environmental Health Perspectives*, *100*, 31-38.
[72] Anderson, F., Hanrahan, C., Olson, L., Burse, J., Needham, V. W., Paschal, L. et al. (1998). Profiles of Great Lakes critical pollutants: A sentinel analysis of human blood and urine. *Environmental Health Perspectives*, *106*(5) 279-289..
[73] Peakall, D., & Lovett, R. (1972). Mercury: Its occurrence and effects in the ecosystem. *BioScience. 22*(1).
[74] Environmental Protection Agency (1999). Polychlorinated biphenyls (PCBs) update: Impact on fish advisories.
[75] Environmental Protection Agency. (1999). Health effects of PCBs. Retrieved May 6, 2007 from http://www.epa.gov/pcb/pubs/effects.html
[76] Environmental Protection Agency (1999). Polychlorinated biphenyls (PCBs) update: Impact on fish advisories.

Domestic production of PCBs was banned in 1977 when concerns over the compounds' toxicity and persistence were raised. More than 1.5 million pounds were manufactured before production ceased.

PCBs are persistent in the environment and have been shown to accumulate in the tissues of animals because of their fat solubility. Due to the persistence of PCBs in the environment, it is often found in aquatic sediments and throughout the food chain, long after the ban on the creation of new PCBs. Although the EPA reports that there have been long-term declines in PCB concentrations in the Great Lakes since the 1970s, the Detroit River continues to be a significant source of PCBs for Lake Erie.[77] Furthermore, a recent survey of fish consumption advisories demonstrates that although contaminant levels of mercury and PCBs have been declining, restrictions on the consumption of Great Lakes sport fish has become more stringent.[78] According to the EPA, those that rely on seafood and fish for subsistence purposes are at higher risk of being effected by PCBs. This is supported by He et al.'s 2001 longitudinal study on Michigan's Great Lakes sport fish consumers' blood serum levels. Although there has been a slight decline or stabilization in some people, researchers found that there has been no significant change in the amount of PCBs found in Great Lakes sport fish consumers' blood serum from 1973 to 1993.[79] This was attributed to the continued exposure to and the long half-life ofPCBs.

C. Dioxins

Polychlorinated Dibenzo-p-dioxins, commonly known as dioxins, are a group of synthetic organic chemicals. They are produced unintentionally as a byproduct of industrial

[77] Environmental Pretection Agency. (2003). *Evaluating ecosystem results of PCB control measures within the Detroit River-Western Lake Erie Basin*. Chicago, IL: Great Lakes National Program Office.
[78] Ibid
[79] He, J., Stein, A., Humphrey, H., Paneth, N., & Courval, J. (2001). Time trends in sport-caught Great Lakes fish consumption and serum polychlorinated biphenyl levels among Michigan anglers, 1973-1993. *Environmental Science and Technology*, *35*(3).

processes such as incineration, combustion, and the bleaching process of pulp wood.[80] Additional sources include diesel trucks and the burning of treated wood. Dioxins are typically released into the atmosphere or introduced into the environment through waste disposal processes.

Humans are most prominently exposed to dioxins through the consumption of food such as fish, meat, and dairy as it accumulates in the fat of animals and is passed through the food chain. The contaminants tend to settle out of the air and into soils and water, building up in the fat of fish. Dioxins are persistent in the environment and they tend to bio-accumulate in fish through the food chain. The accumulation of dioxins in fish creates a risk for anglers, particularly those urban anglers that fish near the source of such contaminants.[81]

Dioxins include a broad array of chemical compounds that share the ability to act as a hormone, a subtle attack on the human and animal body that is not entirely understood.[82] Chemicals that act as hormones are known as endocrine disruptors that have been linked to cancer, particularly in women. Research on animals exposed to dioxins has also shown toxic effects on the liver, gastrointestinal system, blood, skin, endocrine, immune, nervous, and reproductive systems.[83] Long-term human exposure to toxins is typically difficult to study. A massive dioxin release in Sevaso, Italy in 1976 provided such an opportunity for Italian researchers. Bertazzi et al. found that while it remained difficult to prove conclusively that those exposed to the highest levels of dioxins had increased health effects, they did find that in a 15 year period, cancer deaths for men in the exposed areas were greater than the rest of

[80] Environmental Protection Agency (1999). Polychlorinated biphenyls (PCBs) update: Impact on fish advisories.
[81] Ibid.
[82] Birnbaum, L. S. (1994). The mechanism of dioxin toxicity: Relationship to risk assessment. *Environmental Health Perspectives*, *102* (Supplement 9: Toxicological Evaluation of Chemical Interactions).
[83] Environmental Protection Agency (1999). Polychlorinated biphenyls (PCBs) update: Impact on fish advisories.

the population. They suffered other health effects such as respiratory and circulatory system diseases.[84]

4. Communicating the Risks: The Role of the State

In the late 1980s, many U.S. states began looking at ways to protect their constituents from toxicants and created fish consumption advisories. In Canada, this process began earlier in the mid 1970s. The advisories incorporate specific guidelines for people to safely eat fish that include size, specie, and number of meals for a given time period for each population, with more vulnerable populations typically receiving more stringent restrictions. These advisories are created as guidelines for consumers of sport caught fish, with the ultimate choice of which fish and in what quantities they should be eaten being left to the angler to decide. Those who do not receive this information are unable to balance the risks and benefits of fish consumption through an informed decision. For others, factors such as food insecurity and poverty outweigh the risks of eating fish. Thus, the role of the state is to not only to attempt to protect their constituents by providing accurate, timely, and accessible information, but also to assist those who must make these difficult decisions.

A brief description of the fish advisory process illustrates the administrative differences in communication between the United States and Canada. In the United States, state governments individually create and issue fish consumption advisories in a wide variety of ways. Only mercury levels are suggested on the federal level by the U.S. EPA and Food and Drug Administration. Some governments prefer statewide advisories, and others, a smaller scale advisory on a county or watershed level, often depending on how their local governments function and which agency is responsible for issuing the advisory. Further

[84] Bertazzi, P. A., Consonni, D., Bachetti, S., Rubagotti, M., Baccarelli, A., Zocchetti, C. et al. (2001). Health effects of dioxin exposure: A 20-year mortality study. *American Journal of Epidemiology*, *153*(11).

variation occurs with regards to the type of advisories, if they are specific to a body of water or region, or for commercially caught fish. The lack of a universal mandate or guidelines for creating state specific advisories leads to confusion and extreme variations in the quality of the advisories and outreach methods.

The process in Canada is more streamlined with fewer agencies and perhaps more resources. The acceptable level of contamination ingested through fish consumption is administered federally by Health Canada which provides that information to Environment Canada. Environment Canada is then responsible for communicating that information on the provincial level as well as for sampling and testing fish for contamination. In Windsor, the largest Canadian city on the Detroit River, fish consumption advisories are distributed by the Ontario Ministry of Environment when a fishing license is purchased. In the U.S., mercury advisories are suggested by the U.S. EPA and Food and Drug Administration, but these governmental departments depend on the states to provide contamination advisories. Dioxin and PCB advisories are created by individual states with varied processes and there is no uniform guide for fish consumption advisories; however, the Great Lakes states of Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin wrote the Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory.[85] Though most have utilized parts of the protocol for regional advisories, each state adapted it for their own needs.[86] The MDNR tests fish at various locations throughout Michigan and relays the results to the MDCH. The MDCH subsequently establishes the fish advisory based upon the results from the analysis of toxins in the fish samples. These fish advisories are then made available online at specified websites. Detroit and Windsor anglers receive two different

[85] Anderson, H., Amrhein, J. F., Shubat, P., & Hesse, J. (1993). Protocol for a uniform Great Lakes sport fish consumption advisory. Great Lakes Fish Advisory Task Force Protocol Drafting Committee.
[86] Fischer, L. J., Bolger, P. M., Carlson, G. P., Jacobson, J. L., Knuth, B. A., Radike, M. J. et al. (1995). *Critical Review of a Proposed Uniform Great Lakes Fish Advisory Protocol.* Lansing: Michigan Environmental Science Board, Lansing.

advisories for the Detroit River. Many U.S. residents visit Canada to fish, and are thereby required to purchase Canadian fishing licenses where they are provided Canadian advisories, resulting in these anglers coming away with a different message, which adds to their confusion.

Table 3.2 Species Listed in the Michigan and Ontario Advisories[87] [88]

Michigan Advisory		Ontario	
Species	**Contaminants**	**Species**	**Contaminants**
Carp	PCBs, Dioxin	Carp	Mercury, PCBs, Dioxin, Furans, Chlorinated phenols, Chlorinated benzenes, Polycyclic aromatic hydrocarbons
Freshwater Drum	Mercury, PCBs	Freshwater Drum	Mercury, PCBs
Northern Pike	PCBs	Northern Pike	Mercury, PCBs
Walleye	PCBs	Walleye	Mercury, PCBs, Dioxins, Furans
Yellow Perch	PCBs	Yellow Perch	Mercury, PCBs
Suckers	PCBs		
		White Perch	Mercury, PCBs
		White Bass	Mercury, PCBs, Dioxin, Furans, Dioxin-like PCBs
		Rock Bass	Mercury, PCBs
		Catfish	Mercury, PCBs, Dioxin, Furans, Dioxin-like PCBs

United States and Michigan Fish Consumption Advisories

The Michigan Fish Consumption Advisory is a 25 page pamphlet organized by watershed. As seen in figure 3.1 below, it consists of a table with many shapes and boxes. The introduction to the advisory includes a brief discussion of the risks and benefits of eating

[87] Michigan Department of Community Health. (2007). *Michigan family fish consumption guide*. Retrieved March 4, 2008, from http://www.michigan.gov/dnr/0,1607,7-153-10364---,00.html
[88] Ontario Ministry of the Environment. (2007). *Guide to eating Ontario sport fish, 24th edition*. Retrieved March 4, 2008, from http://www.ene.gov.on.ca/envision/guide/

fish, the safest ways to prepare fish, and a description of how to use the information contained in the tables.[89] The advisory specifies how many fish of a particular specie and size in a specific body of water are acceptable to eat per month. These recommendations aid in making the decision to avoid potentially adverse effects of PCBs, mercury, and in some cases dioxins. The advisory considers the average meal to be half a pound of fish and recommends that women and children, considered sensitive sub-populations, eat less fish per month than the average male angler weighing 155 pounds. In Michigan, six species from the Detroit River are listed with consumption limits.

The fish consumption advisory process in Michigan includes several institutional players. Fish are collected for sampling by the MDNR and tested for contamination by the Michigan Department of Environmental Quality (MDEQ). The monitoring results are sent to the MDCH which determines what amounts of contaminants are safe to eat and issues the advisory.

[89] Michigan Department of Community Health. (2007). *Michigan family fish consumption guide*. Retrieved March 4, 2008, from http://www.michigan.gov/dnr/0,1607,7-153-10364---,00.htm

Figure 3.1 2007 Michigan Family Fish Consumption Guide, Pages 10 and 11[90]

▲ Unlimited consumption. ● One meal per month. ▼ One meal per week. ■ Six meals per year. ◆ Do not eat these fish.

Water body	Species	Contaminant(s)	General Population – Length (inches) 6-8	8-10	10-12	12-14	14-18	18-22	22-26	26-30	30 +	Women & Children – Length (inches) 6-8	8-10	10-12	12-14	14-18	18-22	22-26	26-30	30 +
Lake Erie Watershed All other locations refer to general advice on page 5.																				
Cass Lake* (Oakland Co.)	Smallmouth Bass	Mercury, PCBs					▼	▼	▼	▼						●	●	●	●	
	Walleye	Mercury, PCBs					▼	▼	▼	▼	▼					●	●	●	●	●
Clear Spring Lake* (Macomb Co.)	Largemouth Bass	Mercury, PCBs					▲	▼	▼	▼						▼	●	●	●	
Clinton River (Downstream Yates Dam)	Carp	PCBs	▲	▲	▲	▲	▲	▲	▲	▲	▲	●	●	●	●	●	■	■	■	■
	Rock Bass	PCBs	▲	▲	▲	▲	▲					▲	▼	▼	▼	▼				
	Suckers	PCBs	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲	▲
Detroit River	Carp	PCBs, Dioxin	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆	◆
	Freshwater Drum	Mercury, PCBs	▲	▲	▲	▲	▲	▼	▼	▼	▼	●	●	●	●	●	●	●	●	●
	Northern Pike	PCBs							▲	▲	▲							●	●	●
	Suckers	PCBs	▲	▲	▲	▲	▲	▲	▲	▲		▼	▼	▼	▼	▼	●	●	●	
	Walleye	PCBs				▲	▲	▲	▲	▲	▲				●	●	●	●	●	●
	Yellow Perch	PCBs	▲	▲	▲	▲	▲					▲	▲	▼	▼	▼				
Ford Lake* (Washtenaw Co.)	Black Crappie	PCBs	▲	▲	▲	▲	▲	▲				▼	▼	▼	▼	▼	▼			
	Carp	PCBs	▲	▲	▲	▲	▲	▲	▲	▲	▲	●	●	●	●	●	●	●	●	●
	Channel Catfish	PCBs				▲	▲	▲	▲	▲	▲				▼	▼	●	●	●	●
	Walleye	PCBs					▲	▲	▲	▲	▲					▼	▼	▼	▼	▼
Hudson Lake* (Lenawee Co.)	Carp	Mercury	▲	▲	▲	▲	▲	▲	▲	▼	▼	▲	▲	▲	▲	▲	▲	▲	●	●
	Largemouth Bass	Mercury					▲	▼	▼	▼						▲	●	●	●	
Kent Lake* (Oakland Co.)	Black Crappie	Mercury, PCBs	▲	▲	▼	▼	▼	▼				▲	▲	●	●	●	●			
	Carp	PCBs	▲	▲	▲	▲	▲	▲	▲	▲	▲	●	●	●	●	●	●	●	●	●
	Largemouth and Smallmouth Bass	PCBs					▲	▲	▲	▲						▼	▼	▼	▼	
	Walleye	PCBs					▲	▲	▲	▲	▲					●	●	●	●	●

* For species not listed, see general inland lake mercury advisory on page 5.

10 11

The number of fish advisories that are in effect in the United States has grown substantially since their inception. According to the EPA, the total number of advisories nationwide had grown to 3,852 by 2006. This amounts to a total of 38% of the nation's lakes, or 15,368,068 lake acres, and 26% of total river miles, or 930,938 miles total. All of the Great Lakes states, namely: Illinois, Indiana, Michigan, Minnesota, New York, Ohio, Pennsylvania, and Wisconsin include 100% of their lakes under fish consumption advisories, and all but Minnesota and Michigan have included 100% of their rivers. However, Michigan and Minnesota have 3.5% of their rivers under a fish advisory, which is significantly higher than all but 3 other states that do not include all of their rivers under advisory.[91]

[90] Michigan Department of Community Health. (2007). *Michigan family fish consumption guide*. Retrieved March 4, 2008, from http://www.michigan.gov/dnr/0,1607,7-153-10364---,00.html
[91] Environmental Protection Agency. (2007). EPA fact sheet. In *2005/2006 National listing of fish advisories*.

Although the State of Michigan has established an extensive reporting strategy for fish contaminant monitoring,[92] communicating those results to a non-technical audience is challenging. A study completed in 1997 reported that among the estimated 376,000 Great Lakes anglers, only half were aware of Great Lakes fish consumption advisories. Of those who were aware of the advisory, more men were aware than women, and more white anglers were aware than minority anglers.[93] This was attributed to the fact that advisories were received with the purchase of a fishing license, though this is no longer the case. Also, in response to these findings many Great Lakes states produced targeted fish consumption advisories directed to either people of color and/or women of reproductive age to fill the gap for at-risk consumers.[94]

Michigan's health risks communications were targeted to women and children through the Michigan Family Fish Consumption Guide until budget cuts undermined the states ability to do so. In 2004, the MDCH cut its $350,000 appropriations to update and distribute the Michigan Family Fish Consumption Guide. In 2002 and 2003, 50,000 copies were distributed to local health departments, WIC offices, all in addition to the normal distribution that took place when fishing licenses were purchased.[95] Michigan is currently under unprecedented budget constraints and anglers report a lack of access to a physical advisory, though the updated version is available on the MDNR and MDCH websites. The current online addition is targeted to the sport angler that has internet access. The lack of a

---

[92]Michigan Department of Environmental Quality.. Michigan fish contaminant monitoring online database. Retrieved February, 2008, from http://www.deq.state.mi.us/fcmp/Sites.asp

[93] Tilden, J., Hanrahan, L P., Anderson, H., Palit, C., Olson, J., Kenzie, W.M. (1997). Health advisories for consumers of Great Lakes sport fish: Is the message being received? *Environmental Health Perspectives*, *105*(12).

[94] Ashizawa, A., Hicks, H. E., & De Rosa, C. T. (2005). Human health research and policy development: Experience in the Great Lakes region. *International Journal for Hygiene and Environmental Health*, *208*.

[95] Chambers, J. (2004, June 18) State guide to eating fish is victim to cuts – Pregnant women, anglers will have to use old information. *Detroit News*

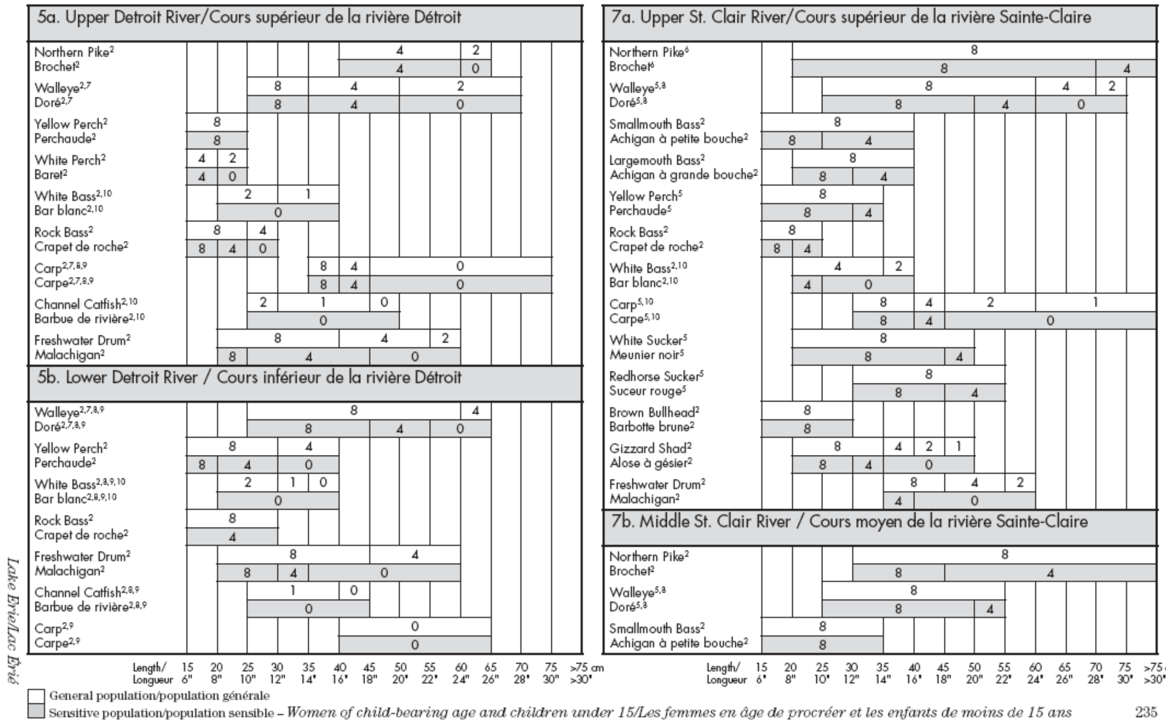
physical advisory pamphlet adds additional confusion and often leaves out vulnerable populations.

Canada and Ontario Fish Consumption Advisories

Canadian fish consumption advisories are presented in the form of a detailed, 279 page document. The physical document is available when a fishing license is purchased, online, and in several other locations such as bait shops, Canadian Tire stores, and liquor stores. The introduction to the guide contains detailed descriptions of the fish testing process, advice for cooking and cleaning fish, descriptions of how to use the guide, historical context of the advisory and monitoring process, and detailed information about each contaminant. The guide is available in 19 languages.[96] Canada began an extensive fish monitoring program in 1976, with the first guide being published in 1977. The current guide recommends restricted consumption of nine species and fish consumption is suggested to be no more than eight servings per month for all populations.

[96] Ontario Ministry of the Environment. (2007). *Guide to eating Ontario sport fish, 24th edition*. Retrieved March 4, 2008, from http://www.ene.gov.on.ca/envision/guide/

Figure 3.2 Guide to Eating Ontario Sport Fish 2007-2008 Edition, Page 235



Fish Consumption on the Detroit River

Residents of Detroit and the surrounding area utilize the Detroit River Area of Concern as a food source.[97] According to the MDNR, fishing on the Detroit River has increased by nearly 30% from 1983 to 2002. Yet, the Detroit River subsistence angler population is quite different from the angler population of greater Michigan and Canada. It is urban, and the resource is located in proximity to several industrial areas and potential sources of contaminants that may compound the risk of exposure. In addition to external pressures, minority and low-income subsistence anglers of the Detroit River are less likely to be aware of the advisory, risks of eating sports fish, and are less likely to practice mitigating measures of catch and preparation.[98] Therefore, urban subsistence anglers are at a high risk

[97] West, P., Fly, M., Larkin, F., & Marans, R. W. (1994). Minority anglers and toxic fish consumption: Evidence from a statewide survey of Michigan. In B. Bryant & P. Mohai (Eds.), *Race and the incidence of environmental hazards: A time for discourse.* Boulder, CO: Westview Press.
[98] Silverman, W. (1990). P. West & W. Redman (eds.). *Michigan sport fish consumption advisory: A study in risk communication*. Ann Arbor, MI: School of Natural Resources and Environment, University of Michigan.

of exposure to PCBs, mercury, and dioxins, and their adverse effects—and yet this group has not been recognized as an at-risk group.

Yet as we have demonstrated here, there is a large body of literature that investigates at-risk anglers based on categories beyond that of just gender. Scholars from coast to coast have investigated how populations' risks may increase based on a series of factors including, but not limited to, gender, age, education, income, and race or ethnicity. They have not only investigated these categories as independent variables, but have also investigated reasons why fishing continues despite risks.

CHAPTER 4: METHODS

CHAPTER 4: METHODS

Methods for Analyzing Characteristics of Detroit River Anglers

This practicum utilized a two pronged approach to analyze the objectives and questions regarding environmental justice issues surrounding fish consumption advisories in the Detroit River Area of Concern: directly interviewing anglers and analyzing the public actions of institutional stakeholders. The methods section is therefore divided into two subsections that outline these separate methodologies.

The first phase of this project included creating and conducting creel surveys with urban anglers on the Detroit River in both Michigan and Ontario. Creel surveys are a method of interviewing anglers during or after fishing activities to determines the number and species of fish they catch as well as other pertinent information regarding the human dimension, fishing experience, and natural environment.[99]

The second phase of this project examined the institutional stakeholders with the ability to make decisions regarding fish consumption advisories on the Michigan shores of the Detroit River. This was conducted to determine what types of actions are being taken by those charged with providing information to those that need it most. This analysis included only Michigan agencies due to the existence of greater environmental justice concerns and risk communication issues in the Detroit area rather than in Ontario.

Angler Survey

Design

The angler survey was designed to reflect our research questions using a matrix of each objective and corresponding question. This method ensured that each research question was addressed, each survey question was valid, and that the overall survey was brief. It

[99] Ditton, R.B. and K.M. Hunt. 2001. Combining Creel Intercept and Mail Survey Methods to Understand the Human Dimensions of Local Freshwater Fisheries. *Fisheries Management and Ecology*. Vol 8, No 4-5, pp 295-301.

included a mixture of structured and open-ended questions. The first few questions were designed to create a relationship with anglers as well as learn about their fishing habits and attitudes. The rest of the survey directly related to our research questions and hypothesis. The combination of structured and open ended questions allowed us to give a brief, ten minute survey and still conduct in-depth analysis of the respondents.

The angler survey is an adaptation of the mental models approach as developed by Morgan et al.[100] This approach uses a systematic method to capture "free responses" from interviewees. Instead of pre-constructing responses that we believed the sample population would give, the mental models approach allowed us to capture their unique responses, the open-ended questions allowing the sample population to express beliefs about hazards and risk in their own terms.[101] Using open-ended questions allowed the interviewer to elicit more complete information from the anglers' thought processes. During the interview process, patterns and/or similar responses emerged, at which point the open-ended questions were transformed into categorical answers.

Due to the nature and time constraints of our practicum we did not use the full mental models approach. Instead, an adaptation of this approach which allowed the use of some structured and open-ended questions was utilized. This provided an opportunity for the researchers to establish a rapport with the anglers, while not taking up too much of their time. It also allowed for greater depth of analysis of many of the questions in the survey. Structured questions can be administered and analyzed much more efficiently than open ended questions.[102] In addition, the use of structured questions allows one to obtain a frequency of a response, hazard or concern much more quickly and efficiently than an open-ended question. Understanding the frequency and breadth of responses targets the concepts

[100] Morgan, G. M., et al. (2002) *Risk communication*. UK: Cambridge University Press.
[101] Ibid., 20.
[102] Ibid., 84.

and misconceptions that are commonly shared throughout the target population.[103] This is the simplest form of analysis to see how prevalent a particular topic or concern is in the community.[104]

Pilot Survey

We began the survey process by drafting a pilot survey with questions targeting our hypothesis. The pilot survey largely consisted of open-ended questions so that we could record a wide range of the anglers' responses. The pilot survey was conducted in early May of 2007 at fishing spots along the Huron River in Ypsilanti and Ann Arbor, Michigan. The Ypsilanti area was selected for the pilot survey to minimize any potential for contaminating our survey population as well as its demographic and economic situation, which were similar to those of Detroit. The responses from the pilot study and conversations with anglers were used to modify and refine the final angler survey.

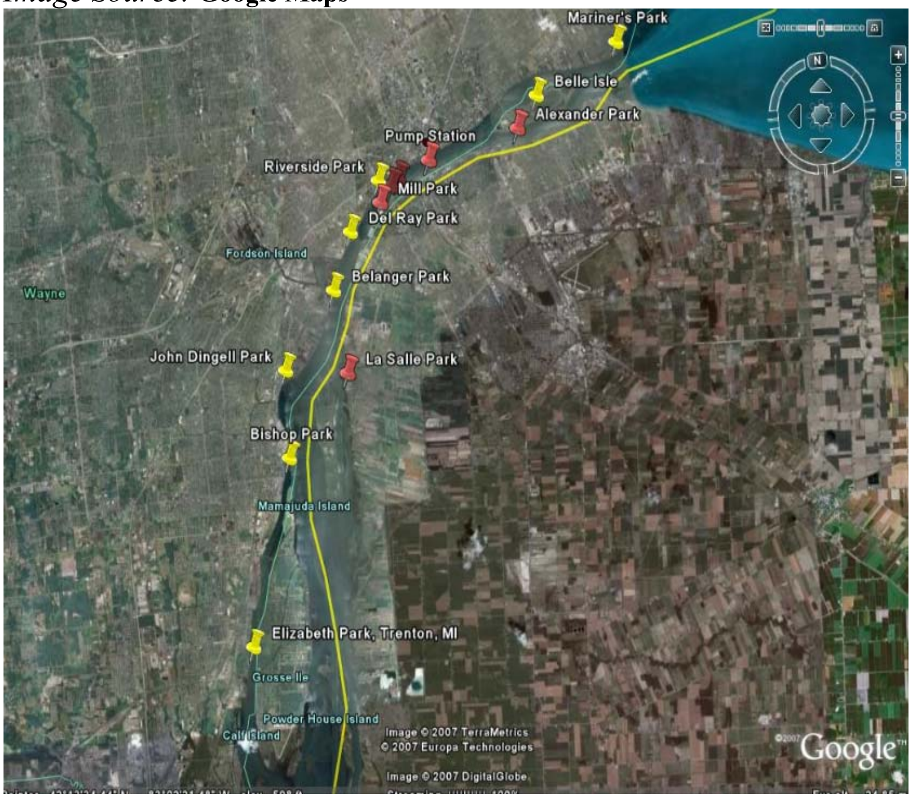
Detroit River Site Selection

The interview sites were selected through a "windshield" site tour of public fishing locations and by word of mouth from anglers throughout the interview process. The windshield survey was conducted by driving along the length of all 32 miles of the Detroit River in Michigan and Ontario and visiting public fishing access points and boat launches. These site tours were conducted in early May on a fair weather, Saturday afternoon when many fishing spots were busy. The parks where anglers were present and fishing were noted on maps and numbered. Many of the popular or best fishing locations are known only to the fishing community, so we visited other locations that were not included in our original assessment throughout the survey process. Only legal, public access fishing locations were

[103] Ibid., 84.
[104] Ibid., 79.

considered for this study for the safety of both the researchers and anglers, though anglers were observed fishing on private property.

Figure 4.1 : Fishing locations, Yellow tacks in Michigan, Red in Ontario
Image Source: **Google Maps**



Survey Day Selection

Interviews were conducted three days a week over an eight week period. Researchers were assigned in pairs to each survey day. Two researchers were required to attend each survey day for safety and time management purposes. Every Saturday and Sunday was designated as two of our three interviewing days and the third day was a randomly selected weekday. The following process was used to equally balance the five possible selections: Monday, Tuesday, Thursday, and Friday were each written on one slip of paper, while Wednesday was written on two slips of paper. A coin toss determined if Monday and Tuesday or Thursday and Friday would be written on a second slip of paper so that eight total slips of paper would be produced. The eight slips were placed randomly in eight envelopes. Each envelope was then opened and the day of the week written on the slip of paper determined the order of weekday survey days. The survey schedule left some flexibility to account for inclement weather and new information regarding fishing locations. A few days of inclement weather were encountered and rescheduled while keeping the number of week and weekend days within the preplanned ratio. We conducted surveys during the period of August 8, 2007 to September 22, 2007.

Statistical Analysis Methodology for Characteristics of Detroit River Anglers

Data Collection

The collected close-ended survey data were entered into a Microsoft Excel spreadsheet and coded. For example, our classification for country was 1 for the United States and 2 for Canada. The open-ended questions were entered verbatim into the database program Filemaker Pro. Each interviewer entered the responses for the interviews she conducted to maintain accurate transcription. To obtain a deeper analysis of the frequency, content, and interest of each respondent,[105] the open-ended responses were coded into distinct variables to allow us to treat them as categorical variables in SPSS.

The demographic variables that characterized our sample population included: race, income, gender, country (United States versus Canada), site, the range of number of fish taken home, catch and release, and non-catch and release. These demographic variables allowed us to analyze our data through the lens of environmental justice. The remaining response variables were analyzed against the sample population environmental justice indicators. Since our data were categorical in nature the chi-square test with an alpha level of .05 was used to determine significance.

[105] Ibid., 79.

Statistical Analysis Methodology for Stakeholders

The external analysis was conducted by searching eleven web-based sites for six selected stakeholders and key words related to fish consumption advisories and environmental justice on the Detroit River. The time frame searched varied by the specific internet-based source. For two searches, The Detroit News and Lansing State Journal, sources dated back to 1999, limited by the search archives capacity; The Detroit Free Press used sources dating back to 1994; and the other search engines used current dates available online. For analysis purposes, each stakeholder was assigned numeric coding: MDCH (1), EPA (2), MDCH (3), USFWS (4), MDEQ (5), and Wayne County (6). The 10 key workd search variables used in this analysis included: the Detroit River, chemicals (mercury, PCB and dioxin), river cleanup, environment, fish (included fishing), justice, license (included permit and permit violation), Wayne County (parks), pollution, and racism. The Detroit River was used as a constant in all searches. The frequency of occurrence of our search terms was recorded. We used the cluster analysis module within SPSS to determine each stakeholder's association with the search variables. Each cluster analysis set a limit of three clusters because the six stakeholders represented three areas. For example, one would expect the U.S. Fish and Wildlife Service and the EPA to have a natural grouping because they are both federal environmental agencies. The resulting clusters differed from each other based on the significant of the variables from an ANOVA with an alpha level of .05.

A factor analysis was conducted to consolidate the topic variables and stakeholder data into meaningful variables. In a factor analysis, a variable's appearance on a given factor signifies its hypothetical correlation with that factor. Variables that load strongly on on a factor are assumed to represent a common construct. Within SPSS we used the principal components factor analysis followed by varimax rotation to obtain what is known as “simple structure” resulting in factors with variables that load strongly on one factor.

CHAPTER 5: RESULTS

CHAPTER 5: RESULTS

Results from Detroit River angler analysis

One hundred and forty-eight anglers were approached and 115 surveys were conducted. Response rates were highest during the middle of the interview period, and began to decline near completion due to repeat candidates and the end of the summer fishing season. Interviewees included those actively engaged in fishing and recreation on the Detroit River front.

Angler demographics

Angler demographics are presented in Table 5.1. Percentages for the characteristics were computed for valid responses. A total of 78 anglers (67.8%) were interviewed in the United States and 37 anglers (32.2%) were interviewed in Canada. The majority of Michigan anglers were interviewed "Downriver" in areas that included Trenton, Ecorse, Wyandotte, and River Rouge for a total at 41.7% of the sample population (*n* 48), while 26.1% of the sample population (*n* 30) were interviewed in the Detroit area. Approximately 83% (*n* 94) of the anglers surveyed were male and 16.8% of the anglers surveyed were female. The median and mode age group was 41 to 65 years of age (*n* 72) with 64.9% of the population. The median age was 45 years old.

Table 5.1 Selected Angler Demographics

Characteristic	n	(%)
Race, N = 111 (unknown for 4 or 3.5%)		
Caucasian	45	40.5
People of Color	66	59.5
Country, N = 115		
Canada	37	32.2
USA	78	67.8
Income, N = 97 (unknown 18 or 15.7%)		
$0-24,999	13	13.4
$25,000-49,999	35	36.1
$50,000-74,999	29	29.9
$75,000-100,000+	20	20.6
Gender, N = 113 (unknown 2 or 1.7%)		
Male	94	83.2
Female	19	16.8
Education, N = 104 (known 11 or 9.6%)		
High school & less	56	53.8
Higher education	48	46.2
Location, N = 115		
Detroit	30	26.1
Downriver	48	41.7
Canada	37	32.2
Age, N = 111 (unknown 4 or 3.5 %)		
18 to 40	33	29.7
41 to 65	72	64.9
Greater than 66	6	5.4

The largest ethnic group was Caucasian, 40.5% (*n* 45), followed by African-American 38% (*n* 44), Asian/Pacific Islander 3% (*n* 4), Latino 3% (*n* 3), Arab/Middle Eastern 4% (*n* 5), Native American 1% (*n* 1), multiracial 4% (*n* 5), and other 4% (*n* 3). Combined, people of color composed 59.5% of the population (*n* 66). The most frequently reported household income level was $25,000 – 49,999, 36.1% of the sample population (*n* 35). The second most frequently reported income was $50,000 – 74,000, 29.9% of the sample population (*n* 29). Approximately 13% of the population earned $24,999 annually or below (*n* 13). For education attainment, 53.8% of the population had a high school education or less (*n* 56) and 46.2% (*n* 48) of the population had obtained higher education (trade school, some college, associate's, bachelor's, and master's degree or above).

Food Security: Importance to Diet, Number and Specie of Fish Taken Home

Respondents were asked how important fish was to their diet. The demographic breakdown of anglers that reported fish important to their diet is presented in Table 5.2. The responses were statistically significant based on race, location, and age. More than three quarters of people of color stated that fish was important to their diet (*n* 57) and more than 80% of Detroit anglers reported fish to be important to their diet. Downriver anglers also reported fish to be more important to their diet (67.4%, *n 43)* than anglers in Canada, yet our analysis between the United States and Canada was not significant. Anglers within ages 40 to 65 (80%, *n* 70) and ages greater than 66 (80%, *n* 5) reported fish consumption to be very important to their diet. This variable was not significant based income, gender, and education yet within the entire angler population having fish in their diet proved favorable.

Table 5.2 Percent of Anglers Who Stated that Fish Was Important to Their Diet

Characteristic	%	X^2	p
Race			
Caucasian	59.5	3.832	.050
People of Color	78.9		
Country			
Canada	61.1	1.767	.184
USA	73.6		
Income			
$0-24,999	66.7	.665	.881
$25,000-49,999	63.6		
$50,000-74,999	78.6		
$75,000-100,000+	66.7		
Gender			
Male	68.5	.426	.514
Female	76.5		
Education			
High school & less	64.2	2.169	.141
Higher education	77.8		
Location			
Detroit	82.8	3.682	.159
Downriver	67.4		
Canada	61.1		
Age			
18 to 40	48.3	10.255	.006
41 to 65	80		
Greater than 6 5	80		

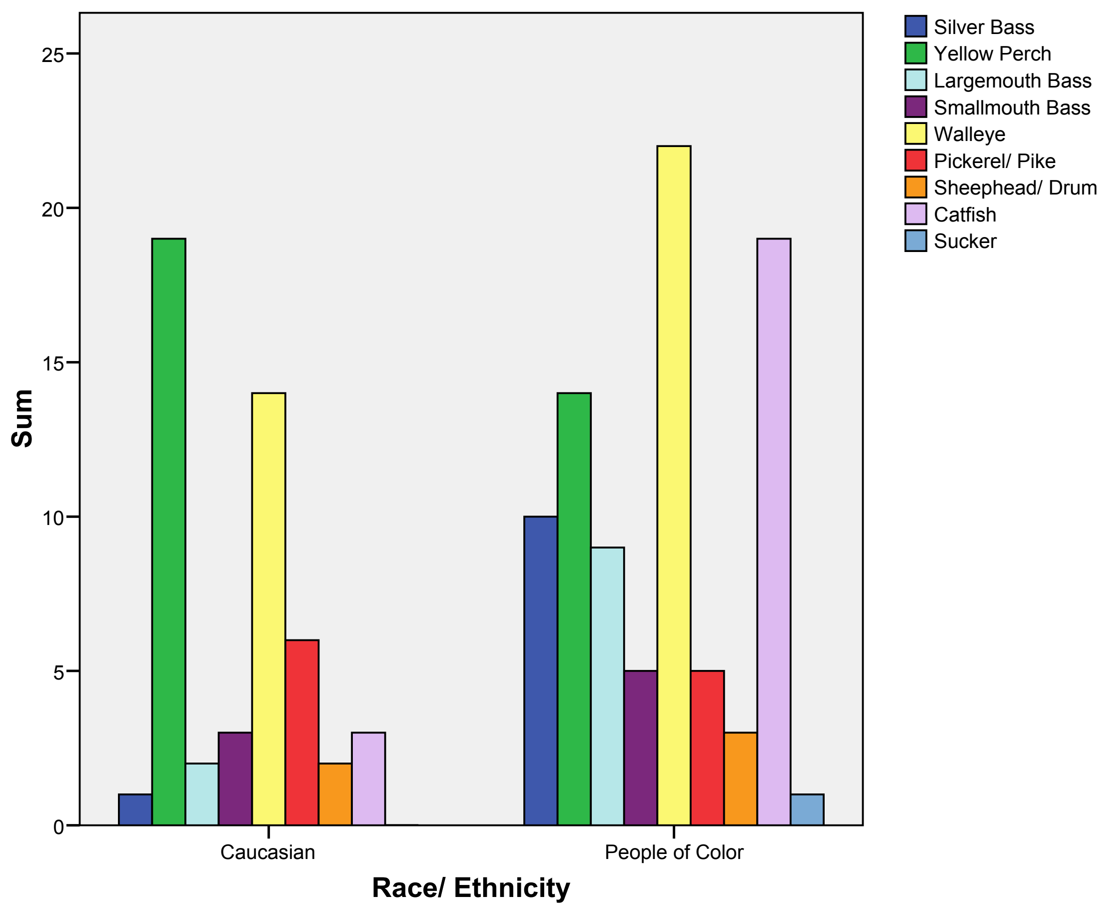
To better understand how important caught fish was to the anglers' diet, we asked them how many fish they took home per week. This question was first divided into three categories: takes home more than 10 fish per week, takes home less than 10 fish per week, and catch and release (takes home no fish). The responses were also divided into two other categories: catch and release, and take home fish (more than 10 fish a week and less than 10 fish a week combined). Table 5.3 displays the results and demographics of fishing habits. More than half of Caucasians interviewed practiced catch and release fishing (*n* 45), whereas 34.4% of people of color interviewed practiced catch and release. The practice of catch and release was statistically significant by country; Canadian anglers practiced catch and release 55.6% (*n* 36) of the time while U.S. anglers practiced catch and release only 35.6% (*n* 73) of the time.

Table 5.3 Demographics and Take Home Fish versus Catch and Release

Characteristic	Catch & Release (%)	Take home (%)	X^2	p
Race				
Caucasian	53.3	46.7	3.789	.052
People of color	34.4	65.6		
Country				
Canada	55.6	44.4	3.930	.047
USA	35.6	64.4		
Income				
$0-24,999	46.2	53.8	1.724	.881
$25,000-49,999	42.4	57.6		
$50,000-74,999	38.5	61.5		
$75,000-100,000+	50	50		
Gender				
Male	44.6	55.4	.988	.320
Female	31.3	68.8		
Education				
High school & less	45.5	54.5	.300	.584
Higher education	40	60		
Location				
Detroit	28.6	71.4	4.854	.088
Downriver	40	60		
Canada	55.6	44.4		
Age				
18 to 40	39.4	60.6	1.775	.412
41 to 65	44.1	55.9		
Greater than 66	16.7	83.3		

The most common species of fish taken home by anglers were walleye and catfish. Figure 5.1 depicts the breakdown of species taken home and angler race/ethnicity. Thirty percent of people of color interviewed took home catfish (*n* 61), while approximately 7% of Caucasians took home caught catfish (*n* 45). The amount of catfish taken home was also significant for location and age. Thirty-one percent of Downriver anglers interviewed took home catfish versus anglers in Detroit and Canada, who took home 10% (*n* 30) and 14% (*n* 37), respectively, of the catfish they caught. Twenty-one percent of anglers interviewed between 18 and 40 years of age, 21.1% (*n* 33), and 67% of those older than 66 (*n* 6) years of age, kept most of their catfish. Walleye was significant by location and country. U.S. anglers took home 42.3% (*n* 78) of their caught walleye. Accordingly, Detroit and Downriver anglers kept 40% (*n* 30) of their caught walleye versus the 48.3% (*n* 48) of Canadian anglers interviewed who kept 13.5% (*n* 37) of their caught walleye.

Figure 5.1 People of Color, Caucasians, and Types of Caught Fish Species



Food Security: Fishing frequency

Two groups were determined through fishing frequency: those that fished more than once per week and those that fish less than once a week, as displayed in Table 5.4. People of color generally fished more than once a week (81.3%, *n* 60), and more often, than Caucasians (60.50%, *n* 43). Men reportedly fished more than once a week (77.4%, *n* 93), and more often, than women (44.4%, *n* 18). The other indicator variables failed to be statistically significant, yet our results demonstrate that the Detroit River angler population generally fished more often than once a week.

Table 5.4 Fishing Frequency

Fishing Frequency	Less than once per week (%)	More than once per week (%)	X^2	p
Race				
Caucasian	30.5	60.5	5.6	.018
People of color	18.8	81.3		
Country				
Canada	34.3	65.7	1.027	.311
USA	25	75		
Income				
$0-24,999	15.4	84.6	1.886	.596
$25,000-49,999	27.3	72.7		
$50,000-74,999	25	75		
$75,000-100,000+	36.8	63.2		
Gender				
Male	22.6	77.4	6.6	.01
Female	52.9	47.1		
Education				
High school & less	25.9	74.1	.039	.844
Higher education	27.7	72.3		
Location				
Detroit	16.7	83.3	2.737	.255
Downriver	30.4	69.6		
Canada	34.3	65.7		
Age				
18 to 40	32.3	67.7	.816	.665
41 to 65	24.3	75.7		
Greater than 66	66.7	66.7		

Food Security: Environmental Justice

To investigate fish consumption and fishing rates as an environmental justice issue, we combined the race and income variables. The intersection of race, income, and fishing frequency is presented in Table 5.5. Income was bifurcated at $50,000 annually into high and low income categories. Here high and low-income people of color fished more than once per week at a rate of 81.5%. Yet not all anglers of the same racial and ethnic category take home fish at the same rate. Seventy-three percent of low-income people of color took fish home versus 56% of high-income people of color. More strikingly, low-income Caucasian anglers only took home fish at a rate of 35%. Not only are people of color fishing more often, but they took home fish more often overall even when controlling for income. These rates are not statistically significant, but do reveal racial and income trends.

Table 5.5 Race, Income, and Fishing Frequency

Race and Income Intersection	Fish more than once per week (%)	Take Home (%)
Low Income Caucasian/ White	68.4	35
High Income Caucasian/ White	57.9	55
Low Income People of Color	81.5	73.1
High Income People of Color	81.5	56
X^2	4.4	6.666
p	.219	.083

Food Security: Change in Access Due to Riverfront Modification

Significant changes have occurred on both the Canadian and U.S. banks of the Detroit River in recent years, including the development of real estate, industrial site clean up, and new park locations. The anglers were asked whether the riverfront modifications significantly changed their fishing behaviors or activities. Table 5.6 highlights angler's responses to riverfront modifications. If the anglers responded yes, they were asked the open-ended question: “how.” Anglers reported a host of changes with positive and negative effects ranging from improved access and cleaner sites to increased crowding and the destruction of fish habitat. Reports of the effects of riverfront development were statistically significant between incomes. The highest ($50,000-74,999, 76.9%, *n* 13) and lowest ($0-24,000, 75%, *n* 8) income ranges most often reported positive riverfront changes. Reports of a negative effect due to riverfront changes were reported by the middle income ($25,000-49,999, 75%, *n* 16) group. Positive and negative changes in riverfront development were evenly split between the highest income groups. Changes in riverfront modification failed to be statistically significant for race, gender, education, country, location, and age.

Table 5.6 Riverfront Modification Results

Changes in riverfront modification	Positive Changes (%)	Negative Changes (%)	X^2	p
Race				
Caucasian	42.9	57.1	.881	.348
People of color	55.9	44.1		
Country				
Canada	46.7	53.3	.049	.825
USA	50	50		
Income				
$0-24,999	75	25	9.617	.022
$25,000-49,999	25	75		
$50,000-74,999	76.9	23.1		
$75,000-100,000+	50	50		
Gender				
Male	47.9	52.1	.012	.913
Female	50	50		
Education				
High school & less	46.9	53.1	.325	.569
Higher education	55	45		
Location				
Detroit	40	60	1.577	.455
Downriver	59.1	40.9		
Canada	46.7	53.3		
Age				
18 to 40	43.8	56.3	2.287	.319
41 to 65	52.6	47.4		
Greater than 66	0	100		

Food security: Perception of water quality

Anglers were asked to rate the Detroit River's water quality on a scale from 1 to 5, 1 being the worst and 5 the best, based on their perception. This variable was significant for race, education, country of residence, and age as illustrated in Table 5.7. People of color gave the Detroit River a higher rating in water quality than Caucasians. Fifty-two percent of people of color said the Detroit River was of moderate quality and 32.2% said it was of high quality; whereas 51.3% of Caucasians (*n* 39) perceived the Detroit River to have poor water quality and 35.9% reported the river to have moderate water quality. Canadian anglers (*n* 32) were more likely to give the Detroit River a lower quality rating, with 46.9% rating it as poor and 43.8% rating it as moderate. U.S. anglers (*n* 74) were more likely to give the river a moderate or higher rating, 45.9% and 29.7% respectively. Of all participants, younger anglers were more likely to give the river a lower quality rating than older anglers. The 18 to 40 year old age group rated the river as having poor water quality 47% (*n* 32) of the time, while 50% of the 40 to 65 (*n* 65) age group said the river had moderate water quality, and 60% of the greater than 66 age group (*n* 5) said the river had high water quality. Of those in the oldest age group, none reported the Detroit River to be of poor water quality.

Table 5.7 Perception of Water Quality

Water Quality	Poor (%)	Moderate (%)	High (%)	X^2	p
Race					
Caucasian	51.3	35.9	12.8	13.564	.001
People of color	17.5	52.4	30.2		
Country					
Canada	46.9	43.8	9.4	7.597	.022
USA	24.3	45.9	29.7		
Income					
$0-24,999	8.3	75	16.7	5.665	.462
$25,000-49,999	36.4	45.5	18.2		
$50,000-74,999	32.1	46.4	21.4		
$75,000-100,000+	35.3	35.3	29.4		
Gender					
Male	27.6	46	26.4	3.099	.212
Female	47.1	41.2	11.8		
Education					
High school & less	31.4	43.1	25.5	.449	.799
Higher education	27.3	50	22.7		
Location					
Detroit	16.7	50	33.3	9.009	.061
Downriver	29.5	43.2	27.3		
Canada	46.9	43.8	9.4		
Age					
18 to 40	46.9	37.5	15.6	9.664	.046
41 to 65	24.6	50.8	24.6		
Greater than 66	0	40	60		

Food Security: Perception of Water Quality and Fish Consumption

To discern whether or not anglers utilized their own perception to judge the appropriateness of fish consumption, we cross tabulated anglers' perception of water quality and tendency to take fish home. Table 5.8 depicts that those who take home more fish perceived the Detroit River to be of higher water quality. Those that practiced catch and release more often gave the Detroit River a lower water quality rating. Indeed those who took fish home at any rate gave the Detroit River water quality a moderate to high rating.

Table 5.8 Perception of Water Quality versus Number of Fish Taken Home

Water quality	Poor (%)	Moderate (%)	High (%)	X^2	p
Take home fish	22	45.8	32.2	9.785	.008
Catch & release	46.3	43.9	9.8		

Anglers that fished more than once a week reported a higher water quality rating than those who fished less than once a week as depicted in Table 5.9. The significance is just beyond a 0.5 alpha. Yet those anglers who fish less than once a week and give the Detroit River a poor rating have an adjusted residual of 2.5.

Table 5.9 Perception of Water Quality versus Fishing Frequency

Water quality	Poor (%)	Moderate (%)	High (%)	X^2	p
Fish more than once/week	24.7	49.4	26	5.879	.053
Fish less than once/week	50	30.8	19.2		

Social Interaction: Fishing habits

The questions regarding anglers' fishing habits highlighted from whom they learned to fish, with whom they shared their caught fish, how caught fish were prepared for personal consumption, and how well they were acquainted with other anglers on the shores of the Detroit River.

Social Interaction: Sharing of Fish with Family, Friends, and Neighbors

We asked the anglers who took home fish, if they shared fish, and if so, with whom. The response was divided into three categories of analysis: fish given to family, fish given to friends, and fish given to the community as depicted in Table 5.10. Age was the best indicator of with whom anglers share their fish. Eighty-four percent (*n* 19) of the 18 to 40 age group shared their fish with family. The amount of sharing their catch with family decreased as age increased. Likewise, the 40 to 65 age group most often shared their catch with the community (32.7%, *n* 55). In addition to age, the option to share their catch with friends was statistically significant for race/ethnicity and country of residence. Twenty-three percent (*n* 52) of people of color chose to share their catch with friends, whereas Caucasians shared their fish with friends only 4% (*n* 26) of the time. Similarly, U.S. anglers chose to share their catch 20.3% of the time while Canadian anglers reported that they did not share their catch. The analysis between income level and the giving of their catch to friends was significant. Approximately 42% of the low-income group ($0-24,999) reported giving their catch to friends, whereas 7.4% (*n* 27) of the middle-income ($25,000-49,999), 10.5% of high-income ($50,000-74,999), and 27.3% of the highest-income bracket ($75,000-100,000+) reported giving their catch to friends. We were not able to determine which income groups gave more often to family and to community as the outcomes were fairly evenly distributed.

Table 5.10 Sharing Fish with Family, Friends, and Community

Sharing of Fish	Family (%)	X^2	p	Friends (%)	X^2	p	Community (%)	X^2	p
Race									
Caucasian	53.8	.021	.886	3.8	4.355	.037	26.9	.214	.644
People of color	55.6			96.2			22.2		
Country									
Canada	55.6	.004	.948	0	.334	.563	33.3	1.338	.247
USA	54.7			20.3			20.3		
Income									
$0-24,999	58.3	4.677	.322	41.7	9.200	.056	8.3	7.569	.109
$25,000-49,999	59.3			7.4			33.3		
$50,000-74,999	47.4			10.5			10.5		
$75,000-100,000+	72.7			27.3			45.5		
Gender									
Male	56.1	.810	.368	15.2	.334	.563	22.7	.218	.641
Female	42.9			21.4			28.6		
Education									
High school & less	50	1.395	.238	21.4	1.117	.291	26.2	.676	.411
Higher education	63.6			12.1			18.2		
Location									
Detroit	53.8	.017	.992	19.2	4.384	.112	30	1.526	.466
Downriver	55.3			21.1			16.7		
Canada	55.6			0			26.7		
Age									
18 to 40	84.2	9.620	.008	5.3	2.254	.324	5.3	7.902	.019
41 to 65	45.5			20			32.7		
Greater than 66	33.3			16.7			0		

Social Interaction: Learning to Fish

As part of the survey, we asked the anglers who taught them how to fish and then divided their answers into 3 categories: someone of their generation, someone of their parents' generation, or someone of their grandparents' generation. Table 5.11 depicts with whom anglers learned to fish from. We wanted to discern if fishing was a cultural and social interaction. However, significance was inconclusive as generational fishing was evenly distributed between the three categories.

Table 5.11 Learning to Fish

Learn to Fish	Same Generation (%)	Parental Generation (%)	Grandparental Generation (%)	X^2	p
Race					
Caucasian	31.1	64.4	4.4	1.813	.404
People of color	34.8	54.5	10.6		
Country					
Canada	43.2	54.1	2.7	3.058	.217
USA	30.8	59	10.3		
Income					
$0-24,999	46.2	38.5	15.4	7.568	.271
$25,000-49,999	22.9	62.9	14.3		
$50,000-74,999	37.9	58.6	3.4		
$75,000-100,000+	50	45	5		
Gender					
Male	37.2	54.3	8.5	1.302	.522
Female	26.3	68.6	5.3		
Education					
High school & less	35.7	58.9	5.4	.935	.627
Higher education	33.3	56.3	10.4		
Location					
Detroit	33.3	50	16.7	6.394	.172
Downriver	29.2	64.6	6.3		
Canada	43.2	54.1	2.7		
Age					
18 to 40	27.3	57.6	15.2	5.3	.25
41 to 65	37.5	58.3	4.2		
Greater than 66	50	50			

Social Interaction: Fish Preparation

Anglers were asked how they prefer to prepare their fish. The possible options included frying, or baking and grilling as illustrated in Table 5.12. Overwhelmingly anglers chose to fry their fish. The option to prepare fish via frying was significant for income and education. All of the income groups except the $50,000-74,999 income bracket prepared their fishing by frying it 90% or more of the time. The $50,000-74,999 income bracket chose to fry their fish 58.8% (*n* 17) of the time.

Table 5.12 Fish Preparation

Preparation of Fish	Fry (%)	Bake or grill (%)	X^2	p
Race				
Caucasian	87	13	.631	.427
People of color	79	20		
Country				
Canada	87.5	12.5	.429	.512
USA	80.4	19.6		
Income				
$0-24,999	90	10.0	8.84	.031
$25,000-49,999	92	8		
$50,000-74,999	58.8	41.2		
$75,000-100,000+	90	10		
Gender				
Male	84.5	15.5	2.087	.149
Female	66.7	33.3		
Education				
High school & less	91.9	8.1	5.744	.017
Higher education	69.0	31.0		
Location				
Detroit	80.8	19.2	.435	.805
Downriver	80	20		
Canada	87	12.5		
Age				
18 to 40	80	20	1.228	.541
41 to 65	80	20		
Greater than 66	100	0		

Social Interaction: Acquaintance with other Anglers on the Detroit River

We asked Detroit River anglers how well they knew other anglers on the shores of the Detroit River. This was a closed-ended question that coded into categories: “know others well” and “don’t know others.” The results were statistically significant by education and location, as illustrated in Table 5.13. Sixty percent of those who had no higher education reported knowing other riverfront anglers well. Approximately 67% of Detroit-based anglers reported knowing other anglers well compared with Downriver or Canadian anglers. Acquaintance with other anglers was not significant by country, race, gender, income, or age.

Table 5.13 Acquaintance with other Anglers

Acquaintance with other Anglers	Know others well (%)	Don't know others (%)	X^2	p
Race				
Caucasian	43.2	56.8	.734	.391
People of color	51.5	48.5		
Country				
Canada	43.2	56.8	.232	.630
USA	48.1	51.9		
Income				
$0-24,999	53.8	46.2	.416	.937
$25,000-49,999	44.1	55.9		
$50,000-74,999	48.3	51.7		
$75,000-100,000+	50	50		
Gender				
Male	47.9	52.1	.071	.79
Female	44.4	55.6		
Education				
High school & less	60	40	5.191	.023
Higher education	37.5	62.5		
Location				
Detroit	66.7	33.3	7.078	.029
Downriver	36.7	63.8		
Canada	43.2	56.8		
Age				
18 to 40	40.6	59.4	1.524	.467
41 to 65	48.6	51.4		
Greater than 66	66.7	33.3		

Communication: Awareness of and Access to the Fishing Advisory

We posed a series of questions to determine the anglers' awareness and familiarity of the fish consumption advisory, illustrated in Table 5.14. First, anglers were asked whether they were aware of the current fish consumption advisory. There was no marked difference between interviewed people of color and Caucasians regarding fish consumption advisory awareness. Awareness of the advisory was, however, statistically significant with age. Sixty-four percent of the age group 41 to 65 (*n* 72) reported being aware of the advisory, and only 40.6% of the age group 18 to 40 (*n* 32) and 33.3% of the age group greater than 66 reported being aware of the advisory. Within income, the highest reported awareness, 72.4%, was in the $50,000 – 74,999 income bracket, while the lowest income bracket demonstrated the lowest awareness of fish advisories (38.5%).

Table 5.14 Awareness of Fish Advisory

Characteristic	Yes (%)	No (%)	X^2	p
Race				
Caucasian	50	50	.611	.434
People of Color	57.6	42.4		
Country				
Canada	45.9	54.1	1.573	.210
USA	58.4	41.6		
Income				
$0-24,999	38.5	61.5	4.900	.179
$25,000-49,999	52.9	47.1		
$50,000-74,999	72.4	27.6		
$75,000-100,000+	55	45		
Gender				
Male	55.3	44.7	.000	.985
Female	55.6	44.4		
Education				
High school & less	52.7	46.3	.326	.568
Higher education	58.3	41.7		
Location				
Detroit	63.3	36.7	2.047	.359
Downriver	55.3	44.7		
Canada	45.9	45.6		
Age				
18 to 40	40.6	59.4	6.111	.047
41 to 65	63.9	36.1		
Greater than 66	33.3	66.7		

Communication: Extent of Fish Advisory Knowledge

The next step in our assessment of advisory awareness was to ask anglers if they could describe the advisory's contents to determine the extent of their knowledge of the advisory. Table 5.15 depicts anglers' knowledge of material within the fish advisory. Nearly all of the Detroit River angler population gave responses with incorrect information, and many were unable to give any response. We were not able to discern statistical significance between those that said nothing, said an incorrect answer, or those that gave a partially correct answer. Yet, there was a marked difference between country of residence and the extent of the angler's knowledge of the advisory's contents. Of the Canadian anglers interviewed, 75% said they were aware of the advisory and could recite correct information pertaining to its content, while only 25% said they were aware and had incorrect or no information regarding its content. Of the American anglers interviewed, only 53.3% said that they were aware and had correct information of the advisory's content, while 48.7% reported awareness but had incorrect or no information about the advisory.

Table 5.15 Knowledge of the Fish Advisory Material

Characteristic	Don't know or wrong (%)	Correct or right idea (%)	X^2	p
Race				
Caucasian	59.1	40.9	2.230	.135
People of Color	72.7	27.3		
Country				
Canada	63.9	36.1	.183	.669
USA	67.9	32.1		
Income				
$0-24,999	76.9	23.1	4.668	.323
$25,000-49,999	68.6	31.4		
$50,000-74,999	51.7	48.3		
$75,000-100,000+	73.7	26.3		
Gender				
Male	67.7	32.3	.682	.409
Female	57.9	42.1		
Education				
High school & less	66.1	33.9	.047	.829
Higher education	68.1	31.9		
Location				
Detroit	60	40	1.569	.456
Downriver	72.9	27.1		
Canada	63.9	36.1		
Age				
18 to 40	84.8	15.2	13.127	.001
41 to 65	53.5	46.5		
Greater than 66	100	0		

Communication: Change in behavior due to advisory knowledge

Next we asked anglers how the advisory's information was helpful to them, if at all. We wanted to determine whether information from the advisory had provided the anglers with more knowledge, or had influenced the anglers to change or modify their fishing habits and behavior. Table 5.16 depicts anglers' knowledge of the fish advisory and its effect on their behavior. Of the entire angler population, approximately 60% believed that the advisory was helpful. Interestingly, 71% of women reported a change in behavior or knowledge, but due to a small sample size of women anglers this is inconclusive.

Table 5.16 Knowledge of Advisory and the Affect on Angler Behavior

Knowledge of advisory	Don't know or wrong (%)	Correct or right idea (%)	X^2	p
Admits no change in behavior	51.4	39.1	.844	.358
Admits change in behavior	48.6	60.9		

Communication: Fish Advisory Awareness and Fish Consumption

To ascertain whether or not anglers' awareness of the fish advisory affected their consumption of fish, we cross tabulated the amount of knowledge with the tendency to take fish home, as illustrated in Table 5.17. These variables were not statistically significant, yet, those who had some idea of the advisory's content were more likely to practice catch and release, but only by a small margin.

Table 5.17 Knowledge of the Advisory versus Number of Fish Taken Home

Knowledge of advisory	Don't know or wrong (%)	Correct or right idea (%)	X^2	p
Take home fish	60.3	54.3	.349	.555
Catch & release	39.7	45.7		

Lastly, anglers were asked whether they knew where they could access a fish advisory. The majority of anglers stated that they could access the advisory on the internet. However, many anglers believed that fish advisories were given with their license or could be obtained at a physical location such as a K-Mart, a Bait Shop or Canadian Tire.

Communication: Environmental Justice and Fish Consumption Advisory Knowledge

As previously noted we combined race and income variables to access knowledge of fish advisories as an environmental justice issue. Table 5.18 illustrates the intersection of race, income, and anglers' knowledge of advisory contents. Again, the results are not statistically significant but interesting. Low-income Caucasian/white anglers correctly reported the contents of the advisory 40% of the time, versus 21.4% of low-income people of color. There was very little difference in the rate of advisory knowledge between different incomes within the Caucasian/white demographic. Overall, individuals of all races and incomes were unaware of the fish consumption advisory contents.

Table 5.18 Race, Income, and Knowledge of the Advisory's Contents

Race and Income Intersection	Knowledge of advisory contents (%)	X^2	p
Low Income Caucasian/white	40	2.8	.408
High Income Caucasian/ White	42		
Low Income People of Color	21.4		
High Income People of Color	35.7		

Results from Stakeholder Angler Analysis

Factor Analysis Results

A factor analysis was conducted to ascertain the similarity of the 11 search engines used in the cluster analysis. Four factors emerged. Table 5.19 illustrates the results of the search engine factor analysis. The Detroit Free Press, Google, Detroit News, and MEC loaded on factor one. The NWF, EMEAC, and the website search loaded on factor two. The Lansing State Journal and Crain's Business Detroit loaded on factor three. The Metro Times and the Sierra Club loaded on factor four, but with opposite sign, indicating an inverse relationship between these two sources.

A second factor analysis was conducted using 10 search variables and two factors emerged. Table 5.20 illustrates the results of the search terms factor analysis. The search variables justice, license, pollution, fish, chemicals [dioxin, mercury, PCB], cleanup, and environment appeared in component one. The variables parks, Detroit River, and racism appeared in component two.

Table 5.19 Factor Analysis of the Search Engines

Search Engine	Factor 1	Factor 2	Factor 3	Factor 4
Detroit Free Press	.889	-.003	-.085	.102
Google	.881	.316	.005	-.041
Detroit News	.880	.119	.334	.057
Michigan Environmental Council	.680	.394	-.057	.071
National Wildlife Federation	.173	.886	-.093	-.208
East Michigan Environmental Action Council	.179	.886	-.096	.139
Website	.239	.885	.159	.237
Lansing	.172	-.025	.909	-.020
Crain's Business Detroit	-.088	-.039	.869	.207
Sierra Club	-.197	.094	.002	-.864
Detroit Metro Times	-.091	.304	.246	.594

Table 5.20 Factor Analysis of Search Terms

Search Term	Factor 1	Factor 2
Justice	.943	.153
License	.940	.036
Pollution	.903	.388
Fish	.881	.447
Chemical	.887	.387
Cleanup	.784	.443
Environment	.782	.520
Parks	.296	.950
River	.235	.943
Racism	.240	.897

Cluster Analysis Results

In the Detroit News searches, the MDNR and EPA appeared together in a cluster, the MDCH, United States Fish and Wildlife Service (USFWS), and MDEQ appeared in another cluster, and Wayne County appeared in a final cluster. The clusters were significantly different from each other with respect to the "Detroit River" and "parks" variables. In the Detroit Free Press searches, the MDEQ appeared in cluster one, Wayne County in cluster two, the MDNR, EPA, MDCH, and the USFWS appeared in cluster three. The variables that significantly distinguish the clusters are environment, fish, justice, license, and parks. The cluster analysis from MEC produced three clusters. The MDNR and USFWS appeared in cluster one, the EPA and Wayne County in cluster two, and the MDCH and MDEQ in cluster three. The clusters are significantly different by the variables chemicals, fish, justice, parks, and pollution. The information from each website was combined according to search variable. The MDNR appeared in cluster one, the EPA in cluster two, and the MDCH through Wayne County in cluster three. The clusters are distinguishable by the following variables: the Detroit River, chemicals, cleanup, environment, fish, justice, license, parks, and pollution. Google was utilized as a broad search engine, highly visible to the public sphere. Wayne County appeared in cluster one, the EPA cluster two, and the MDNR, MDCH, USFWS, and MDEQ appeared in cluster three. The clusters are significantly different by all of the variables except racism. The clusters from Crain's Business Detroit, the Lansing State Journal, the Detroit Metro Times, East Michigan Environmental Action Council, the National Wildlife Federation, and the Sierra Club failed to be significant.

Stakeholder Commonality

The most common variables in this study included fish, pollution, chemicals, river cleanup, and environment. Figures 5.2, 5.3, 5.4, 5.5, and 5.6 depict each stakeholder breakdown by news source. There were few references of the terms justice and license. A total frequency for the topics that hung together as an important environmental factor (fish, pollution, chemicals, and environment) were tallied and plotted against "river" frequencies for the six stakeholders to illustrate how they clustered within search sites. The graphs for the sources that resulted in significant cluster difference are presented subsequently.

Figure 5.2 Stakeholder Clusters from the Detroit News

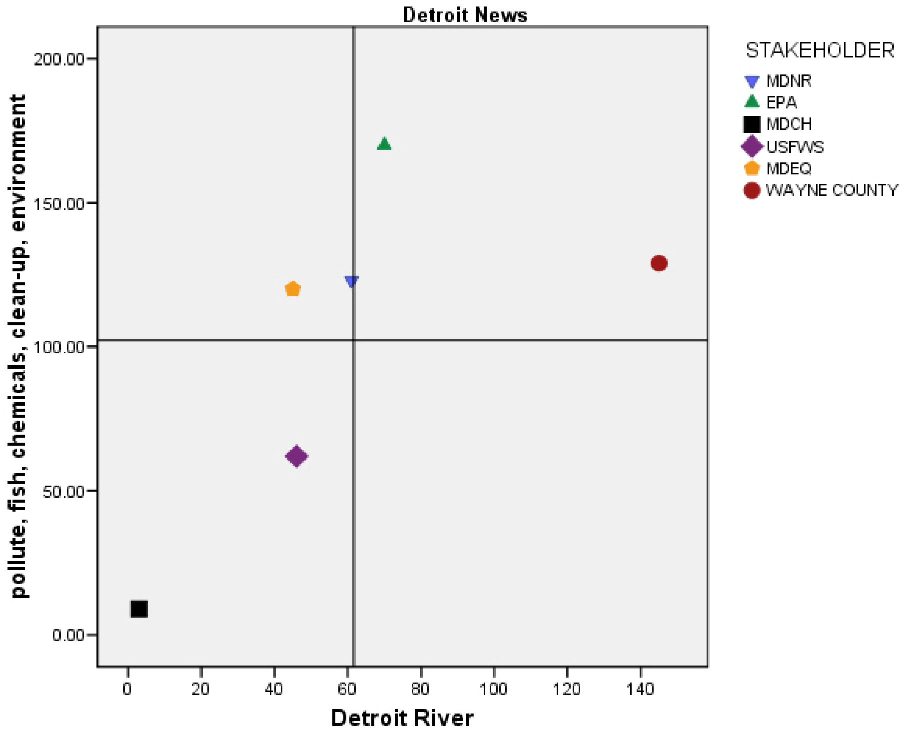


Figure 5.3 Stakeholder Clusters from the Detroit Free Press

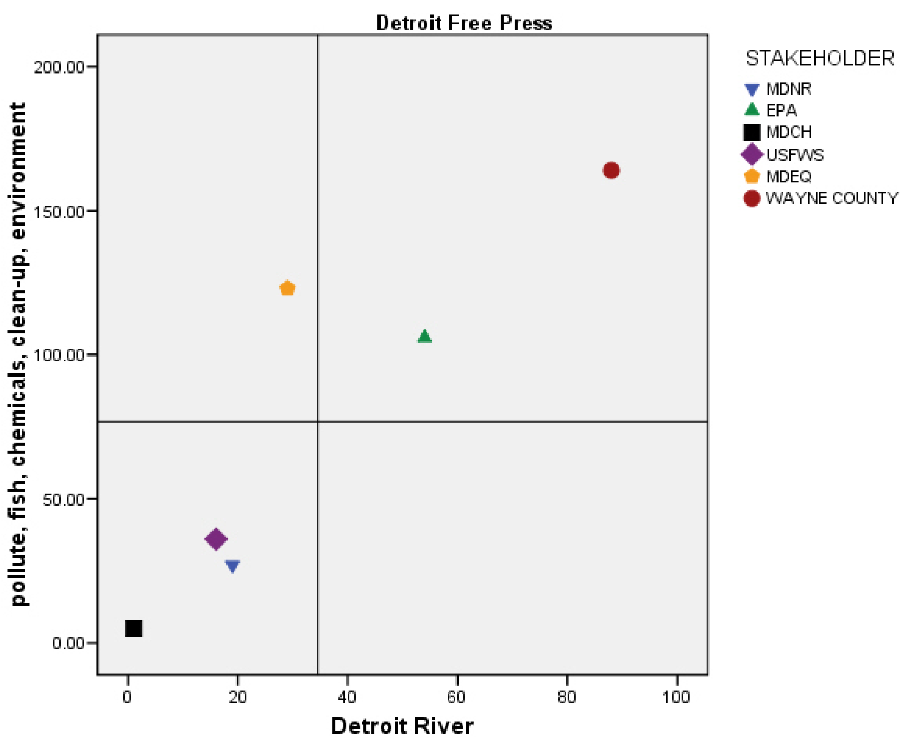


Figure 5.4 Stakeholder Clusters from the Michigan Environmental Council Website

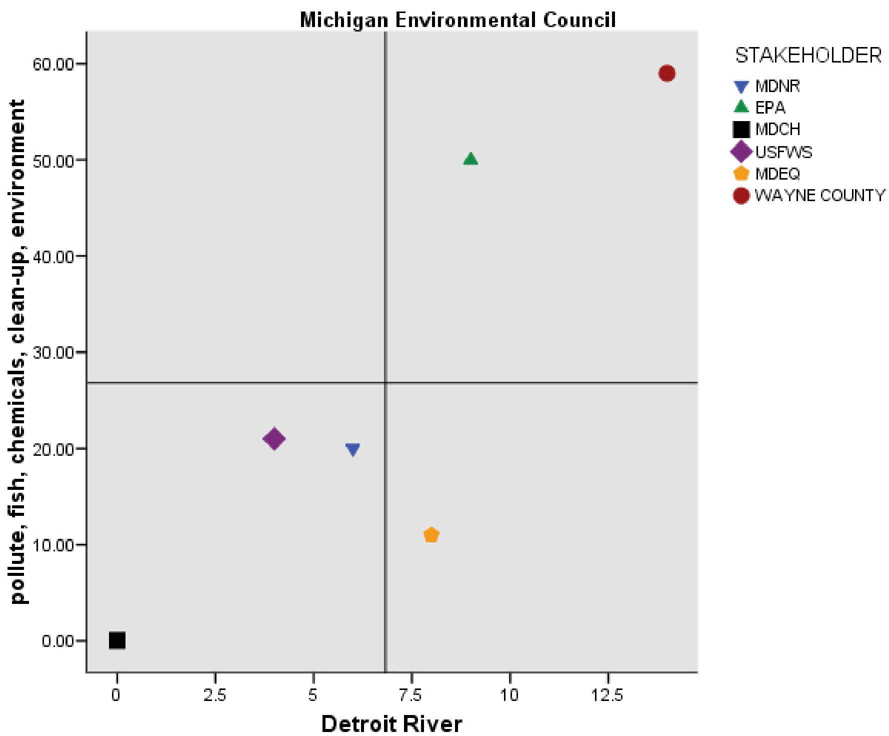


Figure 5.5 Stakeholder Clusters from Various Stakeholder Websites

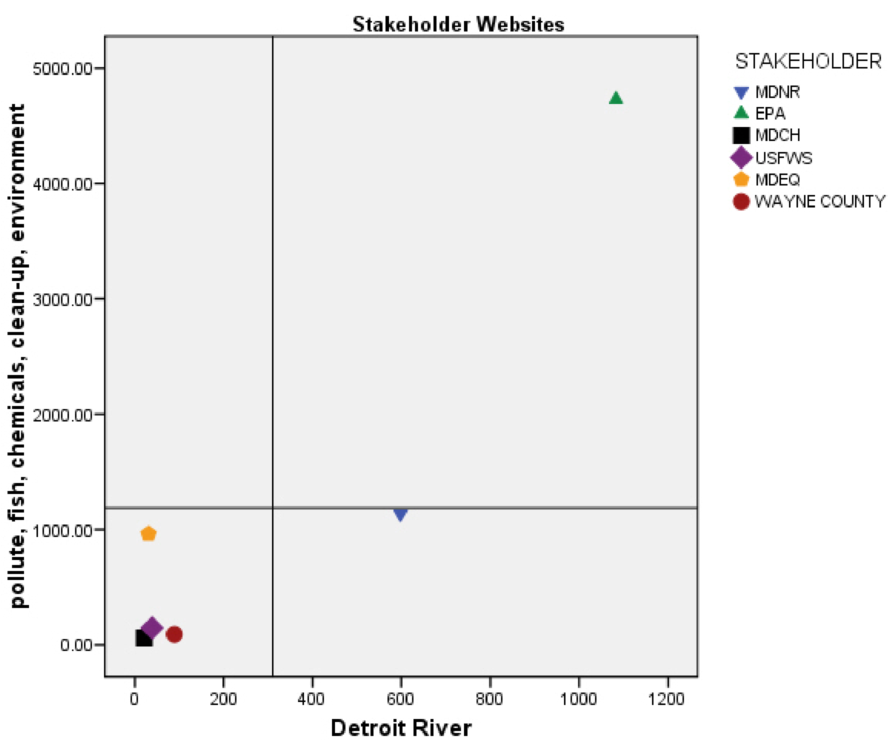
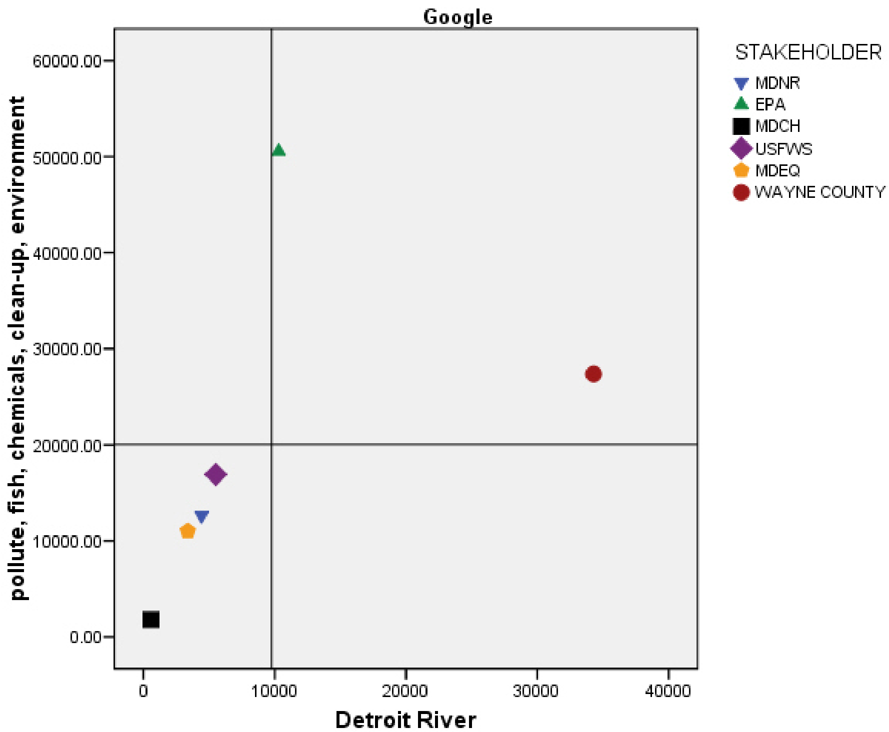


Figure 5.6 Stakeholder Clusters from Google Search Engine



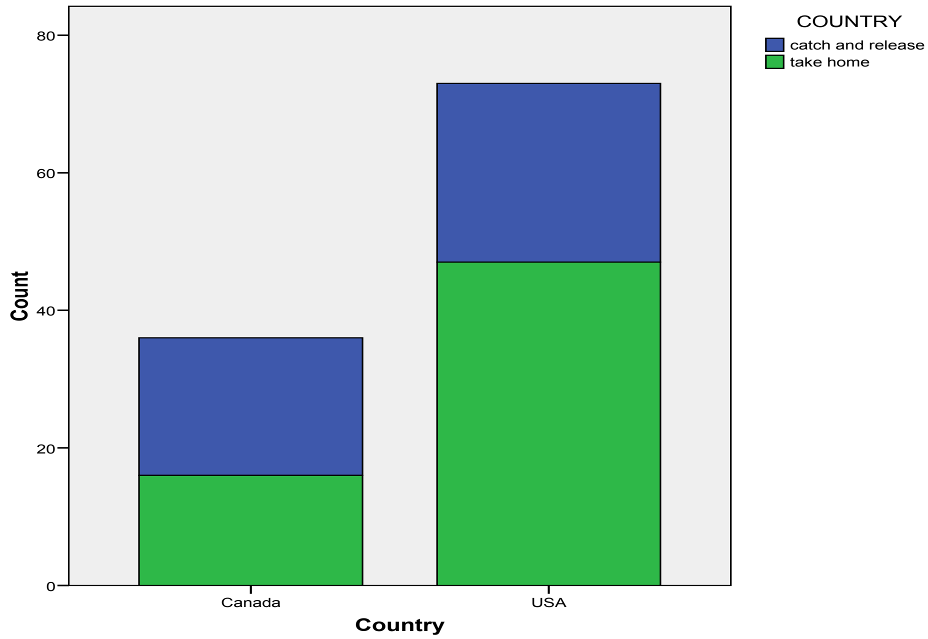
CHAPTER 6: DISCUSSION

CHAPTER 6: DISCUSSION

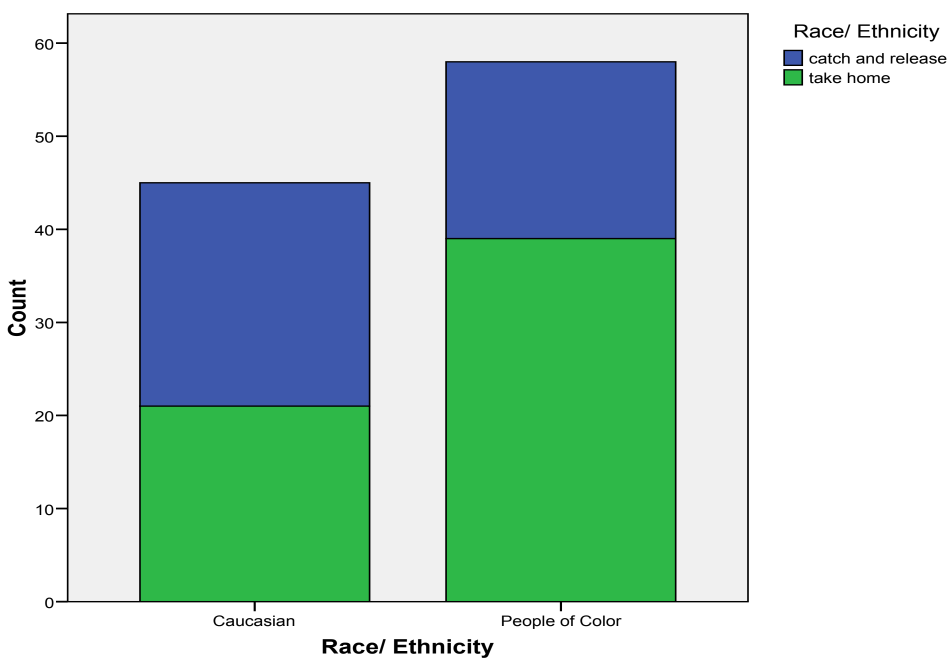
Fish Consumption as an Environmental Justice Issue

Fish consumption advisories and fish consumption on the Detroit River is indeed an environmental justice issue. Fishing for sport versus fishing for food on the Detroit River is significantly marked by race and fishing location, but not by gender, income, education, or age (Figure 6.1 and 6.2 below). We might attribute this disparity to external factors such as the river's flow, proximity to the River Rouge—a major contributor to contaminant loads—or other external factors, however, this disparity cannot be divorced from the racial composition of downriver inhabitants and the City of Detroit. While the City of Detroit is vastly African-American, downriver cities such as Wyandotte and Trenton are over 95% Caucasian. The geographic disparity of those who catch and release also implicitly indicates a racial disparity. When combined with frequency, our results demonstrate that Detroiters are taking more fish home in greater numbers and frequency than their downriver counterparts, putting Detroiters and people of color in a distinctly higher risk category. They are least likely to be aware of risks because of the State's failure to successfully warn them of these potential risks of consuming contaminated fish.

Figures 6.1 Number of People by County Who Practice Catch and Release versus Take Home



Figures 6.2 Number of People by Race/Ethnicity Who Practice Catch and Release versus Take Home



The portrait of subsistence anglers falls in line with other researchers' reports of consumers in other urban areas. Unlike Burger et al., income was not a significant indicator of catch and release versus take home practices, suggesting a more complex interaction with the resource than one based solely on income.[106] West also found in 1992 that low-income anglers of color were not the highest consumption group. He was surprised at the time that low- and middle-income anglers of color were consuming fish at the same rates; we found there was no significant difference, and therefore no change in behavior by income. Yet people of color in the United States, and specifically within the City of Detroit, tend to take home fish more often than their white or Canadian counterparts.

A 47-year old Caucasian woman fishing at Mill Park in Windsor, Ontario stated, "We fish in Windsor purely for pleasure, further north is where the good eating fish are." The woman's comment was indicative of Canadians' preference for pleasure fishing near home and fishing for a food source in other areas. This is consistent with Dawson's findings that Canadian anglers believe that the fish caught "up north" are cleaner, less contaminated, and better tasting.[107] Fishing for sport in contaminated areas like the Detroit River and traveling to other bodies of water to practice fishing for food points towards a luxury of disposable income for travel. This disposable income was contrasted by the comments of one angler of color who candidly stated that, "White people fish for sport, I fish for child support." Yet fishing in and consuming fish from the Detroit River is not purely an economic indicator as reflected in consumption by income. Rather we must look beyond simple economics to understand what motivates people to consume fish from the Detroit River. When we asked anglers if they fished in other locations, some anglers mentioned

[106] Burger, J., Stephens, W., Boring, C., Kuklinski, M., Gibbons, W. J., & Gochfield, M. (1999). Factors in exposure assessment: Ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River. *Risk Analysis*, *19*(3).
[107] Dawson, J. (1997). Hook, line and sinker: A profile of shoreline fishing and fish consumption in the Detroit River area. *Health Canada Fish and Wildlife Nutrition Project.*

other local areas and other anglers referenced going up north or down south to fish. More research is definitely needed regarding geographical preferences for recreational activities and its relationship to social structures like race and income.

Women are also more likely to take fish home, but due to the small sample size of women on the riverfront, our result is inconclusive. The interesting aspects regarding race, location, and gender are reflected in the simple demographics of Detroit. In 2006, 40% of Detroit's households headed by a female lived below the poverty level. The added pressure to provide resources for their families compounds the weight of costs and benefits when deciding whether or not to take fish home. Formerly, advisories were distributed to WIC offices, but since Michigan's Department of Natural Resources budget was cut, women and children at high risk have not received information through local resources. More research is needed on women anglers in Detroit and on the exposure pathways drawn from Detroit River fish.

There are several possible reasons why some people practice catch and release fishing and others take fish home for consumption. Many of those that consume fish also reported a higher perception of water quality. This indicates that those who feel the water is clean also feel that the fish are safe to take home and consume. Anglers with a low perception of water quality tended to use fishing as a social activity rather than as a food resource. Those anglers who preferred to take fish home, especially anglers of color, reported sharing their catch with others. Hornbarger et al. found in 1994 that the gift culture of fish was important to African-Americans on the Detroit River, indicating that there was social capital attached to catching and sharing fish. This proved to be true for many in our sample population within Detroit. People often said that they offered the fish they caught to family and some anglers said that they gave it to their friends, neighbors, churches, or held community barbeques. Given the insecure food situation that many people in Detroit face, fish have become a social currency as well as a health and nutrition asset. For some anglers, catch and release fishing refutes the very simple need for food. Subsequently, we explore some of the explanations for prioritizing the benefits of fish consumption over the risks of potential exposure to contaminants.

Types of Fish

It is important to discuss not only what population is taking fish home but also what species of fish are consumed and how often they are consumed. Figure 6.3 illustrates the sum of specie preference by race/ethnicity. Some species, such as catfish and carp, are more highly contaminated than others. Fish species is also an indicator of cultural or racial preference. While only 6% of Caucasian anglers reported taking catfish home to consume, 31% of people of color reported engaging in this activity. People of color reported taking home silver bass eight times more often than that of white anglers, and largemouth bass over three times more often, while Caucasian anglers reported taking yellow perch home nearly twice as often as people of color. This suggests that racial and ethnic groups on the Detroit River have established different preferences in regards to consumable fish species. This concurs with Hornbarger et al.,[108] Burger,[109] and Hunt's[110] conclusion that ethnic and racial groups have different behaviors and preferences with regard to type of species consumed.

The reasons that the different racial and ethnic groups surveyed take home different fish species are likely based on cultural differences. Some anglers candidly commented that many people of color migrated to the Detroit area from the South during the industrial

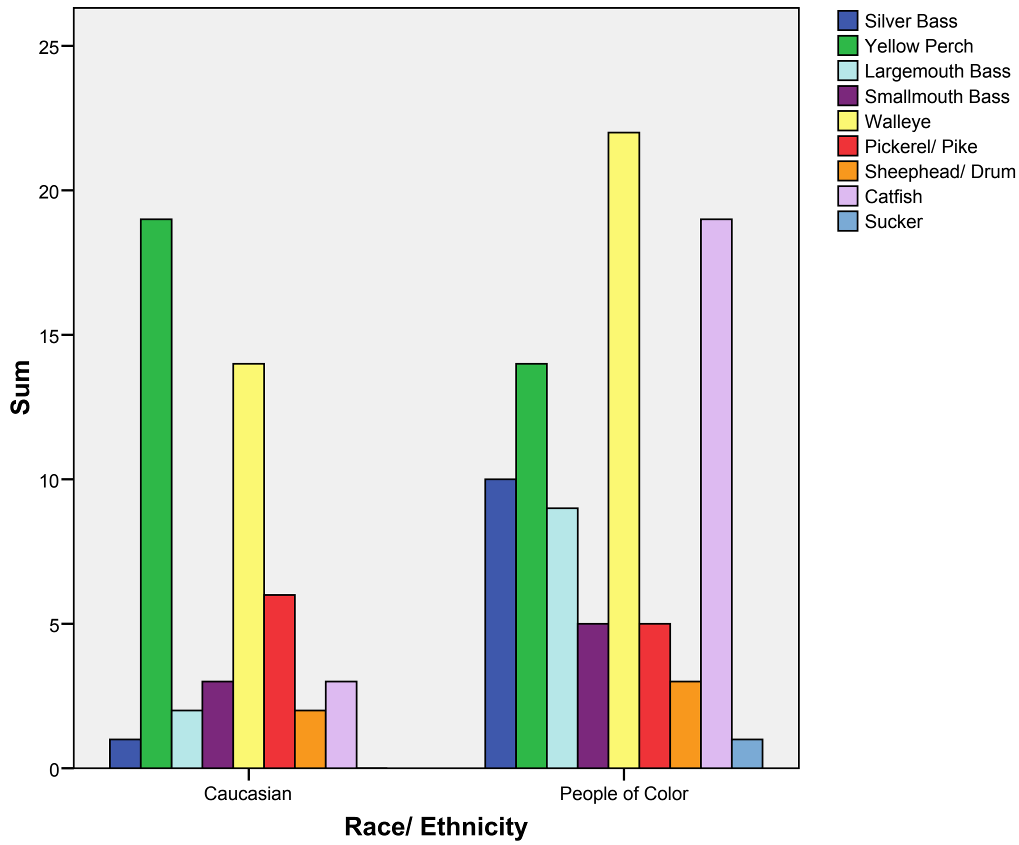
---

[108] Hornbarger, K., MacFarlene, C., & Pompa, C. R. (1994). Target audience analysis: Recommendations for effectively communicating toxic fish consumption advisories to anglers on the Detroit River. In *Natural Resources Sociology Lab Technical Report #11*. Ann Arbor, MI: Natural Resource Sociology Research Lab, University of Michigan.
[109] Burger, J. (2002). Consumption patterns and why people fish. *Environmental Research.* Section A 90, 125-135.
[110] Hunt, K., & Ditton R. (2002). Freshwater fishing participation patterns of racial and ethnic groups in Texas. *North American Journal of Fisheries Management, 22*(1).

revolution in search of jobs and to escape racial inequalities that beleaguered southern states. With them, they brought the cultural activities of fishing as well as cooking southern style food that includes catfish as a favored dish. This is supported by our statistics that fishing as an activity is intergenerational. We infer that those who learned such a skill also learn which fish are acceptable for consumption. Walleye is a species that is often caught for sport and and is generally favored by all anglers for consumption. There is an international walleye and bass fishing tournament on the Detroit River that actively promote pelagic sport fish, typically more available to those that have access to boats. This type of sport fishing is then often attributed to more affluent anglers.

Yet there is a social stigmatization of those people who eat certain types of fish species, a stigmatization that is racialized in Detroit. Some people believe that anglers who consume fish from the Detroit River—especially benthic, or bottom feeding, fish—are poor, or inferior in some way. Bottom-feeders like catfish and carp are more likely to have higher levels of contaminants than pelagic fish of the same water body because of their trophic feeding level. Therefore, benthic fish are often referred to, or suggested to be, "dirty" or "bad" fish. One Caucasian angler admitted not knowing many details in the advisory, but said he knows, "Don't eat too many bottom feeders, especially not catfish." Another angler in Elizabeth Park stated, "I don't mean to be racist, but black people eat carp." Another Downriver angler said, "Black people will eat anything." These statements were misinformed representations which directly associated the perceived unacceptable habit of consuming benthic fish with a single racial group. The acceptability of consumption of benthic fish is tempered by contamination. Thus, the interface of pelagic specie preference and fish contamination not only puts those with preferences for benthic fish in a higher risk category for contamination, but also associates them with inappropriate social behavior, i.e., eating bad fish. With their lack of protection from contamination, benthic fish, and their consumers will continue to be stigmatized socially and racially. More qualitative information is needed to assess fish consumption as an acceptable practice.

Figure 6.3 Sum of Specie Preference by Race/Ethnicity



Frequency of Fishing

Of the anglers surveyed, there is a sharp distinction between those who fish infrequently and those who fish consistently throughout the summer months. In comparing those anglers who fish greater than once a week and those who fish less than once a week, the majority of those who fish more than once a week were men of color on the U.S. side of the Detroit River and within the City of Detroit. This may be explained by the large population of people of color in Detroit, but it also points to our many conversations with anglers who felt more comfortable fishing in certain areas and parks. For example, Mariner's Park on the east side of Detroit was a favored location for people of color. At

Mariner's Park, they had developed a real sense of community in which they were able to be themselves and share culturally significant experiences. The anglers noted the many activities they share together including fish fries, equipment sharing, and knowledge exchanges.

Some of the anglers that we interviewed in Detroit had been fishing for up to 40 or 50 years, and shared much knowledge with us about fishing, preferred fishing spots and changes in access over long periods of time. Anglers in Detroit utilized many different parks on the river to fish. We often went from Belle Isle, Riverview Park on the Southwest side and Mariner's Park on the East side, at times meeting anglers we had previously interviewed throughout our study period. Through these regular visits to fishing spots, social capital is built and knowledge is shared. For example, many anglers in Detroit spoke openly and at length about invasive species and the arrival of the round goby. Without reading a newspaper, or finding information on the internet, its presence was known by anglers, and behaviors shared. Anglers also skinned and gutted fish to share knowledge with our research team and demonstrate the fish's anatomy. An entire lexicon of fish health assessments, independent from the state advisory, had been established to discuss fish edibility. This confers with Beehler's study in Buffalo, New York, that showed African-American men preferring localized knowledge over state-based information. Local knowledge not only shows expertise and experience on the river, but brings commonality to the space. In Beehler's article, he mentions that African-American New York anglers have at times interacted with Detroit anglers, and that their language and preferences for fishing differed. Detroit is a unique fishing community that values time on the river, and relies on it for food, but also for a social community.

From these insights we can infer that subsistence anglers of color are not only taking fish home at a greater proportion and eating more types of fish, but are fishing with more frequency than Caucasian anglers. Simply put, eating fish from the Detroit River is acceptable to some, depending on what types of fish are consumed and what part of the river they come from. In 1992, West found that black anglers consumed more fish, and more types of fish than Caucasian anglers.[111] This not only indicates that fish consumption is an environmental justice issue on the Detroit River, but one that has been sustained for at least the past 15 years.

Are Fish Consumption Advisories an Environmental Justice Issue?

Our research has shown that fish consumption advisories on the Detroit River are indeed an environmental justice issue. Anglers fishing on the Detroit River do so in contaminated waters. While it may seem that they have the choice to consume or not consume the fish they catch, there are several compounding factors including cultural values, communication of risk, access to information, food insecurity and institutional trust. The following discussion demonstrates in detail that this is indeed the case.

Awareness of the Fish Consumption Advisory

Knowledge of fish consumption advisories on the Detroit River is an environmental justice issue. The contents of the fish consumption advisory also represent an environmental justice issue due to the difference in angler specie preferences and behaviors on the Detroit River. These issues indicate the complicated relationship anglers have with information held within the fish consumption advisory and the State of Michigan that develops it.

We asked Detroit River anglers if they were aware of the local fish consumption advisory, and then asked a follow up question regarding what they could tell us about the

[111] West, P., Fly, M., Larkin, F., & Marans, R. W. (1994). Minority anglers and toxic fish consumption: Evidence from a statewide survey of Michigan. In B. Bryant & P. Mohai (Eds.), *Race and the incidence of environmental hazards: A time for discourse.* Boulder, CO: Westview Press.

local fish consumption advisory. Roughly half of all respondents reported awareness of the advisory, which is consistent with Tilden's findings in 1997 on the Great Lakes.[112] There was no significant difference between any particular group by income, education, race/ethnicity, or nation. When prompted to state *what* they knew about the consumption advisory, very few participants could clearly describe the advisory's contents. Few anglers could correctly report the advisory's details, such as naming a specific contaminant or the recommended reduced fish consumption by species. There was no significant difference between any of the racial or ethnic groups regarding the amount of knowledge they could recite regarding the fish consumption advisory. However, low income anglers of color were least knowledgeable of the advisory's contents. Taken as a whole, our findings support concerns highlighted in our literature review that awareness of the fish consumption advisory in the Great Lakes area is low among all populations.[113] [114]

The only significant category in awareness of the fish consumption advisory was age. The least awareness age group was individuals less than forty years of age. This is consistent with Tilden et al.,[115] Anderson et al.,[116] and Imm.[117] Imm compared the results of advisory awareness between 1997 and 2001 in the Great Lakes area and found that the youngest age group, 18-34 years of age, had actually decreased in awareness from 49% to 38%, while the older age groups either reported similar or increased awareness. Imm's

---

[112] Tilden, J., Hanrahan, L P., Anderson, H., Palit, C., Olson, J., Kenzie, W.M. (1997). Health advisories for consumers of Great Lakes sport fish: Is the message being received? *Environmental Health Perspectives*, *105*(12).
[113] Ibid.
[114] Imm, P., Knobeloch, L., Anderson, H., & and the Great Lakes Sport Fish Consortium. (2005). Fish consumption advisory awareness in the Great Lakes Basin. *Environmental Health Perspectives*, *111*(10).
[115] Tilden, J., Hanrahan, L P., Anderson, H., Palit, C., Olson, J., Kenzie, W.M. (1997). Health advisories for consumers of Great Lakes sport fish: Is the message being received? *Environmental Health Perspectives*, *105*(12).
[116] Anderson, Hanrahan, Smith, Draheim, Kanarek, & Olsen, J. (2004). The role of sport-fish consumption advisories in mercury risk communication: A 1988-1999 12 state survey of women age 18-45. *Environmental Research*, *95*.
[117] Imm, P., Knobeloch, L., Anderson, H., & and the Great Lakes Sport Fish Consortium. (2005). Fish consumption advisory awareness in the Great Lakes Basin. *Environmental Health Perspectives*, *111*(10).

findings, along with our research, might suggest that as anglers grow older they become interested in the substance and information of fishing advisories. Yet the younger age group, while practicing anglings, does not seek out that information. With the absence of access to a Michigan fish advisory, younger anglers do not receive the information when they purchase a license, and therefore, must voluntarily seek out the fish consumption advisory on the internet.

In the United States, the Michigan fish consumption advisory is only available on the internet, whereas in Canada the advisory is available online and in print at multiple locations, including businesses that sell fish licenses. Anglers were asked if they were aware of the location in which they could access a fish consumption advisory, if indeed they wished to read it. Although not statistically significant, 50% of people of color knew where they could access the fish consumption advisory compared to roughly 74% of their Caucasian counterparts. One hundred percent of anglers over 65 were aware that it was available on the internet, indicating an overall awareness of the advisory and where to find it.

An angler may be aware of that fish consumption advisory has been issued, but if it is not readily available at a local shop, he or she may not be able to access it at all. Even still anglers are not able to access the advisory online or are unaware of its existence. Some suggested that a sign on the riverfront or publishing the information in a newspaper would be adequate. In the past, WIC offices distributed advisories directly to at risk populations such as women and children, which provided information access to the most vulnerable populations. It would be beneficial to once again target those that are at most risk. Additionally, further research must be conducted concerning internet access. Many people knew that the advisory could be found online, but did not indicate whether they had access to a computer, or the skills and knowledge to go online and find it.

Awareness of fish consumption advisories, and anglers' relationship to its information, are two qualitatively separate categories of analysis. If knowledge is not incorporated, it could be for a variety of reasons, such as distrust of the state as suggested by Hornbarger et al. or food security issues as previously discussed. When asked about the fish consumption advisory, one 71-year-old, African American male stated, "White people don't want us to eat anything, they want us to starve." This particular angler was very distrustful of any information provided, and continued to state his displeasure with the system and disregard for information from institutional sources. An angler in River Rouge demonstrated a similar sentiment, stating, "The people in Lansing, they don't know what's going on down here—and they don't care." This confirms the continued distrust within the angling community that Hornbarger et al. found in 1994.[118] Therefore fish consumption advisories are an environmental justice issue as the state fails to provide adequate information and protect the anglers from the polluted waters.

Locally generated knowledge becomes an important aspect of risk communication on every level. But how local is local enough? Beehler suggests that sources of knowledge must be generated by the community itself as a form of agency.[119] The anglers we spoke with had their own vocabulary to assess the health of fish. Many anglers commented that a bad fish is one that smells like oil, has tumors or sores, or is soft to the touch. They explained that fish such as these should not be eaten. Others claimed that a bad fish will taste bad or that a good fish will curl in the pan. More investigation on local forms of

[118] Hornbarger, K., MacFarlene, C., & Pompa, C. R. (1994). Target audience analysis: Recommendations for effectively communicating toxic fish consumption advisories to anglers on the Detroit River. In *Natural Resources Sociology Lab Technical Report #11*. Ann Arbor, MI: Natural Resource Sociology Research Lab, University of Michigan.
[119] Beehler, G., McGuiness, B., & Vena, J. (2001). Polluted fish, sources of knowledge, and the perception of risk: Contextualizing African American anglers' sport fishing practices. *Human Organization*, *60*(3) 288-287.

knowledge and assessment should be done to highlight the connections between local forms of knowledge, language, and their links to contamination risk and exposure.

The State's Role

Inevitably, anglers depend on the state to communicate which fish are acceptable to eat and which fish are unsafe to eat, as the state is the sole source of contaminant testing and consumption advisories. Neither Michigan nor Ontario mandate that anglers limit their consumption and neither imposes a fine or fee associated with simple consumption. The fish consumption advisory is a suggestion to reduce risk. The state has the monopoly on the information, knowledge, and resources associated with not only monitoring the fish within the Detroit River but also existing and emerging pollution. This monopoly of information is extremely important to note, because this information, pertinent for some anglers to change their behavior, is still not readily accessible. Other interactions between U.S. anglers and the state exacerbate the distrustful relationship, which further conflates the fish consumption issue with the food security issue.

Fish consumption advisories and other testing methods in the Detroit River are inherently skewed as only certain types of fish are listed or tested. For example, the Michigan fish consumption advisory for the Detroit River does not list catfish. Catfish are also not listed as a fish tested through the MDEQ's Fish Contaminant Monitoring Program on the Detroit River.[120] In Canada however, catfish are listed and limited consumption is recommended both the Upper and Lower Detroit River. Therefore,unless U.S. anglers obtain the Ontario Fish Consumption Guide, they will not be exposed to this information. If an angler from the United States does receive the Canadian advisory, they are receiving

[120] Michigan Department of Environmental Quality. Fish contaminant monitoring program. Retrieved March 8, 2008, from http://www.deq.state.mi.us/fcmp/.

information that is inconsistent with the Michigan advisory, which may confuse the angler. This scenario is a potentially hazardous one for the U.S. catfish consumer. In one study conducted through the Great Lakes Institute for Environmental Research, shockingly higher levels of total PCBs were found in channel catfish than in other benthic feeding fish.[121]

The testing of fish for contaminants, and fish consumption advisories, are therefore an environmental justice issue on the U.S. side of the Detroit River. Subsistence anglers on the U.S. bank of the Detroit River have access to a limited amount of information concerning their specific eating habits. This limited information places U.S. anglers in a food insecure environment due to contaminants and the lack of information catered to their specific behavior and culture. This problem is linked to the lack of information present in Michigan-based fish consumption advisories, state testing, and the advisory's limited distribution channels. Because of variation in behavior, historical disenfranchisement, and spatial segregation, this problem is racialized, largely affecting the family and community structure of subsistence anglers.

Moreover, in assessing subsistence anglers' understanding of the fish consumption advisory we must also look at the other forms of river governance. The state's other representative on the Detroit River is the DNR. Some anglers of color reported that plain clothed DNR officers came and took away their catch and equipment without revealing their status as an officer until after the angler showed their fish. Anglers' interactions with the river are moderated by the state, which assumes the dual role of enforcement and regulation of the anglers. Since 1994 some anglers have continued to ask: instead of regulating anglers, why doesn't the state stop harmful pollution?[122] From this perspective, which further

[121] Li, H., Drouillard, K. G., Bennett, E., Haffner, D., & Letcher, R. (2003). Plasma associated halogenated phenolic contaminants in benthic and pelagic fish species from the Detroit River. *Environmental Science and Technology,* 37, 832-839.
[122] Hornbarger, K., MacFarlene, C., & Pompa, C. R. (1994). Target audience analysis: Recommendations for effectively communicating toxic fish consumption advisories to anglers on the Detroit River. In *Natural*

illustrates that fish consumption advisories are indeed an environmental justice issue, one can understand how anglers who depend on the Detroit River for food resources, could reject the presence of the advisory as a defiant act of self-preservation. Food security then becomes an issue of power relative to the role of the state and the urban angler.

How Does Fish Consumption Affect Food Security Issues?

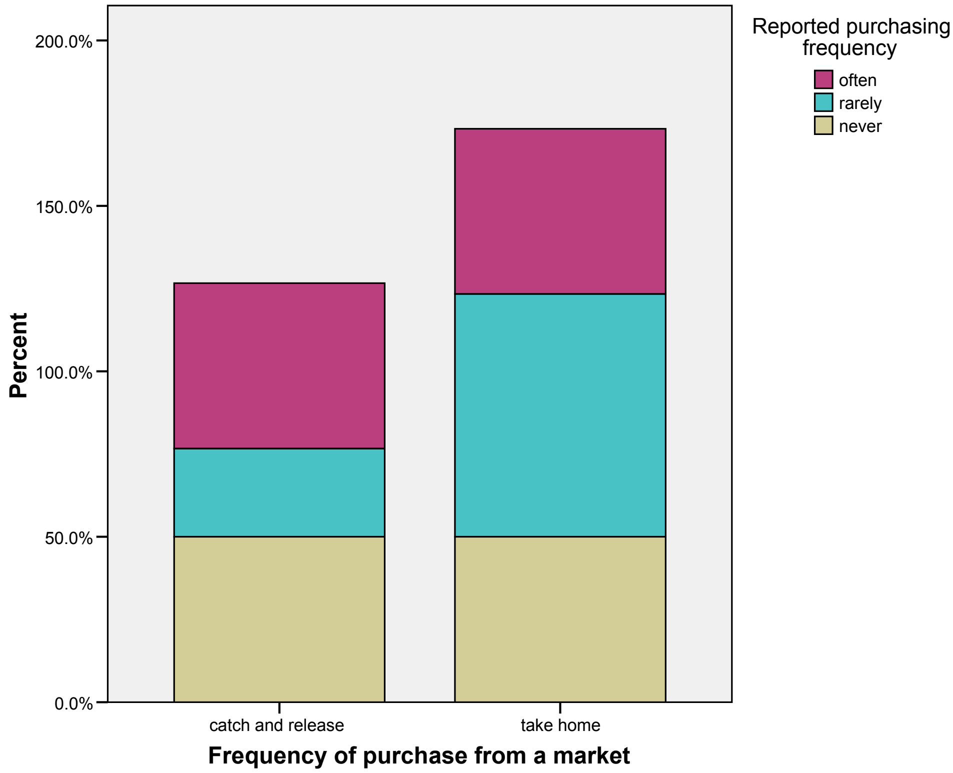
At the onset our research, Detroit was already considered a "food desert"—a place where a majority of food distribution centers sold non-food products. News of one of the last chain grocery stores closing piqued our interest and sense of urgency about the food security situation in Detroit. We therefore sought to determine what elements make fishing in the Detroit River a secure food resource. It is important to note that fish are a viable food resource not simply because they are present, but also because fish are considered safe, socially and physically acceptable. Fish consumption as a secure food resource is tempered by contamination, species, social preference, access to alternatives, and a personal risk assessment contingent on a variety of factors, primarily perception.

Importance of Fish to the Diet

People of color assigned significantly greater importance to the role of fish within their diet overall. Figure 6.4 illustrates the frequency of fish purchased by anglers from a market. Yet in Canada, 55% of all anglers reported that fish was an important aspect of a well-balanced diet, compared to 35% of U.S. anglers, although Canadian anglers generally don't take their catch home. This discrepancy could be explained by the multiple sources of fish purchasing and consumption within Canada. By nation, a larger proportion of U.S. anglers reported that they rarely buy fish from a market or grocery store.

Resources Sociology Lab Technical Report #11. Ann Arbor, MI: Natural Resource Sociology Research Lab, University of Michigan.

Figure 6.4 Frequency of Fish Purchase from a Market



Social and Cultural Activities

Our results overwhelmingly indicated that fishing is a social activity, yet fish consumption is not socially acceptable for all. According to the state, unlimited consumption of certain fish is not acceptable or safe. Likewise, according to many people, any amount of consumption of certain species, like carp or catfish, is taboo. And according to some fish consumers, catfish and other species are favored over others. Again, people of color do not fish for sport at the rate that white anglers do—and the different groups, even when controlling for income, have different behaviors with regards to their interactions with fishing and fish consumption. Sharing fish caught from the Detroit River plays an important social role for anglers of color. This demographic shares their fishing knowledge and catch to build social capital that may accrue more benefits than the perceived cost of contamination exposure. The risk of food insecurity is a factor in that some anglers reported a lack of accessible fishing areas and limitations of consumption through contamination risks.

Sharing fish as a social activity

Fishing can be understood as an important intergenerational, social and cultural activity, from which knowledge is generated and passed on to others. Fishing is a learned skill, often taught by someone of a parental or grand parental generation. Of all anglers surveyed, approximately 60% of them learned how to fish from their parental generation and 35% learned from someone of their own age. Seventy-seven percent of the anglers surveyed, reported having taught someone else to fish. Many anglers reported that they found fishing to be an important aspect of their lives that allowed them to relax and enjoy nature. It was also often reported that fishing was a welcomed change, an opportunity to enjoy time with family and friends, particularly children. This information is consistent across all incomes, races, ages, and education levels. The idea of shared knowledge creates the foundation for our understanding of social acceptability of fishing as an activity. Yet there is a marked difference in those who fish for recreation or sport versus those who take their catch home for consumption.

Eighty-three percent of those who consume their catch report sharing it with others. Significantly, U.S. people of color with an annual household income of less than $25,000 reported "friends" as the primary recipients of their Detroit River catch. The highest income bracket, and those aged 40-65 over any other age group proved to be the significant characteristic in giving food to the community. In addition to the fact that fishing is an intergeneration activity, the act of giving fish away to family and friends suggests a larger network of fish consumers beyond that of Detroit River anglers. This is especially dependant upon the angler's age, race or ethnicity, income level, and nation of residence.

Hornbarger et al. and Dawson also highlight the importance of gift culture on the Detroit River, indicating that sharing fish has long been a tradition.[123]

Access

Over the past several years, both the United States and Canada have been developing their riverfronts as an effort to both meet the Remedial Action Plan's goals to eliminate the beneficial use impairments, and to rehabilitate the riverfront for multiple uses such as parks, entertainment, and housing. The developments have been met with both criticism and praise. We asked anglers if their fishing habits were affected by the riverfront changes, and their responses were roughly divided into positive and negative comments. Other forms of access to the resource are related to boating, and as stated before, access to other bodies of water.

Park Access

Many anglers referred to the improved environment along the river, including increased safety, cleaner areas in new parks, railings, grass, and decreased rabble-rousing from individuals perceived to be a threat. In Canada, recently renovated downtown parks offer clean walkways and sculpture parks. In Detroit, the Downtown Riverwalk has expanded shore access and the Detroit International Wildlife Refuge has begun to invest heavily in the shoreline improvements southwest of the city. In response, some anglers reported improved access to the river, more fishing options, cleaner sites, and improved parking and road access. One 60–year-old, African-American male fishing at Belanger Park in the United States noted that the "parks are much nicer, no 'crazy acting' people." An

[123] Dawson, J. (1997). Hook, line and sinker: A profile of shoreline fishing and fish consumption in the Detroit River area. *Health Canada Fish and Wildlife Nutrition Project.*

Arab/Middle East angler at Dingell Park reported that the changes discouraged "messy anglers" who are "unwelcome" at the recently renovated parks.

Many anglers also complained of reduced access to favored fishing spots and explained that former fishing sites had been replaced with new parks in which they felt unwelcome. The transference of public property to housing, or private property, also presented a challenge. One angler fishing at Dingell Park in Wyandotte, Michigan, noted that the new developments created "less area to fish, more pubic areas for kids and sitting." Other anglers indicated the new parks, attracting more people to downtown areas, making them more crowded and unwelcoming to anglers. A 47-year-old, female angler from Mill Park in Windsor, Canada, noted that she "didn't like to fish downtown, too many people, it is not quiet enough." Some anglers argued that the new parks were degrading the environment, destroying fish habitat, and contributing to the pollution. To support this criticism, they highlighted the rip rap rocks on shore, construction, and increased litter and trash from park visitors. A 49-year-old, African male fishing on Belle Isle noted that "They cut the fisherman out from fishing. They are cut off from the bank fishing. It affects them in that they can not afford a boat. The majority of people cannot afford a boat in Detroit. Many people buy property [along the shore] and they don't want you fishing there."

Our research team also noticed the incredible amount of private property that spanned the Canadian areas south of La Salle, and a lack of industrial areas adjacent to fishing areas. Canadian anglers have a direct view of the industrial activities on the Michigan side of the River. Although there remains some areas of industrialization on the Canadian shore, they are buffered by private property and green areas that make the river inaccessible. Canadian fishing spots do, however, have direct views of industrial areas on the Michigan side. Smoke stacks, factories, and other industrial sites are visible from the Canadian parks as well as the American ones. In the City of River Rouge, the park is located entirely within the property of an industrial site. The upkeep and investment in parks may also influence the perception of water quality.

Anglers that fish from the banks of Trenton's Elizabeth Park have recently received a lot of press about the Detroit River, and the country's first International Wildlife Refuge, in which the park is placed. The park is beautiful and clean, with new boardwalks, weekend music, and other community activities. To enter Riverside Park from the City of Detroit, anglers must cross one of the heaviest truck traffic areas from the Ambassador Bridge. In Riverside Park, as well as Mariner's Park on the east side of Detroit, there is trash, litter, iron parts, and broken glass. There are no bathrooms and anglers and others are left without decent necessities. Although some men feel this is not required for outdoor activities, many indicated that women and children did not feel comfortable recreating here without bathroom facilities. The City of Detroit has recently invested millions of dollars into the new Riverwalk and Belle Isle, but some anglers no longer feel welcome to fish on those shores. This disparity on the U.S. side has not gone unnoticed. One angler commented that, "Downriver they take care of their anglers. And the Grand Prix is the only reason they cleaned up Belle Isle." More research should be conducted regarding the disparate resources along the Detroit River and how it affects anglers' relationship to the River.

Access to Open Waters

We asked anglers if they had fished by boat and many indicated that they do on occasion, but without physical evidence of boating activity and frequency it was difficult to verify these statements. One African-American angler summed up the disparity in water access by stating that, "People in boats are generally white . . . there is definite segregation of people in boats and fishing on the shore—it is very crowded when the fish are running and boaters call police on the shore anglers." Interactions such as these demonstrate the strain between boaters and on-shore fisherpeople, with those with more access using their position to intimidate and remove any competition from other anglers. Another angler explained that people in Detroit simply cannot afford boats, and therefore cannot compete or utilize the more lucrative fishing spots away from shore.

Perception of Water Quality and Fish Consumption

The limitations on fish consumption are related to the quality of the water that flows down the Detroit River. The perception of water quality is highly variable, but significantly determined by race, age, and locality. Anglers of color generally rate the water quality to be of moderate to high quality and white anglers tended to rate the water quality as moderate to low. Those who perceive the Detroit River to be of moderate or of high quality were found in the United States, and remarkably in the City of Detroit, rather than their Downriver counterparts. This same demographic not only tends to fish more frequently, but are more likely to take fish home rather than practice catch and release.

We understand these findings to reflect the highly segregated geography in Wayne County. Anglers in Detroit take great pride in fishing on the Great Lakes. It offers an escape from the city's stress, heat, and traffic. Mariner's Park in Detroit, specifically, is located at the intersection of the Detroit River and Lake St. Clair, which we found to be quite beautiful, with no views of industrial activities. Rather, Mariner's Park was an area where the water was filled with boaters and revelers from the wealthier northern suburbs of the Gross Pointes and St. Clair Shores. While the park itself was in disrepair, the surrounding views across the river and on Lake St. Clair are of trees and naturally landscaped areas. The lack of visual contact with polluting activities may influence anglers' perception of the Detroit River as clean.

Older anglers also believed that the water quality had improved, often explaining that fish kills or oil spills were common in the past compared with the present. Many older anglers noted that the water is "much cleaner than it used to be." A feeling of pride in Detroit is also incredibly important to maintaining the integrity of the community and its resources. Believing that the Detroit River's water quality is high is integral to accessing fish as a food resource in a generally food insecure area like Detroit. We might assume that for an angler to believe the river is polluted is to devalue his or her source of a healthy food resource.

Perception of water quality is also related to the relationship that anglers have to the resource. Those anglers who fish on the Detroit River more than once a week also have a more positive association, and therefore perception, of the resource. People in Detroit also commented that along with the improved water quality, the fish were getting bigger and increasing in quantity. Some anglers were concerned about how the fish's behavior has changed. For example, they preferred fatty food baits rather than worms. Anglers were also concerned about water levels, indicating that they have been steadily dropping. But those who visited the river with greater frequency did have very positive attitudes about the resource and its contents.

Canadian anglers performed catch and release fishing more often than Michigan anglers, fished less frequently, and generally reported a lower water quality in the Detroit River. This may indicate increased awareness of contamination in fish or more concern for the amount of contamination they visualize in the Detroit River. A 42-year-old, Caucasian male fishing at La Salle Park in Ontario noted that the water "Has gotten cleaner, still not up to par. As long as we have big industry in Sarnia, it will never be clean." Although many Canadian anglers recognized clean-up efforts and political movement toward remediation, consumption levels were still significantly less than in the United States. Wide-spread distribution of the fish consumption advisory may be the cause for fish consumption concerns, but other forms of health knowledge may be accessible with conflating factors such as universal health care available in Canada.

We visually observed the presence of several industrial areas clearly visible to Canadian anglers directly across the river from where most public fishing areas are located. Many of the locations where Canadian anglers fished were also not polished parks, but rather empty dirt lots that were difficult to access. These lots were often littered with trash and the only access to the waterfront was through a precarious hike down large rip rap boulders. Canadian anglers also pointed out the many industrial activities, including Zug Island, they were able to see from their favorite fishing spots both in Ontario and Michigan. This may contribute to the Canadian anglers' perception of lower water quality than their American counterparts.

Balancing the Risks and Benefits

Knuth et al. offer interesting insights into the process of the evaluation of risk in their 2003 report on weighing health benefits compared to health risks.[124] Of the nearly 5,000 anglers interviewed, they found that when risks of contamination were high most respondents would eat less fish regardless of the benefits, yet when risks were low anglers changed their behavior in accordance with the magnitude of the perceived benefits. With regards to water quality, if an individual believes that the water quality is good, he or she is more likely to take fish home. Knuth et al.'s research points to an interesting relationship of self-evaluation necessary for food security and fish consumption.

[124] Knuth, Connelly, Sheeshka, &Patterson, J. (2003). Weighing health benefit and health risk information when consuming sport-caught fish. *Risk Analysis*, 23(6) 1185-1197.

Those who caught and ate fish in the Detroit River felt they could trust the Detroit River as a resource because they could look at the water or fish and directly assess them. One African American angler fishing at Elizabeth Park in Trenton, Michigan, noted that he was aware of the fish consumption advisory, but "paid no attention [to the advisory], the same stuff [can be bought] in the grocery store." This angler elaborated, "Why would I buy something I can catch myself," but also indicated that he felt there was no need to pay attention to the information provided because the store bought alternatives were associated with the same risks. There was also a sense of safety in locally caught fish. The fear of buying fish from a grocery store was also expressed by some anglers who did not trust the source of store purchased fish. One angler stated that there was a higher risk involved in eating fish brought from China than those caught in the Detroit River. This viewpoint may have some validity as Hites found that farmed salmon had significantly larger amounts of total contaminants than wild salmon[125]. For those who did not consume Detroit River fish, the sentiment was the opposite. Many believed that sushi or store bought fish were more reliable, safer, or cleaner. Without a similar advisory relating the contaminant levels compared to Detroit River fish, many will remain in the dark about their contaminant exposure.

There is also an interesting cultural component to the process of risk evaluation. If we add the cultural value of fishing as a benefit to the process of risk evaluation in the way Knuth et al. did with health benefits, we can understand the negative trade off involved with giving up fish.[126] Gift culture, as a practice, infers social capital built in exchange for non-monetary goods. In Detroit, sharing fish with family, friends, or the community plays an important role in social cohesion. To accept fish consumption as a health risk, thus sacrifice

---

[125] Hites, R. A., Foran, J. A., Carpenter, D. O., Hamilton, M. C., Knuth, B. A., & Schwager, S. J. (2004). Global assessment of organic contaminants in farmed salmon. *Science*, *3*, 226–229.
[126] Knuth, Connelly, Sheeshka, &Patterson, J. (2003). Weighing health benefit and health risk information when consuming sport-caught fish. *Risk Analysis*, 23(6) 1185-1197.

the gifting process would have great social consequences. Health officials in Native American communities have reported similar trends.[127] If one community is threatened by elevated risks and abandons the cultural practice, aspects of the tribe's culture are also threatened.

Health risks must also be weighed against other relative community risks in Detroit. One angler stated that "Fishing is the perfect drug prevention program." This angler keenly highlighted that other personal safety issues are present so that fish contamination seems like less of a risk. Many in Detroit have already been told that the air and soil are contaminated, meaning the threat of contaminated fish is minor or yet another layer of risk.[128][129] One Detroit angler offered fish to his elderly neighbors, saying that if he didn't bring food, who knows what they would eat. Anglers must balance other personal and environmental risks compared to their assessment of the risk of fish contamination.

With this we would like to offer fish consumption advisories and environmental justice on the Detroit River to the body of literature dealing with food security in the City of Detroit. Fishing is a culturally acceptable way of accessing a healthy source of Omega-3 fatty acids and offers a seasonally consistent resource. People share knowledge and resources, be it bait, fishing spots, or fish. In an area where access to fresh fruit and vegetables are scarce, fish is a healthy component for creating a well-balanced diet. Some subsistence anglers on the Detroit River are simply not willing to allow the state to moderate their behavior, gift culture, knowledge, or access to relaxation and food. The question is

---

[127] Corey, F. (2007). Aroostook Band of Micmacs: Fish consumption advisory issues. In *EPA Forum on Contaminants in Fish*, Retrieved June 26, 2007, from http://www.epa.gov/waterscience/fish/forum/2007/pdf/section2g.pdf

[128] Keehler, Dvonch, Yip, Parker, Israel, Marsik, Morishita, Barres, Robins, Brakefield-Caldwell, & Sam, M. (2002). Assessment of personal and community level exposures to particulate matter among children with asthma in Detroit, Michigan as a part of community action against asthma. *Environmental Health Perspectives*. *110*(2).

[129] Bryant, B. & Hockman, E. (1994). *Hazardous Waste and Spatial Relations According to Race and Income in the State of Michigan*. (R) in progress.

then, how can we protect those most vulnerable from contamination without removing the value of such a practice?

Cluster Analysis Discussion

Many anglers use sources other than the state issued fish consumption advisory to derive conclusions about the Detroit River, Michigan sport fish, current pollution news, and efforts towards river cleanup. Local newspapers are quite often the source of this information and the most prominent sources of information in our study included the Detroit News and Google. It appears that these information sources are not only highly visible in the public sphere but also provide significant information about fish and pollution on the Detroit River.

The Detroit News, the MDCH, USFWS, and MDEQ were the four most visible stakeholder agencies. These three stakeholders are the most active in providing information on the Detroit River when searching for the phrases: pollution control, fish testing, and water quality (MDEQ), park improvement through the International Wildlife Refuge (USFWS), and fish consumption advisory development and distribution (MDCH). The MDEQ and MDCH are responsible for developing the Michigan fish consumption advisory. Overall these institutions are responsible for the monitoring, recuperation, and overall ecological health of the Detroit River, and furthermore, responsible for providing local residents with that information. It is advantageous that this local news source actively engages in the dialogue between anglers and the environmental governance institutions. And since the Detroit River is a very popular and heavily used fishing location, it is of the utmost importance the connection between anglers and institutions. Based on the high level of reporting it is possible to state that fish, the Detroit River, and pollution, are very visible and important concerns of residents along the river.

Our search in Google yielded the EPA and Wayne County as the two most visible stakeholders on the Detroit River. Their cluster was defined by parks, fish, pollution, and river cleanup, which allows us to assume that concerning the Detroit River, these two agencies are highly correlated with pollution, parks, and cleanup on the Detroit River. Both of these agencies are active in monitoring polluting industries. Therefore, we can also assume that these agencies have the most impact on holding industries accountable for pollution and demanding cleanup.

Cluster Analysis Conclusion

The visibility of several government institutions' actions concerning fish, pollution, and communication on the Detroit River offers the general public some idea of what the institutions' responsibilities are within the region. This also offers the general public, and citizen organizations, a point of reference from which river governance can be assessed, critiqued, or potentially accessed. Of the six government institutions that were active in some capacity on the Detroit River, the MDCH, USFWS, and MDEQ, defined by the terms Detroit River, environment, fish, parks, and pollution, are the most prevalent category from the Detroit News. The Detroit Free Press defined the clusters similarly to the Detroit News. It appears as though the Detroit News and Free Press were the strongest determinants in regards to what concepts each stakeholder was related to in the public sphere.

Anglers can rely on the Detroit newspapers to report on the Detroit River environment and name the appropriate institutions responsible for their governance. Yet these sources generally do not connect racial, social, or environmental justice issues. Whether or not anglers choose to either blame, or praise institutions mentioned above is also a separate but necessary component of future analysis. Furthermore, considering that these institutions are not democratic electorates, this may also confer with issues of trust related to the Detroit River's governance and anglers. Institutional accessibility or accountability was not explored in this study, but is a necessary component for future research.

.

Limitations

As with all studies, we dealt with some limitations and challenges that may affect our data and results. These limitations include the small overall sample size of anglers, the comparatively small number of Canadians, and the short time span during which the surveys were conducted. By the end of the survey period, we began to encounter many of the same anglers we had already interviewed. Some anglers mentioned that the hot August weather was a lull in the fishing season due to the "dog days of summer," which may have lowered the number of anglers fishing on the shores of the Detroit River during our survey period. We traveled to Canada several times and did not encounter anglers at any of the locations, indicating a generally lower number of Canadian anglers on the Detroit River. Fishing locations on both sides of the river often proved to be a research challenge as well. One way that we found locations for interviewing anglers was by asking about their favorite fishing spots during the survey process. Many anglers reported fishing at locations that are not official parks. These areas were very often fenced in or industrial private property, into which we did not feel comfortable venturing. This limited us from encountering some favored fishing spots and possibly the most vulnerable fishing population.

Another barrier to the interviewer-angler trust relationship was their past experiences with the DNR and trust. Trust between the interviewees and anglers may also have been a factor. While only a few anglers declined to participate in the survey, many of those who did participate indicated a lack of time or interest in speaking with us. Additionally, those who may have been afraid of our keeping track of their catch numbers may not have been entirely truthful when self-reporting. Some anglers responded with answers such as “enough” or “the limit” when asked how many fish they take home. This likely affected our data on the self-reported numbers of fish consumed by anglers. One way we dealt with these trust issues was to provide refreshments to the anglers

Regardless of these limitations and challenges, we had an overall pleasant and positive experience interviewing anglers on the Detroit River. Most anglers were open and happy to provide their input for our study, as well as curious to find out the results. The survey and anecdotal information we gathered will be invaluable to our understanding of the environmental justice issues surrounding fish consumption on the Detroit River.

Playground area at Belanger Park, River Rouge, MI

Elizabeth Park, Trenton, MI – Boardwalk

Elizabeth Park, Trenton, MI – Boardwalk

Fishing Dock at Belanger Park, River Rouge, MI

Riverside Park, Detroit MI

Mill Park, Ontario, Canada

Mill Park, Ontario, Canada

Summary

Our study's purpose was to identify angler groups on the Detroit River and assess which among them rely on the Detroit River as a food extractive resource. We sought to engage in a dialogue with the anglers on their perception, knowledge, and attitudes towards fishing and fish consumption on the Detroit River Area of Concern. Specifically, we asked anglers about their fishing habits, their fish consumption patterns, and the extent to which they were concerned about water quality and its effects on the fish. This information was then used to understand how fish consumption relates to Detroit River AOC fish consumption, water quality and contamination perception, and the intersection within a food secure network. Simply put, to whom is eating fish from the Detroit River acceptable, and why or why not.

1. In the subsequent discussion we seek to understand if fish consumption is an environmental justice issue. For those individuals living around the Detroit River, they flock to the Detroit River for leisure and to fish. However, we also found that anglers of color and U.S. anglers were taking fish home with them at a higher rate, fishing more frequently, and sharing their fish with friends and family. The network of river to table may be wider than we once formerly thought.

2. Fish consumption advisories can also been seen as an environmental justice issue, however, further explanation is required. Anglers of color report awareness of the fish consumption advisory at a greater proportion than their white counterparts. Yet when asked to recall information from the advisory, over 70% of anglers of color and 60% of Caucasian anglers reported that they could not recall any of the advisory's information or were wrong when recounting facts. The message relaying the dangers of elevated fish consumption is

not reaching everyone across the board—and it is especially not reaching people of color. In addition, there are several external considerations that should be taken into account when discussing the advisory's creation. For example, certain species of fish and explanations of chemicals are not represented in the U.S. advisory that are available in Canadian advisory. This creates an additional consideration for environmental justice, in that agencies are currently not responding to the cultural differences and preferences of anglers by race and ethnicity. This is highlights the idea that an effective advisory would not deal solely with angler awareness, but also agency awareness.

3. On the agency side of this equation, we sought to understand the way in which institutions were working to protect angler populations and the corresponding ecosystem. To accomplish this, we looked at how governing bodies within the United States interact with the Detroit River, and how that is reflected in the news and on the internet. Pollution, fish, clean-up, and environment are the terms most often associated with the Detroit River. Racism and justice did not closely associate with the Detroit River. The Detroit News, Detroit Free Press, and Google were the best in providing information about the terms: pollution, fish, Detroit River clean-up, and the environment. Overall, it depends on which resource you are looking at to see how river agencies relate to those concepts.

4. Lastly, we wanted to incorporate what we knew about food insecurity and our findings on subsistence fishing on the Detroit River. We asked what elements make fishing in the Detroit River a secure food resource. Our results demonstrated that fishing is a social activity, yet fish consumption is not socially acceptable for all anglers. Again, people of color do not fish for sport at the rate that white anglers do—and the different groups, even when controlling for income, have different behaviors in regards to their interactions with

fishing and fish consumption. Sharing fish caught from the Detroit River plays an important social role for anglers of color. These anglers share knowledge about fishing and contamination as well as their catch, building social capital and potentially accruing more benefits than the perceived cost of contamination exposure. The risk of food insecurity is a factor for some anglers reporting a lack of fishing areas and consumption limitations.

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

CHAPTER 7: CONCLUSION AND RECOMMENDATIONS

In 2005 and 2006, 22 states and Washington D.C. reported that 100% of their lake acres and river miles were under advisory for one or more contaminants. The total number of active advisories in the United States in 2005 totaled 3,373.[130] In 1992, the state of Michigan eliminated appropriations necessary to communicate those risks through a physical advisory. Ashizawa states that, "As our scientific knowledge base increases, policy evolves resulting in changes to improve the activities used to promote and protect the public health. The more targeted approach by Great Lakes states [Wisconsin and Pennsylvania] for fish advisory communication programs is an example of that change."[131] However, our data show that this decision is not affecting all populations in the same ways. If scientific knowledge is increasing on fish consumption risks, who is this scientific information or policy serving, or protecting?

More efforts for targeted fish consumption advisories must respond to the actual behaviors of high risk groups. In the case of environmental research, the connection between contaminants and human activities is paramount. With regards to the specific case of Detroit, Michigan, and beyond, the continued contextualization of race and income must take place. We have found that Michigan fish consumption advisories do not adequately communicate the risks according to fish consumer habits and behaviors in the Detroit River. In 1992, West wrote that, "A broader confirmation of these pilot study findings would also have implications for more intensive, focused 'targeting' of fish consumption advisory communications to sub-groups such as urban minorities that are at a greater risk due to disproportionate consumption of fish from polluted rivers, but who may be less apt to read

[130] Environmental Protection Agency. (2007). 2005/2006 National listing of fish advisories. In *USEPA Office of Water*. Retrieved March, 4 2008, from http://www.epa.gov/fishadvisories
[131] Ashizawa, A., Hicks, H., & de Rosa, C. (2005). Human heatlh research and policy development: Experience in the Great Lakes region. *International Journal Hygiene and Environmental Health*, *208*.

and abide by standard fish consumption advisory brochures." These findings were available as early as 1990,[132] and they remain true in 2008.

The state of Michigan may not have the ability to address fish consumption advisory issues because of current budget constraints, but other efforts are taking place to protect anglers. Those efforts must take into consideration anglers' knowledge, attitudes, and beliefs regarding fish and contamination. They must not provide anglers with information regarding contamination but allow anglers to be a part of the process of defining risk. Otherwise, government institutions will continue to run the risk of speaking "in the undifferentiated bureaucratic monotone… which perpetuates environmental injustice by failing to consider the cultures, attitudes, and behaviors of a segment of the population that does not look like bureaucrats of the state."[133] Decentralization of natural resource management and the contextualization of costs and benefits within the community that is exposed to those risks are both at the crux of the environmental justice movement.[134] We again define environmental justice in this context as people of color and those with low-incomes are differentially impacted by the risks of contaminated fish because fish consumption advisories fail to take into consideration cultural, social and economic needs. Because of cultural, economic, and food security reasons, they are forced out of habit to fish the Detroit River, contaminated by point and non-point source pollution. This becomes an environmental injustice issue when the State fails to protect its citizens by relying on ineffective fish advisories or fails to reclaim the river to a more acceptable and healthy resource for multiple use.

---

[132]. West, P., Fly, M., Larkin, F., & Marans, R. W. (1992). Minority anglers and toxic fish consumption: Evidence from a statewide survey of Michigan. In B. Bryant & P. Mohai (Eds.), *Race and the incidence of environmental hazards: A time for discourse.* Boulder, CO: Westview Press

[133] Chess, C., Burger, J., & McDermott, M. H. (2005). Speaking like a State: Environmental justice and Fish consumption advisories. *Society and Natural Resources*, 18.

[134] Floyd, M., & Johnson, C. (2002). Coming to terms with environmental justice in outdoor recreation: A conceptual discussion with research implications. *Leisure Sciences*, *29*, 50-77.

With this we offer several recommendations that have come from the anglers and our research experience.

1. Create and Distribute a Creative and Easy to Understand Advisory

As one of the main issues surrounding fish consumption advisories on the Detroit River remains access to information, we recommend that the state or an NGO issue an easy to read advisory that is actually printed and provided to anglers when they purchase their licenses. Cuts in the advisory program's state funding have created the need for seeking creative funding options such as small grants or highlighting the issue's importance to those in the legislature. Reinstatement of the WIC distribution of fish consumption advisory to target at risk mothers in an easy to read and understand format is also recommended.

Another potential solution could be to build signs on the river front that inform anglers of the advisory. We have observed this technique employed in other states where general information was provided on shore-side signs that incorporate pictures and guides. This could also be a distribution point for pamphlets and additional information regarding the advisory and high-risk groups. A visible and stationary sign in major fishing parks could potentially be produced through grant funding.

2. Incorporate Cultural Values into the Risk Model.

Fish consumption advisories have been utilized for the past several decades across the country in many types of communities. Some of these advisories are targeted to specific cultural communities and appear to be more effective as they are able to take specific needs into account. One such example is in Alaska where the administering agency has a program promoting fish consumption at appropriate rates among native Alaskans for whom fish is an integral staple in their diet. Many other states issue paper advisories in creative ways that attract the anglers' attention and engage them in participation. These include laminated rulers that indicate the lengths that are safe to eat and in what quantities as well as easy to read pocket-sized pamphlets.

3. Issue the Fish Consumption Advisory in the Detroit News and Detroit Free Press

Fish consumers do not understand what PCBs are and the potential impacts they can have on human development. Although many people are aware of the presence of mercury in the Detroit River as popularized by Marvin Gaye's "The Ecology," (1971) they are not necessarily aware of sources of mercury and the deleterious effects on human health. MDCH currently has this information and could easily distribute an informational packet to the media much like a public service announcement. As public service announcements are a requirement for local TV and radio stations, this information could be created by interns through small grants and provided to local stations for broadcasting. This information must cater to the watershed, much like the advisory, since the AOC is becoming a more critical issue.

4. Assess the Disproportionate Distribution of Resources on the Detroit River for Parks

There is an awareness that funds and resources allocated to the International Wildlife Refuge are not reaching the City of Detroit. This creates a disproportionately burdensome aesthetic for anglers in Detroit. This process must incorporate community input in the modification of parks that offer fishing access. One angler stated that there was not one park in the City of Detroit with handicap access. Many anglers feel unwelcome in newly developed parks within the city. Other anglers believe that downtown Detroit and Downriver parks are spotless while the eastside and southwest side parks are in need of repair and cleanup. Canadians also indicated that new developments were destroying the natural habitat and breeding areas of fish, altering their fishing behavior. Many of these anglers chose to fish in undeveloped parks that are unofficially marked, putting them in danger of sanction.

5. A Joint Fish Consumption Advisory between Ontario and Michigan

Michigan and Ontario currently develop fish consumption advisories separately. The information varies from province to state, although they share the same body of water. The sharing of information of information between these governments will reduce the gap in knowledge on potential contaminant sources and the consequences of those contaminants. It will also increase access to the advisories and reduce confusion on behalf of the anglers. The Integrated Assessment led by CILER aims to do just this.[135]

6. Youth Education and Intergenerational Programs

One of the anglers interviewed for this study suggested that the Detroit River and Parks along the Detroit River could be used as an educational tool. Although Michigan State University Extension—Wayne County provides this service, their resources are limited. This angler rather suggested that people bring their children to the river on the weekend to expose them to the benefits and splendors of the natural resources in their own backyard.

7. Incorporate Information about Water Quality into the Information Network

We were often asked: what exactly is the water quality like in the Detroit River? Anglers understand that water quality in the Detroit River is linked to the Great Lakes and they are concerned with the ecosystem's health. Anglers know that water levels have been

[135] www.ciler.umich.edu/fca

going down and are concerned. They also believe that the water quality has improved over the past several decades, but are unsure as to how much it has improved. There should be a simple mechanism to incorporate emerging and historical contaminants in the news regularly. There should also be reports indicating temporal trends of those contaminants over time. This will generally incorporate anglers' knowledge of water quality on the Detroit River without directly threatening their resource or frightening them individually.

8. Give Anglers of Color a Space to Promote Recreation in Culturally Appropriate Ways

Anglers in Detroit and the surrounding areas are very proud of their heritage and hobbies. Many anglers feel as though they have been forgotten by the City of Detroit, which in their opinion, wants to sell their parks, forget them, or exclude them from new parks. Anglers of color in Detroit have a long history on the Great Lakes and on the Detroit River. Positive portraits of anglers of color will counterbalance negative stigma around fish consumption and around the activity of fishing as an old man sport for teens. There must be a positive identity for anglers of color in the popular media to attract and maintain a healthy relationship to the environment in the city.

BIBLIOGRAPHY

ACCESS website March 4, 2008, from http://www.accesscommunity.org/site/PageS erver?pagename=Community_Health_and_Research

Alaimo, K. (2005). Food insecurity in the United States: An overview. *Top Clinical Nutrician*, *20*(4), 281-298.

Anderson, H., Amrhein, J. F., Shubat, P., & Hesse, J. (1993). Protocol for a uniform Great Lakes sport fish consumption advisory. Great Lakes Fish Advisory Task Force Protocol Drafting Committee.

Anderson, Hanrahan, Smith, Draheim, Kanarek, & Olsen, J. (2004). The role of sport-fish consumption advisories in mercury risk communication: A 1988-1999 12 state survey of women age 18-45. *Environmental Research*, *95*.

Anderson, F., Hanrahan, C., Olson, L., Burse, J., Needham, V. W., Paschal, L. et al. Profiles of Great Lakes critical pollutants: A sentinel analysis of human blood and urine. *Environmental Health Perspectives*, *106*(5).

Ashizawa, A., Hicks, H., & de Rosa, C. (2005). Human heatlh research and policy development: Experience in the Great Lakes region. *International Journal Hygiene and Environmental Health*, *208*.

Beehler, G., McGuiness, B., & Vena, J. (2001). Polluted fish, sources of knowledge, and the perception of risk: Contextualizing African American anglers' sport fishing practices. *Human Organization*, *60*(3).

Bertazzi, P. A., Consonni, D., Bachetti, S., Rubagotti, M., Baccarelli, A., Zocchetti, C. et al. (2001). Health effects of dioxin exposure: A 20-year mortality study. *American Journal of Epidemiology*, *153*(11).

Birnbaum, L. S. (1994). The mechanism of dioxin toxicity: Relationship to risk assessment. *Environmental Health Perspectives*, *102* (Supplement 9: Toxicological Evaluation of Chemical Interactions).

Bryant, B. & Hockman, E. (1994). *Hazardous Waste and Spatial Relations According to Race and Income in the State of Michigan*. (R) in progress.

Bryant, B., & Mohai, P. (1992). The Michigan conference: A turning point. *EPA Journal*, *18*(1).

Bullard, R., Mohai, P., Saha, R., & Wright, B. (2007). *Toxic wastes and race at twenty 1987-2007: A report prepared for the United Church of Christ Justice and Witness Ministries*.

Burger, J. (2002). Consumption patterns and why people fish. *Environmental Research*, Section A 90, 125-135.

Burger, J., Stephens, W., Boring, C., Kuklinski, M., Gibbons, W. J., & Gochfield, M. (1999). Factors in exposure assessment: Ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River. *Risk Analysis*, *19*(3).

Burger, J., Warren, S., Boring, C., Kuklinski, M., Gibbons, W. J., & Michael Gochfield (1999). Factors in exposure assessment: Ethnic and socioeconomic differences in fishing and consumption of fish caught along the Savannah River. *Risk Analysis, 19*(3).

Center for Disease Control's National Center for Chronic Disease Prevention and Health Promotion (2005). Behavioral risk factor surveillance system. March 4, 2008, from http://apps.nccd.cdc.gov/brfss/

Chambers, J. (2004, June 18) State guide to eating fish is victim to cuts – Pregnant women, anglers will have to use old information. *Detroit News*,

Chess, C., Burger, J., & McDermott, M. H. (2005). Speaking like a State: Environmental justice and Fish consumption advisories. *Society and Natural Resources*, 18.

Clarkson, T. W. (1992). Mercury: Major issues in environmental health. *Environmental Health Perspectives*, *100*, 31-38.

Corburn, J. (2002). Combining community-based research and local knowledge to confront asthma and subsistence-fishing hazards in Greenpoint/Williamsburg, Brooklyn, New York. *Environmental Health Perspectives*, *110*(2).

Corey, F. (2007). Aroostook Band of Micmacs: Fish consumption advisory issues. In *EPA Forum on Contaminants in Fish*, Retrieved June 26, 2007, from http://www.epa.gov/waterscience/fish/forum/2007/pdf/section2g.pdf

Dawson, J. (1997). Hook, line and sinker: A profile of shoreline fishing and fish consumption in the Detroit River area. *Health Canada Fish and Wildlife Nutrition Project.*

Detroiters Working for Environmental Justice. March 8, 2008, from http://www.dwej.org/

Ditton, R.B., & Hunt, K. M. (2001). Combining creel intercept and mail survey methods to understand the human dimensions of local freshwater fisheries. *Fisheries Management and Ecology*, *8* (4-5), 295-301.

Egeland, G. M., & Middaugh, J. P. (1997). Balancing fish consumption benefits with mercury exposure. *Science, New Series*, *278*(5345).

Environmental Protection Agency (1999). Polychlorinated biphenyls (PCBs) update: Impact on fish advisories.

Environmental Protection Agency. Health effects of PCBs. Retrieved May 6, 2007 from http://www.epa.gov/pcb/pubs/effects.html

Environmental Protection Agency. (2007). EPA fact sheet. In *2005/2006 National listing of fish advisories*.

Environmental Pretection Agency. (2003). *Evaluating ecosystem results of PCB control measures within the Detroit River-Western Lake Erie Basin*. Chicago, IL: Great Lakes National Program Office.

Environmental Protection Agency (2007). *Great Lakes Areas of Concern.* Retrieved March 4, 2008 from http://epa.gov/greatlakes/aoc/detroit.html

Environmental Protection Agency. (2007). 2005/2006 National listing of fish advisories. In *USEPA Office of Water*. Retrieved March 4, 2008 from http://www.epa.gov/fishadvisories

Environmental Protection Agency (2008). Environmental justice. Retrieved March 4, 2008 from http://www.epa.gov/compliance /basics/ejbackground.html

Environmental Protection Agency. (2001) Fact Sheet: "Mercury Update: Impact of Fish A dvisories" June 2001.

Environmental Protection Agency Great Lakes National Program Office (2004). *Framework for the Great Lakes Regional Collaboration*. Retrieved March 4, 2008 from http://www.epa.gov/glnpo/

Fischer, L. J., Bolger, P. M., Carlson, G. P., Jacobson, J. L., Knuth, B. A., Radike, M. J. et al. (1995). *Critical Review of a Proposed Uniform Great Lakes Fish Advisory Protocol.* Lansing: Michigan Environmental Science Board, Lansing.

Floyd, M., & Johnson, C. (2002). Coming to terms with environmental justice in outdoor recreation: A conceptual discussion with research implications. *Leisure Sciences*, *29*, 50-77.

Gallagher, M. (2006). Examining the impact of food deserts on public health in Detroit. *La Salle Bank Midwest.*

Great Lakes Area of Concerns, GLIN Website, Retrieved March 4, 2008 from http://www.greatlakes.net/envt/pollution/aoc.html

Great Lakes Commission (2002). *An overview of the U.S. Great Lakes AOCs*. U.S. EPA Great Lakes National Program Office and the Great Lakes Commission.

Hamelin, A., Habicht, J., & Beaudry, M. (1999). Food insecurity: Consequences for the household and broader social implications. *American Society for Nutritional Sciences.*

Harris, W. (2004). Fish oil supplementation: Evidence for health benefits. *Cleveland Clinic Journal of Medicine*, 71(3).

Hartig, John (2007). Detroit River International Wildlife Refuge. U.S. Fish and Wildlife Refuge. Retrieved March 4, 2008 from http://www.fws.gov/Midwest/De troitRiver/

He, J., Stein, A., Humphrey, H., Paneth, N., & Courval, J. (2001). Time trends in sport-caught Great Lakes fish consumption and serum polychlorinated biphenyl levels among Michigan anglers, 1973-1993. *Environmental Science and Technology*, *35*(3).

Hites, R. A., Foran, J. A., Carpenter, D. O., Hamilton, M. C., Knuth, B. A., & Schwager, S. J. (2004). Global assessment of organic contaminants in farmed salmon. *Science*, *3*, 226–229.

Hornbarger, K., MacFarlene, C., & Pompa, C. R. (1994). Target audience analysis: Recommendations for effectively communicating toxic fish consumption advisories to anglers on the Detroit River. In *Natural Resources Sociology Lab Technical Report #11*. Ann Arbor, MI: Natural Resource Sociology Research Lab, University of Michigan.

Hunt, K., & Ditton, R. (2002). Freshwater fishing participation patterns of racial and ethnic groups in Texas. *North American Journal of Fisheries Management*, *22*(1), 52-65.

Imm, P., Knobeloch, L., Anderson, H., & the Great Lakes Sport Fish Consortium (2005). Fish consumption advisory awareness in the Great Lakes Basin. *Environmental Health Perspectives*, *111*(10).

Keehler, Dvonch, Yip, Parker, Israel, Marsik, Morishita, Barres, Robins, Brakefield-Caldwell, & Sam, M. (2002). Assessment of personal and community level exposures to particulate matter among children with asthma in Detroit, Michigan as a part of community action against asthma. *Environmental Health Perspectives*. *110*(2).

The Kirwan Institute for the Study of Race and Ethnicity (2007). Land banking in Detroit. March 4, 2008 from http://kirwaninstitute.org/news/news_ landbankdetroit.html

Knuth, Connelly, Sheeshka, &Patterson, J. (2003). Weighing health benefit and health risk information when consuming sport-caught fish. *Risk Analysis*, 23(6).

Kris-Etherton, P. M., Harris, W. S., & Appel, L. J. (2003). Omega-3 fatty acids and cardiovascular disease: New recommendations from the American Heart Association. *Arteriosclerosis, Thrombosis and Vascular Biology*, *23*(151).

Lewis Mumford Center via Schultz et al. (2002). *Metropolitan racial and ethnic change—Census 2000.* March 8, 2008 http://www.albany .edu/mumford/census

Li, H., Drouillard, K. G., Bennett, E., Haffner, D., & Letcher, R. (2003). Plasma associated halogenated phenolic contaminants in benthic and pelagic fish species from the Detroit River. *Environmental Science and Technology,* 37, 832-839.

Maxwell, S. (1996). Food security: A post-modern perspective. *Food Policy*, *21*(2), 155-170.

Michigan Department of Community Health (June, 2007). Fish consumption survey of people fishing and harvesting fish from the Saginaw Bay Watershed. Saginaw Bay Watershed Initiative Network. March 8, 2008, from www.twwatch.org.

Michigan Department of Community Health. (2007). *Michigan family fish consumption guide*. March 4, 2008 http://www.michigan.gov/dnr/0,1607,7-153-10364---,00.html

Michigan Department of Environmental Quality. Fish contaminant monitoring program. March 8, 2008 http://www.deq.state.mi.us/fcmp/.

Michigan Department of Environmental Quality. Michigan fish contaminant monitoring online database. Retrieved February, 2008, from http://www.deq.state.mi.us/fcmp/Sites.asp

Molnar, J. (1999). Sound policies for food security: The role of culture and social organization. *Review of Agricultural Economics*, *21*(2).

Morgan, G. M., et al. (2002) *Risk communication*. UK: Cambridge University Press.

Office of the Governor. 2007. Executive Directive 2007-23. March 4, 2008, from http://www.michigan.gov/gov/0,1607,7-168-36898-180696--,00.html

Ontario Ministry of the Environment. (2007). *Guide to eating Ontario sport fish, 24th edition*. March 4, 2008, from http://www.ene.gov.on.ca/envis ion/guide/

Peakall, D., & Lovett, R. (1972). Mercury: Its occurrence and effects in the ecosystem. *BioScience. 22*(1).

Ponce, R. A, Bartell, S. M., Wong, E. Y., LaFlamme, D., Carrington, C., Lee, R. C. et al. (2000). Use of quality-adjusted life year weights with dose-response models for public health decisions: A case study of the risks and benefits of fish consumption. *Risk Analysis*, *20*(4).

Ratcliffe, H. E., & Swanson, G. M. (1996). Human exposure to mercury: A critical assessment of the evidence of adverse health effect. *Journal of Toxicology and Environmental Health*, *49*, 221-270.

The Riverfront Conservancy. (2003-2005). Mission statement. Retrieved February 3, 2008 from http://detroitriverfront.org/index.asp?item=321&name=Mission+Statement&site=5

Rose, D. (1999). Economic determinants and dietary consequences of food insecurity in the United States. *American Society for Nutritional Sciences.*

Schultz, A. J., Williams, D., Israel, B., Lempert, L. B. (2002). "Racial and spatial relations as fundamental determinants of health in Detroit. *The Milbank Quarterly*, (*80*)4, 677-707.

Sharp, E. (April 10, 2003). Fewer anglers find fish at the end of the lines. *Detroit Free Press*.

Sidhu, K. S. (2003). Health benefits and potential risks related to consumption of fish or fish oil. *Regulatory Toxicology and Pharmacology*, *38*, 336-344.

Sierra Club, March 8, 2008 http://www.sierraclub.org/environmental_justice/ National Wildlife Federation internship opportunities explicitly list environmental justice, and have created partnerships with DWEJ towards this goal. Also East Michigan Environmental Action Council has worked with Michigan Welfare Rights of water shut-offs in Highland Park, http://www.emeac.org/

Silver, E., Kaslow, J., Lee, D., Sun, L., Lynn, T. M., Weis, E. et al. (2007). *Environmental Research*, *104*.

Silverman, W. M. (1990). Michigan sport fish consumption advisory: A study in risk communication. A thesis submitted in partial fulfillment of the requirements for the degree of MS. SNRE. UM. Committee: West, Patrick, and Walter Redmond.

Statistics Canada, 2001 Census, http://www12.statcan.ca/english/census01/home /index.cfm

Sugrue, T. (1996). *The origins of urban crisis: Race and inequality in postwar Detroit.* Princton, NJ: Princton University Press.

SWEV website March 4, 2008 http://www.sdevonline.org/

Tilden, J., Hanrahan, L P., Anderson, H., Palit, C., Olson, J., Kenzie, W.M. (1997). Health advisories for consumers of Great Lakes sport fish: Is the message being received? *Environmental Health Perspectives*, *105*(12).

United Church of Christ. (1987). *Toxic wastes and race in the United States: A national report on the racial and socio-economic characteristics of communities with hazardous waste sites*. Commission for Racial Justice United Church of Christ.

U.S. Department of Agriculture. (2008). Food and nutrition service. March 4, 2008, from h ttp://www.fns.usda.gov/fsec/.

West, P., Fly, M., Larkin, F., & Marans, R. W. (1992). Minority anglers and toxic fish consumption: Evidence from a statewide survey of Michigan. In B. Bryant & P. Mohai (Eds.), *Race and the incidence of environmental hazards: A time for discourse.* Boulder, CO: Westview Press.

Zenk, S., Schultz, A., Israel, B., James, S., Bao, S., & Mark Wilson. (2006). Fruit and vegetable access differs by community racial composition and socioeconomic position in Detroit, Michigan. *Ethnicity and Disease, 16*, 275-280.

www.census.gov

www.ciler.umich.edu/fca

Staff writer. (2007, Dec. 15-21). Granholm names Dan Krichbaum chief operating officer. *Arab American News.*

Appendix I

Detroit River Fish Consumption Advisory Angler Survey

Date: ______________ Location: _______________ Angler # ____________

INTRODUCTION

1. How many years have you been fishing on the Detroit River?

____

2. Why do you fish?

☐ Leisure ☐ Escape or quite ☐ Close to nature ☐ Family ☐ Community Building
☐ Food source ☐ Social gatherings (Family, friends, fish fry)
☐ Other ____

____

3. Where are the best fishing spots along the Detroit River?

____

4. When are the best times to fish? ____

5. Do you fish at any other location? ☐ Yes ☐ No
   5a. If so, where? ____

6. How often do you fish in the Detroit River?

☐ Everyday ☐ Very often (1-3 times weekly) ☐ Somewhat often (1-3 times monthly) ☐ Infrequently (1-2 per summer) ☐ Almost never (once a year)

BOATER QUESTIONS (If no, skip to question 10)

7. Do you ever fish by boat? ☐ Yes ☐ No
   7a. If yes: What type of boat do you typically fish in? ________________________

____

8. When you are fishing on the Detroit River by boat, how far do you typically go out from shore? ____

9. Are the fish a different quality further away from the shore? ☐ Yes ☐ No
   9a. If yes, please explain: ____

BEHAVIOR

10. In fishing season, about how many fish do you catch a week? ____________________
    10a. Of these, how many do you take home and consume?______________________

11. About how many fish per week (in fishing season) is that? ________________________

12. What type of fish do you typically take home? What sizes (in inches)?
Species _______________ Size ____________________
Species _______________ Size ____________________
Species _______________ Size ____________________
Species _______________ Size ____________________
Species _______________ Size ____________________

13. Have you ever exchange fish for another good? ☐ Yes ☐ No
    13a. If yes, can you tell me a little bit about that? ______________________________
____

14. Who taught you how to fish/how did you learn to fish? ___________________________
____

15. Have you taught anyone how to fish? ☐ Yes ☐ No
    15a. If so, who? ____

16. How do you like to prepare and cook the fish? __________________________________

17. Generally, do you cook it yourself or does someone else? ☐ Self ☐ Other
    17a. If someone else, who does that most of the time? ________________________

18. Do you remove the head, tail, skin, fat, and bone from the fish before you eat it?
    ☐ Yes ☐ No
    18a. If yes, why? ____

19. Do other members of your household or community eat the fish you catch?
    ☐ Yes ☐ No
    19a. If yes, who? ____

20. How important is fish as part of your diet?
☐Very important ☐ somewhat important ☐ Important ☐ Somewhat not important ☐ Not at all important

21. How often do you buy fish from the market? ☐Very often ☐ somewhat often ☐ often ☐ not often ☐ rarely
    21a. If yes, what types? ____
____

22. How well do you know the other fisherpeople along the river?
☐ Extremely well ☐ Very well ☐ Well ☐ Not very Well ☐ Not at all

23. Where are the most popular or crowded areas to fish? ____________________________

24. Are new parks and developments changing where you fish? ☐ Yes ☐ No

24a. If yes, how?____

CURRENT FISH ADVISORY

25. Are you aware of the current fish consumption advisory? ☐ Yes ☐ No

26. What can you tell me about the current fish consumption advisory distributed by the state? ____

27. Do you know where you can access a fish advisory pamphlet or information?
☐ Yes ☐ No

27a. If yes, where?____________________________________

28. How are the fish consumption advisories helpful to you? ____________________

29. Has this pamphlet influenced how or where you fish, if at all?
☐ Yes ☐ No ☐ Don't Know ☐ N/A ☐ Other ________________________

29a. If Yes, How? ____

30. How would you prefer to receive fish advisory information?
☐ Internet ☐ Church ☐ Health Clinic ☐ River signs ☐ Community Center ☐ TV
☐ Radio ☐ Barber ☐ Corner Store ☐ Bait Shop ☐Other ____________________

CONTAMINATION AWARENESS

31. How would you rate the water quality of the Detroit River (1 being the lowest, 5 the highest)?
☐ 1 ☐ 2 ☐ 3 ☐ 4 ☐ 5

32. Tell me a little bit about how water quality affects fish:

33. How do you determine if the fish is good to eat?

34. If you think a fish is not good to eat, what do you do with it?

35. Where did you learn how to gauge if fish is not good to eat?

36. Do you share that information with other fishermen? ☐ Yes ☐ No
   36a. If yes, how often? ☐ Always ☐ Sometimes ☐ Never

37. In the time since you have been fishing on the Detroit River, what changes, if any, have you noticed in fish or water quality? ____
____
____

38. What information, if any, would you like to know about fishing and water quality?
____
____

OPTIONAL

39. Age: ___________

40. Gender: ☐ Male ☐ Female

41. Zip Code: ___________

42. Number of members in household: ___________

43. Race/Ethnicity:
☐ Caucasian
☐ African American/Black
☐ Latino
☐ Asian/Pacific Islander
☐ Native American
☐ Arab/ Middle Eastern
☐ Other: ______________

44. Highest Education Level:
☐ Middle School
☐ Less than High School Diploma
☐ High School Diplopma/GED
☐ Trade School
☐ Some college
☐ Associates Degree
☐ Bachelor's Degree
☐ Masters Degree or above

45. Yearly Household Income:

- ☐ 0 – 24,999
- ☐ 25,000 - 49,999
- ☐ 50,000 - 74,999
- ☐ 75,000 - 99,999
- ☐ 100,00

46. ADDITIONAL COMMENTS AND NOTES