Mussel Watch Great Lakes Contaminant Monitoring and Assessment: Phase 1

NOAA National Centers for Coastal Ocean Science
Center for Coastal Monitoring and Assessment

Kimani Kimbrough
W. Edward Johnson
Annie Jacob
Michael Edwards
Erik Davenport
Gunnar Lauenstein
Thomas Nalepa
Mike Fulton
Anthony Pait

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Executive Summary

Recovery and rehabilitation of the Great Lakes requires the availability of sound water quality data to formulate effective, science-based policies and develop appropriate management actions. The International Joint Commission has identified monitoring as a critical component in the management and protection of the nearshore zone of the Great Lakes. The NOAA National Centers for Coastal Ocean Science (NCCOS) Mussel Watch Program (MWP) is one of the few active biomonitoring programs with a basin-wide presence and a record of consistent monitoring in the nearshore zones for close to two decades. In keeping with the mission of NCCOS to support healthy and resilient coastal communities, MWP initiated monitoring the status and trends of chemical contaminants in the Great Lakes in 1992, using dreissenid mussels as sentinel organisms. Mussels are abundant in the outer harbors on breakwaters and other hard substrates throughout the Great Lakes. These stationary, filter-feeding bottom dwellers accumulate contaminants, possess limited ability to metabolize them, are representative of local conditions, and shed light on availability of contaminants to move up the food chain, thus making them an excellent tool for contamination monitoring and assessment.

Following the inception of the Great Lakes Restoration Initiative (GLRI) to address the significant environmental issues plaguing the Great Lakes region, MWP expanded its regional monitoring activities in the Great Lakes in 2009 to include all U.S. Areas of Concern (AOCs). This enhanced effort falls under the "Toxic Substances and Areas of Concern" focus area outlined in the GLRI Action Plan. The overall objective of the expanded monitoring is to assess remediation effectiveness, and provide relevant biological data to support decision making for "Beneficial Use Impairment" (BUI) removal and subsequent delisting of AOCs. The stated objective is being addressed through a phased approach utilizing a suite of mussel and sediment indicators at newly established sites within AOCs, and by leveraging the long-term monitoring data at reference sites for meaningful interpretation of AOC status and recovery.

Herein, we report the results from the first phase under GLRI, mainly mussel tissue and sediment chemistry data obtained by MWP, with the goal of providing a high-level basin-wide perspective on the relative magnitude and extent of contamination in AOCs. This was achieved by comparing:

1) tissue chemistry from AOCs to reference sites;
2) sediment chemistry from AOCs to both MWP Great Lakes reference sites and coastal marine sites distributed nationwide and;
3) sediment chemistry to relevant thresholds.

Due to the availability of dreissenid mussels on and near breakwaters, this baseline assessment focused on river mouths of AOCs, and provides the foundation upon which subsequent intensive (spatially and temporally) AOC assessments will be carried out. Through numerous partnerships, MWP has begun to incorporate innovative techniques and methods in select AOCs. The results from these intensive sampling efforts will be the focus of subsequent reports. This first report sheds light on the bioavailability of select contaminants from a proven bioindicator and demonstrates the value of long-term monitoring programs in making informed coastal ecosystem management decisions.

Thank you,

The Great Lakes Mussel Watch Team

Project Overview

- With Great Lakes Restoration Initiative funds, NOAA Mussel Watch expanded monitoring activities into all U.S. Areas of Concern (AOCs) and added additional analyses to address Beneficial Use Impairment (BUI) target goals and effectiveness of AOC restoration efforts.
- All U.S. AOCs were sampled for mussel tissue and/or sediment as part of the Phase 1 Great Lakes baseline study.
- Historic Mussel Watch sites, primarily located in shallow (<20 ft) nearshore lake water, were used as reference sites for comparison with AOCs.
- National sediment sites were used to bring perspective to Great Lakes sediment concentrations.
- Mussel contaminant concentrations provided an assessment of bioavailable contamination inside and outside AOC boundaries.

The Great Lakes constitute the largest freshwater system in the world, containing more than 90% of the nation's, and 20% of the world's freshwater supply. The Great Lakes basin is home to over 35 million people and supports numerous economic activities including agriculture, industries, commercial and sport fisheries, tourism, and recreation. Exploitation of the Great Lakes has resulted in multiple environmental challenges and has negatively impacted many beneficial uses of this globally treasured natural resource.

In 2009, the Great Lakes Restoration Initiative (GLRI) was signed into law to restore and rehabilitate the designated areas in the Great Lakes. This initiative is guided by an action plan created by a task force of 11 federal agencies (GLRI Action Plan, 2010) and identifies five focus areas:

1. Toxic substances and Areas of Concern;
2. Invasive species;
3. Nearshore health and nonpoint source pollution;
4. Habitat and wildlife protection and restoration; and
5. Accountability, education, monitoring, evaluation, communication and partnerships.

While considerable progress has been made in improving the condition of the Great Lakes through environmental legislation and the Great Lakes Water Quality Agreement between the United States and Canada (GLWQA, 2012), pollutant loadings from point and non-point sources, and legacy contaminants in sediment continue to impair the Great Lakes ecosystem. This report focuses on the legacy contamination in U.S. AOCs, which are defined in the GLWQA as "a geographic area designated by the Parties where significant impairment of beneficial uses has occurred as a results of human activities at the local level." There are 31 AOCs on the U.S. side (5 of those shared with Canada) with one or more Beneficial Use Impairments (Table 1; Figure 1). BUIs have to be removed for the AOCs to be delisted. AOC specific BUIs are too numerous to list here but can be found online at http://www.epa.gov/glnpo/aoc/.

The National Oceanic and Atmospheric Administration (NOAA) Mussel Watch Program (MWP) administered by the National Centers for Coastal Ocean Science (NCCOS) has used dreissenid mussels to monitor contaminants in the nearshore zones of the Great Lakes since 1992. This contaminant monitoring effort in the Great Lakes is part of a larger contaminant monitoring program that began in 1986 and currently includes more than 300 sites nationwide (Figure 2). In the Great Lakes, MWP established 7 sites in the inaugural year and more sites were added in the initial years after the invasion and proliferation of Ponto-Caspian mussels *Dreissena polymorpha* and *Dreissena rostriformis bugensis* (zebra and quagga mussels, respectively) that became established in the region in the late 1980s (Carlton 2008; Mills et al., 1993; Robertson and Lauenstein, 1998). The abundance and widespread distribution of dreissenid mussels in the nearshore areas of the Great Lakes (except Lake Superior) renders them ideal candidates for routine contaminant monitoring.

Dreissenid mussels are widely used as bioindicators in Europe and their native Ponto-Caspian region, because of their high filtering rates, high lipid content and the ability to bioaccumulate contaminants from water, algae and suspended sediments (de Kock and Bowmer 1993; Bervoets et al., 2005; Berny et al., 2003; Gossiaux et al., 1998; Reeders and bij de Vaate 1992). Other favorable characteristics of dressenids as biomonitors include ease of collection, abundance, sessile life cycle, limited ability to metabolize lipophilic contaminants, and utility in effects-based monitoring. In addition, the recognition of dressenid mussels as keystone species of the Great Lakes ecosystem (Vanderploeg et al., 2002),reinforces its critical value in the assessment of the overall health and ecological forecasting of the Great Lakes.

Table 1. There were 31 U.S. Areas of Concern (AOCs) in the U.S. Great Lakes suffering 1 or more of 14 Beneficial Use Impairments (BUIs) listed. MWP provides data and information to potentially support the decision making to remove select BUIs.

Restrictions on fish & wildlife consumption	Eutrophication or undesirable algae
Tainting of fish and wildlife flavor	Restrictions on drinking water
Degradation of fish & wildlife populations	Beach closings
Fish tumors or other deformities	Degradation of aesthetics
Bird or animal deformities or reproduction problems	Added costs to agriculture or industry
Degradation of benthos	Degradation of phytoplankton & zooplankton populations
Restrictions on dredging activities	Loss of fish & wildlife habitat

Project Approach for Phase 1: Basin-Wide Baseline Assessment

- Established sites in all U.S. AOCs, and assessed contaminants in mussels and sediments in these new sites;
- Leveraged data, information, and knowledge from long-term Mussel Watch sites in Great Lakes (1992-present) and nation (1986-2009) and evaluated the extent and magnitude of pollution in AOCs relative to long-term Mussel Watch monitoring sites (i.e. reference sites).
- Determined baseline chemical contaminant levels at AOCs and reference sites, to compare regional, lake-wide, and local progress toward AOC chemical reduction targets.

Currently, there are 25 long-term Mussel Watch sites in the Great Lakes from Duluth, MN on Lake Superior at the mouth of the St. Louis River to Cape Vincent, NY where Lake Ontario flows into the St. Lawrence River. The majority of these sites were established away from known impacted areas, following the overall program directive to measure contamination at sites that represent ambient concentrations. These long-term monitoring sites thus served as reference sites for contamination assessment in highly impacted areas (e.g., AOCs) in the Great Lakes.

Aligning with the focus of GLRI, MWP expanded its monitoring activities in the region to include all U.S. AOCs (Figure 1). The overall objective of the expanded monitoring was to provide relevant biomonitoring data to potentially support decision making for BUI removal and subsequent delisting of U.S. AOCs. The stated objective is being addressed through a two phase approach utilizing mussel and sediment indicators. Phase 1 effort, the basin-wide assessment of mussels and sediment at newly established sites within U.S. AOCs and long-term Mussel Watch sites (i.e. reference sites) is presented in this report. Phase 2 has two ongoing parts consisting of intensive mussel sampling in select U.S. AOCs (where remediation is imminent or has already occurred) for improved spatial coverage, and probabilistic ecosystem assessments to characterize sediment quality in select AOCs. As part of the Phase 2 intensive mussel sampling initiative, newer biomonitoring approaches including the use of caged mussels for contaminant source tracking and effects-based monitoring to assess mussel health have been incorporated.

In this report, we summarize contaminant chemistry data in mussels and sediment for the Phase 1 basin-wide assessment and leverage two decades of historic Mussel Watch Program data from the Great Lakes and the Nation (Figure 2) for comparison.

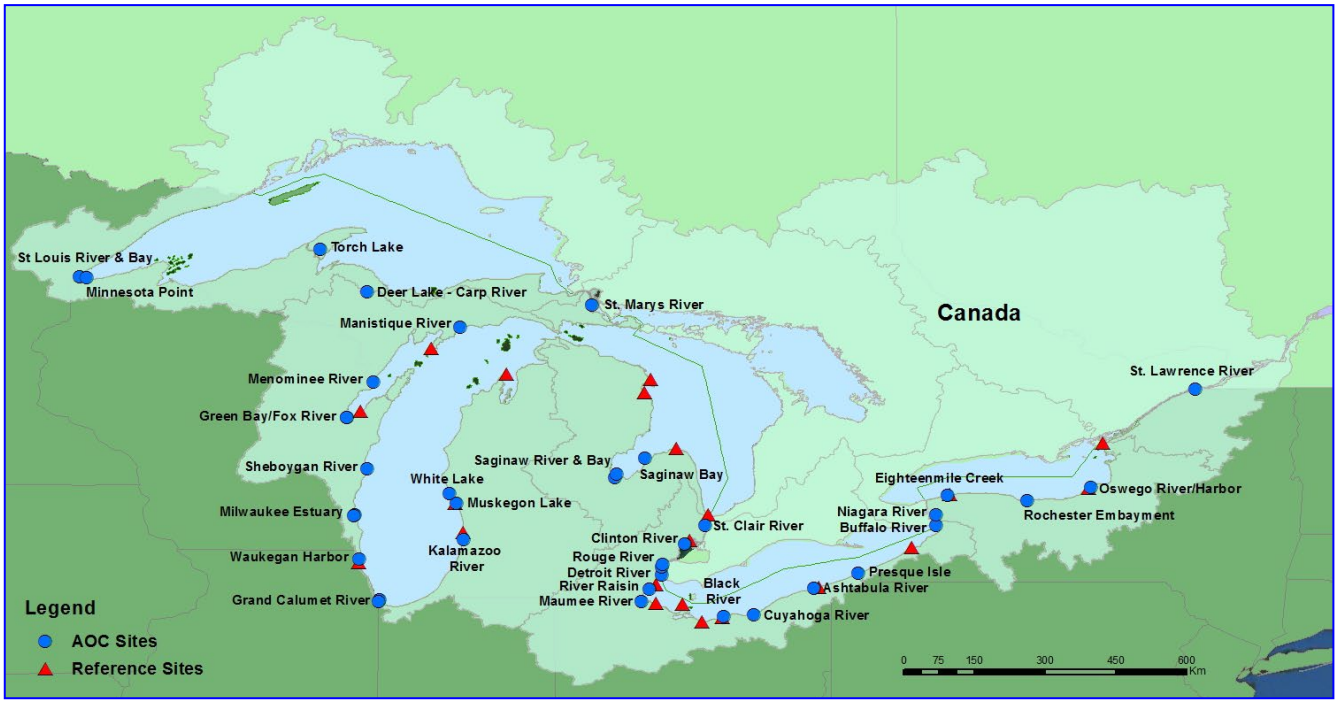


Figure 1. Mussel Watch Great Lakes baseline assessment U.S. AOC sites (labeled).

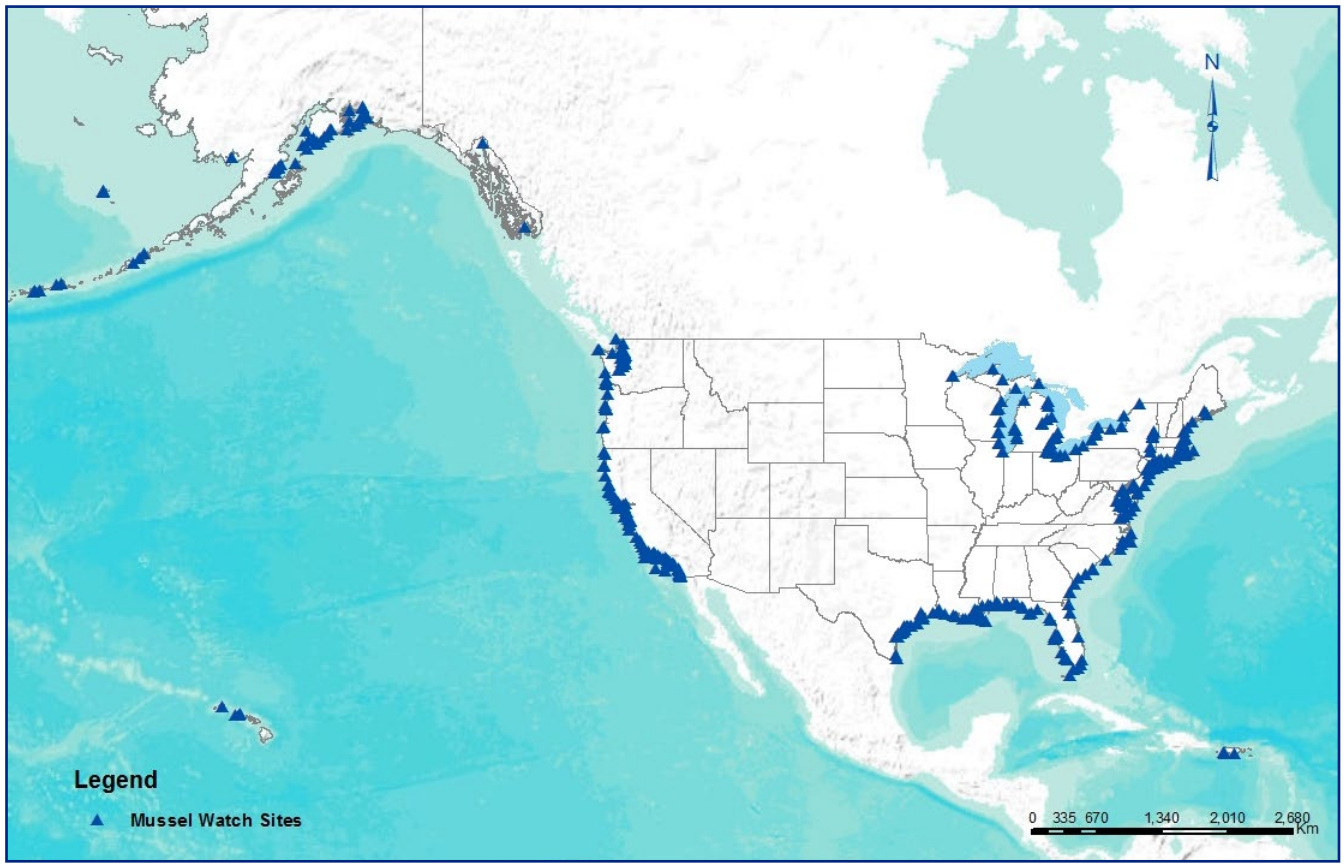


Figure 2. National Mussel Watch sites.

The basin-wide baseline data presented here can be used by stakeholders and resource managers for AOC remediation effectiveness assessment and as an additional biological line of evidence to support BUI removal. Specifically, mussel tissue concentrations could potentially be used to set target chemical reduction goals for remediation purposes as these mussels are robust indicators of biovailable contamination. Further, mussels serve as a potential additional line of evidence to support decision making with respect to "Restriction on fish and wildlife consumption" BUI. Unlike fish, which move in and out of AOC boundaries, mussels bioaccumulate and integrate contaminant exposure at the specific location where they are found in an AOC. More importantly, mussels have limited ability in metabolizing xenobiotics, including PAHs and PCBs, compared to fish (Farrington, 1983).

The role of dreissenid mussels in contaminant cycling and biomagnification of pollutants (indirectly via deposition of feces and psuedofeces, and directly via predation in the food chain) in the Great Lakes is well documented (Bruner et al., 1994a, b; Morrison et al., 1998; Marvin et al., 2000; Cho et al., 2004). Monitoring contaminants in dreissenids can thus not only reflect ambient contamination levels, but can also further our understanding of trophic transfer and biomagnification. Recently, the International Joint Commission (IJC 2011) emphasized the need for a greater understanding of nearshore zone processes and management, subsequent offshore effects, and the health of the lakes as a whole. To these ends, monitoring of chemical, biological, and toxicological indicators in dreissenid mussels provides a means to further assess temporal trends, biological uptake, and ultimate fate of many contaminants.

Current & Future Work

Our baseline monitoring effort in 2009/2010 was in essence an expansion of the fixed sampling design of traditional Mussel Watch and provides a synoptic view of the relative magnitude and extent of contamination in the harbor areas of AOCs and reference sites. In order to better address contamination and remediation issues of specific AOCs, Mussel Watch has adopted multi-parameter assessments and incorporated newer techniques and approaches to the existing methods. For mussels, we have intensified sampling, both spatially and temporally, in select AOCs (e.g., Sheboygan River AOC; Figure 3) to provide a more robust measure of bioavailable contamination, have utilized deployment of caged mussels to source track contaminants in areas where extant mussels beds are not found (Figure 4), and have incorporated effects-based monitoring to complement body burden

Figure 3. Densification of mussel and sediment samples temporally and spatially.

measurements. For the sediment matrix, probabilistic sediment quality assessment was carried out to report on sediment chemistry, benthos and sediment toxicity, which could directly address Degradation of Benthos BUI. These focused efforts in select AOCs have been implemented through successful partnerships and collaborations with the local, state and federal entities. The results from these ongoing and future work will be the focus of subsequent reports.

Figure 4. Caged mussels, passive samplers and Hester Dendys being retrieved after deployment for 6 weeks in Manistique River AOC.

Methods

- Mussel Watch sampled sites in all U.S. AOCs under GLRI.
- In the eastern Great Lakes (downstream from Detroit), one mussel station (when available) and one sediment station were established per site in 2009.
- In the western Great Lakes, additional resources allowed establishment of one mussel station (when available) and up to three sediment stations per site in 2010.

Mussel Watch sampled sites in 31 U.S. AOCs as part of the basin-wide baseline assessment under GLRI (Figure 1) in 2009 and 2010. All mussel sites were established at river mouths or outer harbor areas where stone breakwaters provided a colonizing substrate for dreissenid mussels. When available, one mussel station and one sediment station per site were collected from each site in the eastern Great Lakes (downstream from Detroit) in 2009. In the western Great Lakes, one mussel station and up to three sediment stations were collected per site in 2010. The Grand Calumet River and St. Louis River AOC are the exception, each had 2 baseline mussel sites. One composite sample comprising 50-100 mussels was sampled from each sation. Only sediment samples were collected at Torch Lake, Carp River, St. Marys River, Kalamazoo River and Rouge River.

Contaminant monitoring of mussels and sediment in the Great Lakes by MWP began in 1992. Prior to GLRI, MWP was monitoring 25 sites routinely in the Great Lakes. Data from long-term MWP sites that were located in AOCs (Milwaukee Estuary, Niagara River, Rochester Embayment, Saginaw River and Bay, and Grand Calumet River) were included in AOC results throughout this document. Long-term MWP sites located outside of AOCs were used as reference sites and were compared to AOCs (Figure 5). The reference sites were located within watersheds that represented a variety of land uses and occured within the shallow, nearshore zones (< 20 ft).

Within a MWP site, sediment stations were co-located with mussel stations. Some sites did not have fine-grained (percent silt-clay) sediments and hence sediment sites were relocated nearby, consistent with procedures of the National Coastal Assessment Quality Assurance Project Plan 2001-2004 (US EPA 2001). Sites were sampled on a biennial basis; Lakes Ontario and Erie sites were sampled in odd years, and Lakes Huron, Superior and Michigan sites in even years.

Sample Collection

Mussels were collected from natural substrates by diving or dredging. Upon collection, mussels were rinsed with site water to remove debris, placed in freezer bags, packed on water ice and shipped to laboratories within two days. Samples for sediment chemistry, toxicity, and the benthic community analyses were collected concurrently with a Young-modified, van Veen grab sampler (0.04 m^2) deployed from a small boat. Protocols for sample collection, preparation and analysis are found in the Quality Assurance Project Plan and in Lauenstein and Cantillo (1998 and references therein), Kimbrough and Lauenstein (2006), Kimbrough et al., (2006), and available online at http://coastalscience.noaa.gov/projects/detail?key=179

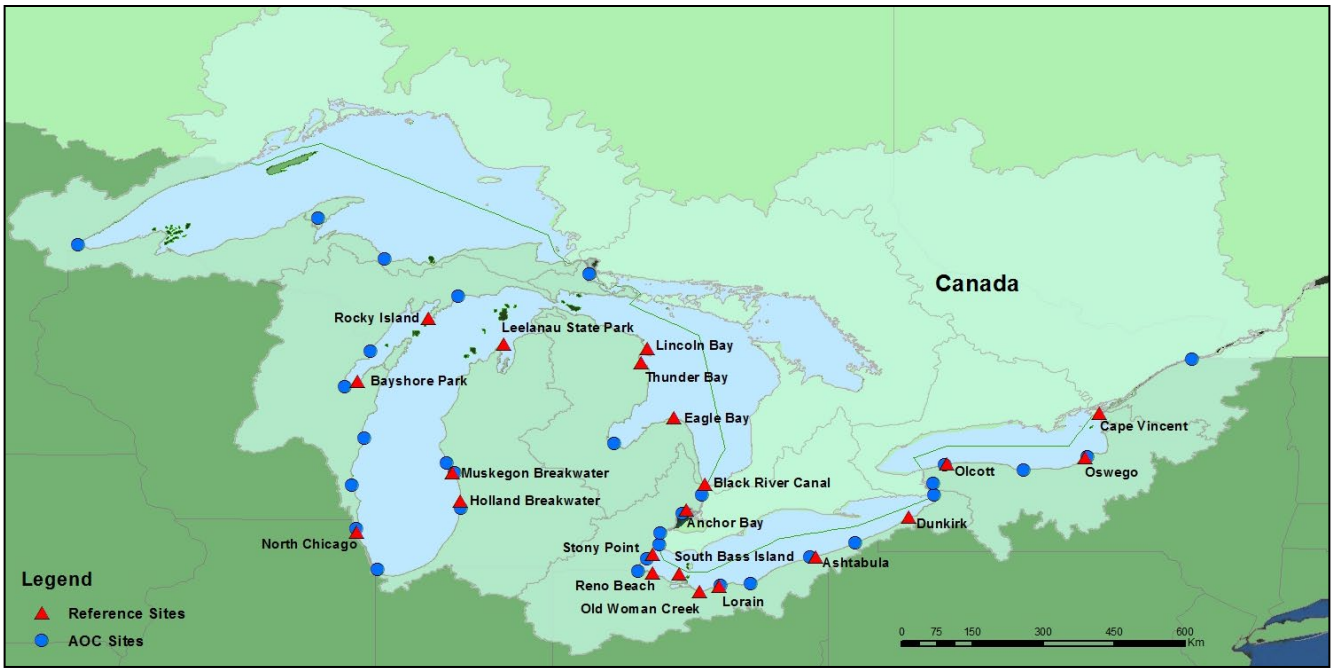


Figure 5. Mussel Watch reference sites (labeled).

Table 2. Contaminants summarized as part of the Expanded Great Lakes MWP. The complete list of contaminants and associated method detection limits can be downloaded at http://coastalscience.noaa.gov/projects/detail?key=179

Compound class	Compound
Trace elements	Arsenic, cadmium, copper, lead, methyl mercury, mercury, zinc
Chlordane	Alpha-chlordane
Chlorpyrifos	Chlorpyrifos
Dichlorodiphenyltrichloroethane and metabolites (DDT)	2,4'-DDD; 2,4'-DDE; 2,4'-DDT; 4,4'-DDD; 4,4'-DDE; 4,4'-DDT
Heptachlor	Heptachlor
Hexachlorobenzene	Hexachlorobenzene
Mirex	Mirex
Polycyclic aromatic hydrocarbons (PAHs)	Benzo[a]pyrene, benzo[e]pyrene
Polychlorinated biphenyls (PCBs)	PCB8/5, PCB18, PCB28, PCB 29, PCB31, PCB44, PCB45, PCB49, PCB52, PCB56, PCB66, PCB70, PCB74, PCB87, PCB95, PCB99, PCB101/90, PCB105, PCB110, PCB118, PCB128, PCB138, PCB146, PCB149, PCB151, PCB153/132/168, PCB156, PCB158, PCB170/190, PCB174, PCB180, PCB183, PCB187, PCB194, PCB195/208, PCB199, PCB201, PCB206, PCB209

Contaminants

The recently established AOC sites together with long-term MWP reference sites provide relevant data to aid in the cleanup and subsequent delisting of AOCs. All sites were monitored for a wide array of contaminants, including trace elements and legacy organic contaminants. For the purpose of this report, only select and relevant analytes are presented (Table 2); however, data for additional analytes can be downloaded (http://coastalscience.noaa.gov/projects/detail?key=179). Ancillary measurements for mussels and sediment were also recorded. For mussels, these consisted of gonadal index, wet weight, dry weight, percent lipid, and shell length and volume. For sediment, these consisted of grain size (percent sand, silt and clay) and total organic carbon.

Data Quality

The Mussel Watch Program used a performance based quality assurance process to ensure data quality. This effort has been in operation since 1985 and is designed to document sampling protocols, analytical procedures and laboratory performance. Analytical laboratories used by the Mussel Watch Program are required to participate in exercises with assistance from the National Institute of Standards and Technology (NIST) and the National Research Council of Canada (NRC) to ensure data are comparable in accuracy and precision (Willie, 2000; Schantz et al., 2000).

Statistical Analysis

Tissue and sediment contaminant concentrations from all the AOC and reference sites were assigned to a concentration range (high, medium and low) using hierarchical Wards cluster analysis. This analysis allowed clustering of contaminant concentrations into groups such that the numbers contained within a group are more like each other than any other number in a different group. Results in the low, medium and high categories did not represent measurements that have exceeded regulatory thresholds; rather, it denoted that they are significantly higher than the preceding category ($p < 0.05$; Wilcoxon). The high, medium and low categories are not associated with human health or ecosystem health endpoints. In cases where the concentration measurements could not be grouped into a category of at least 3, the measurements were labeled as outliers, and removed to perform the analysis again.

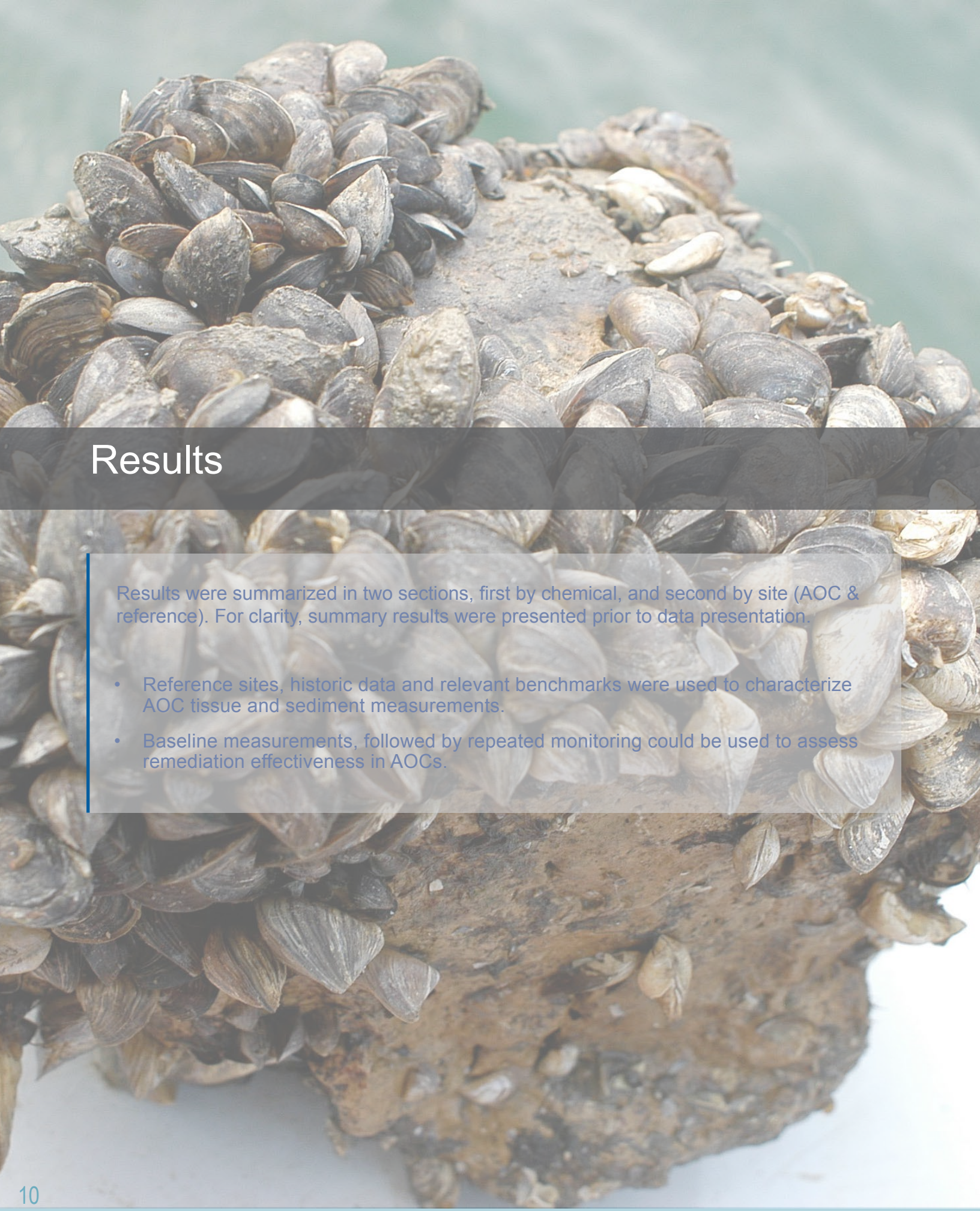
The Shapiro-Wilks test was used to test for normality. None of the analytes tested had a normal distribution so non-parametric statistics were used. The non-parametric Kruskal Wallis test was used to test for significant differences in contaminant concentrations among AOCs and reference sites, and between national and Great Lakes (inclusive of AOC and reference) sites. Data summaries (descriptive statistics) for selected chemicals measured in mussel tissue and sediment are provided categorically by chemical and by site. Descriptive statistics are organized by site type (AOC and reference site), and by matrix (mussel and sediment). Sediment results for the Great Lakes are compared to the latest national MWP survey (2006/2007). Concentration of contaminants in *dreissenid* mussel tissue from the Great Lakes were not compared to concentrations found in mussels/ bivalves from other regions because of contaminant uptake and bioaccumulation differences among species.

Benchmarks and Background

Resource managers rely on chemical-specific, numerically based benchmarks to guide their actions to ensure protection of the environment and/or human health. This report uses the term “benchmark” to describe any published chemical concentration or concentration range reported in sediment (e.g.,“criteria,” “standard,” guideline,” value,” indicator,” “alert or action level,” “tolerance level,” “threshold level”).

Sediment benchmarks commonly reported in the literature as sediment quality guidelines (SQGs) rely on empirical or theoretically based approaches that are predictive of toxicity and bioaccumulation. For this report, we used freshwater sediment quality guidelines reported by MacDonald et al., (2000), their consensus-based numbers, Probable Effects Concentration (PEC), and Threshold Effects Concentration (TEC). The PECs are SQGs for individual chemicals above which adverse effects in sediments are expected to frequently occur, whereas TECs were developed to provide an estimate of conditions where toxicity would not be expected. If no SQG was reported by MacDonald et al., (2000), NOAA SQuiRTs (Screen Quick Reference Tables) were consulted, followed by the Canadian Environmental Quality Guidelines.

Benchmarks for biota, including shellfish, are scarce. The FDA provides “action levels” and “tolerance levels” for fish and shellfish for a few chemicals but these are intended for regulating food safety and commerce. The EPA provides “screening levels” for management decisions to issue fish consumption advisories, but these are of limited value for assessing mussel contaminant levels. In this study, we have not attempted to compare dreissenid mussel tissue concentration to any existing thresholds for other bivalve tissue. Instead, the mussels tissue concentrations in U.S. AOCs were interpreted by leveraging data from reference sites.



Results

Results were summarized in two sections, first by chemical, and second by site (AOC & reference). For clarity, summary results were presented prior to data presentation.

- Reference sites, historic data and relevant benchmarks were used to characterize AOC tissue and sediment measurements.
- Baseline measurements, followed by repeated monitoring could be used to assess remediation effectiveness in AOCs.

Major results and discussion, based on statistical comparisons of AOCs, references sites, and coastal marine sites, are presented in the ensuing paragraphs. Graphical summarization of results by analyte and by site appear in the Analyte and Site Characterization sections respectively.

AOC vs. Reference Sites

Data analyses indicated that greater than 50 percent of all tissue and sediment measurements (AOC and reference sites) were categorized as low, and greater than 85 percent of all measurements were categorized as low or medium (Figure 6). Conversely, high and outlier sites together represented 5-15 percent of all sediment and tissue measurements (Figure 6). The difference between AOC and reference sites was primarily found in the percentage of each that comprise the elevated measurements found in the high and outlier categories. For trace elements and organics in sediment, and organics in tissue, a higher proportion of high and outlier measurements were found at AOC sites (Figure 6). In contrast, the percentage of outlier and high measurements were almost equal for trace elements in mussel tissue in AOC and reference sites.

For tissue, no significant difference was found between AOC and reference sites for trace elements examined except for cadmium. Cadmium concentrations in mussels from reference sites were higher than those from AOC sites (Kruskal Wallis; $p < 0.05$; Figure 7). Four of the nine organic analytes (DDT, Benzo[a] pyrene, Benzo[e]pyrene and PCB) measured in dreissenid tissue were significantly higher at AOCs

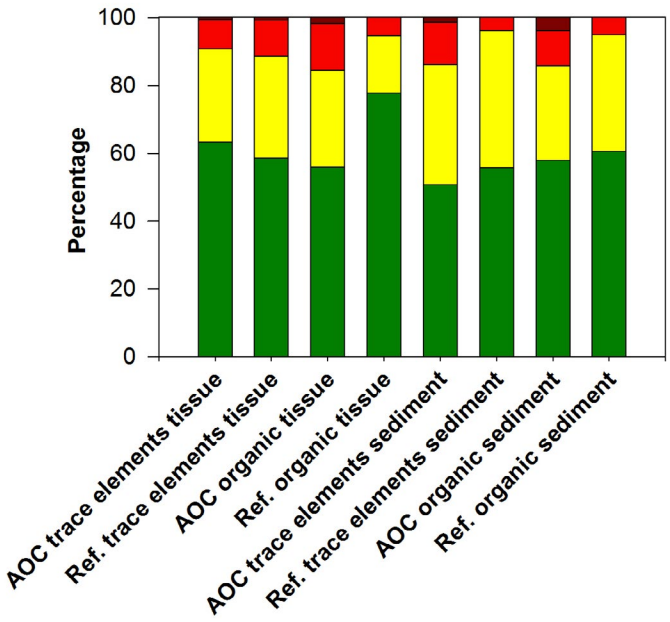


Figure 6. Percentage of low (green), medium (yellow), high (red), and outliers (maroon) categories for metals and organics in AOCs and reference sites (Ref.) for both tissue and sediment matrices.

when compared to reference sites (Kruskal Wallis; $p < 0.05$; Figure 7). The lack of significance among other analytes may be due to the fact that majority of sites (both AOC and reference sites) have concentrations that fall in the low and medium categories.

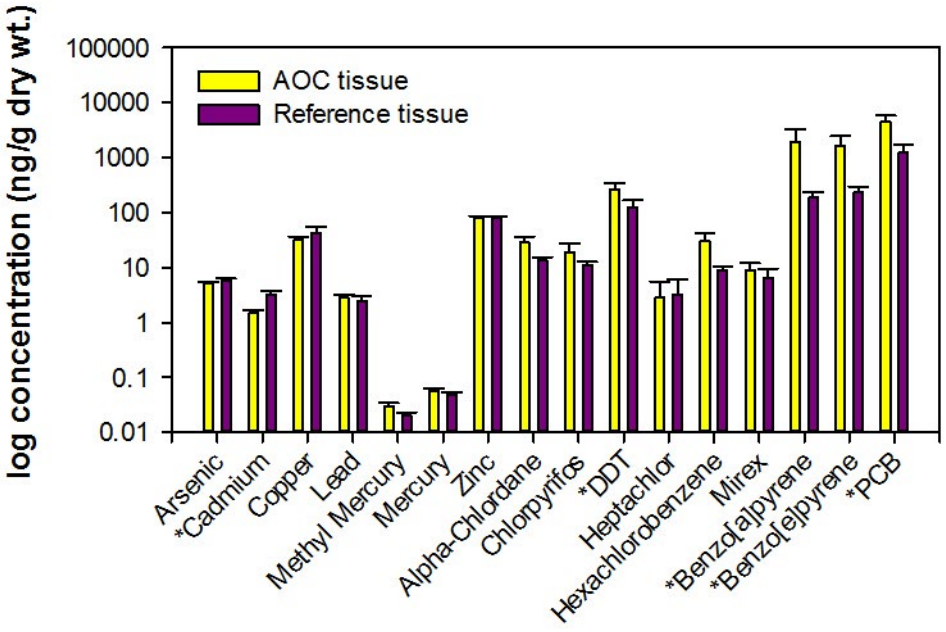


Figure 7. Comparison of AOC and reference sites tissue measurement means with standard error bars. Asterisk represent analytes with significant differences. Organic compounds are lipid normalized.

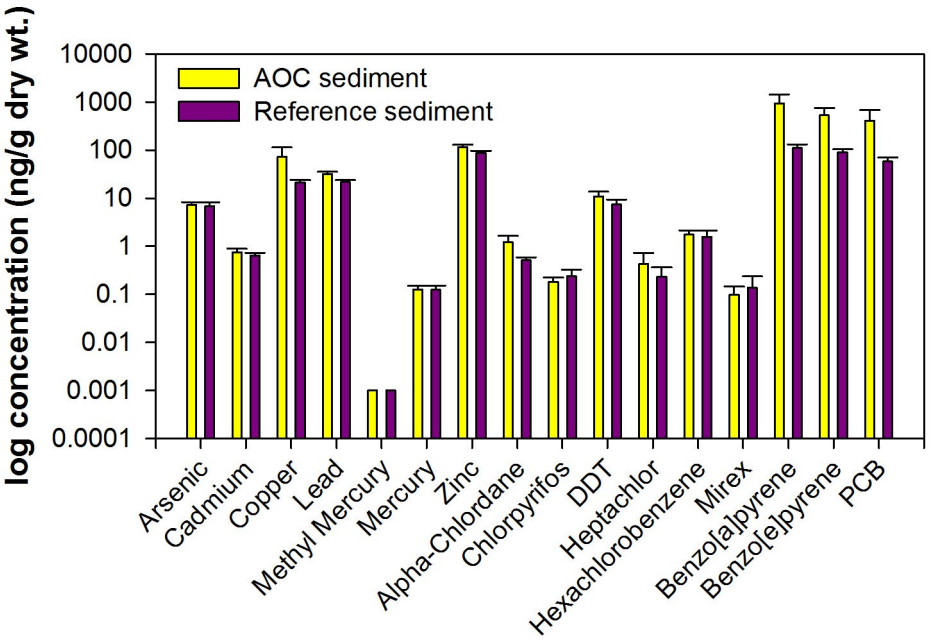


Figure 8. Comparison of AOC and reference sites concentration means with associated standard error bars.

For sediment, there were no significant differences found between AOCs and reference sites for organics or trace elements (Kruskal Wallis; $p > 0.05$; Figure 8).

Great Lakes vs. National Sediment Sites

The sediment concentrations for all analytes from Great Lakes were higher than the concentrations from the rest of the MWP sites in the nation (Kruskal Wallis; $p < 0.05$; Figure 9). All of the trace elements and organic contaminants examined were higher in the Great Lakes with respect to the nation as a whole irrespective of inclusion of AOCs in the analysis (Figure 9), that is, even Great Lakes reference sites were higher.

MWP's national sediment measurements are obtained from small embayments, estuaries, and open coast sites, many of which have higher flushing/turnover rates when compared to the Great Lakes. Conversely, the residence time of some of the persistent pollutants in the Great Lakes is higher, which may partly explain the difference between national and Great Lakes sediment measurements.

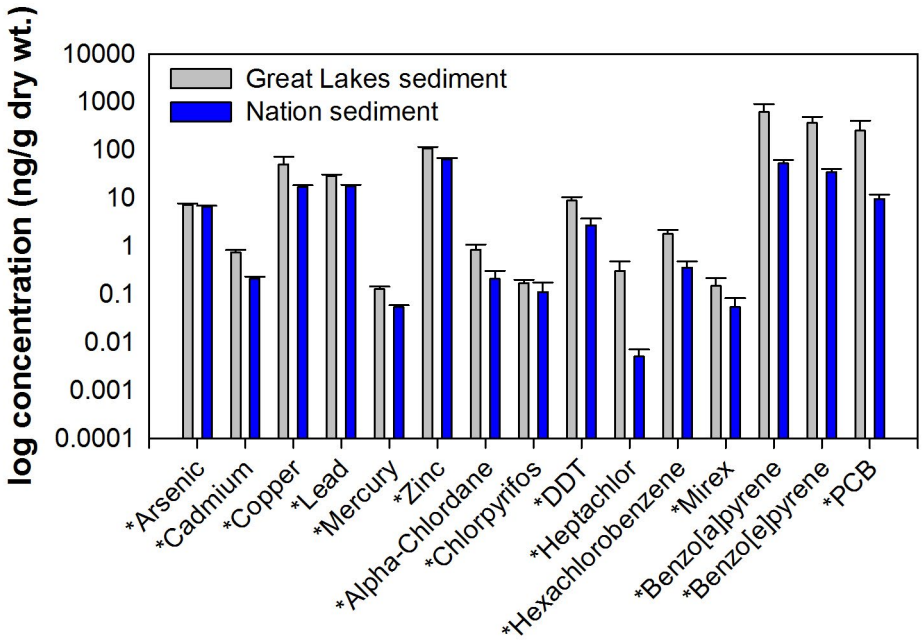


Figure 9. Comparison of Great Lakes (AOCs and reference sites) and national sediment concentration means with associated standard error bars. Asterisk represent analytes with significant differences.

Comparison Among AOCs

To identify the relative magnitude and extent of contamination in the outer harbor areas among AOCs, heat maps were generated for both tissue and sediment, which show the heirarchical Ward's cluster analysis categories (outlier, high, medium and low). These heat maps summarize the data in maps and associated figures in Section 2 & 3, and clearly show the utility of using one unique matrix for characterizing sites as well as dentifying sites with elevated concentrations that require further investigation. However, unlike abiotic measurements, mussels integrate the contaminant signal over long periods of time allowing for a time-integrated indication of environmental contamination. More importantly, contaminant tissue burden in mussels that reside at the base of the food chain reflect contaminant bioavailability and bioaccumulation potential, and thus provide information about environmental contamination and effects that cannot be defined by abiotic matrices. Therefore, having mussel tissue data from AOC sites across the basin provide biologically relevant data that can be used in making informed management decisions.

Readers should be mindful that these results are not representative of the entire AOC and that low concentrations in the harbor area (where the majority of the sites are located) do not imply that the entire AOC is free of contamination. However, this baseline assessment effort helps identify the contaminant concentration in the harbor, which can serve as a chemical reduction target goal for remediation purposes. To provide enhanced characterization of AOCs, intensive sampling is required, and has begun at some prioirity AOCs.

Benchmarks

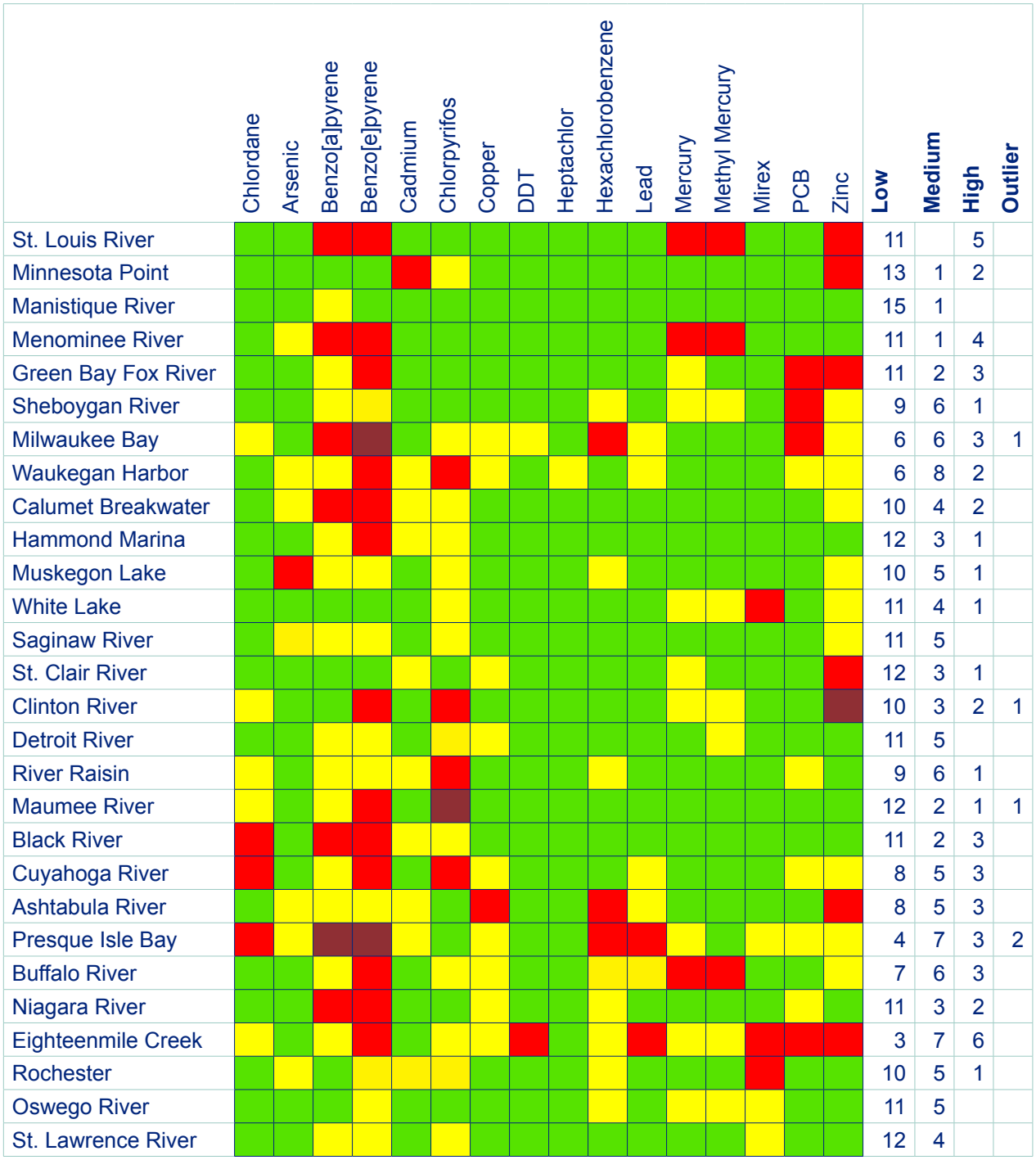
Specific benchmarks and threshold concentrations were not found for dreissenid mussels. As such, mussel tissue concentrations from AOCs were compared to concentrations obtained from reference sites. In contrast, for sediment, consensus based TEC and PEC sediment quality guidelines (MacDonald et al., 2000) was used to compare concentrations from AOCs and reference sites. For several chemicals (DDT, PCBs, benzo(a)pyrene), the mean reference site concentration exceeded or was only slightly below the reported TEC. Other chemicals with TEC exceedances at many sites included arsenic, cadmium, copper, lead, total mercury, zinc, chlordane (as alpha chlordane), DDT, and heptachlor epoxide (as heptachlor).

Interpretation of Chemical Data

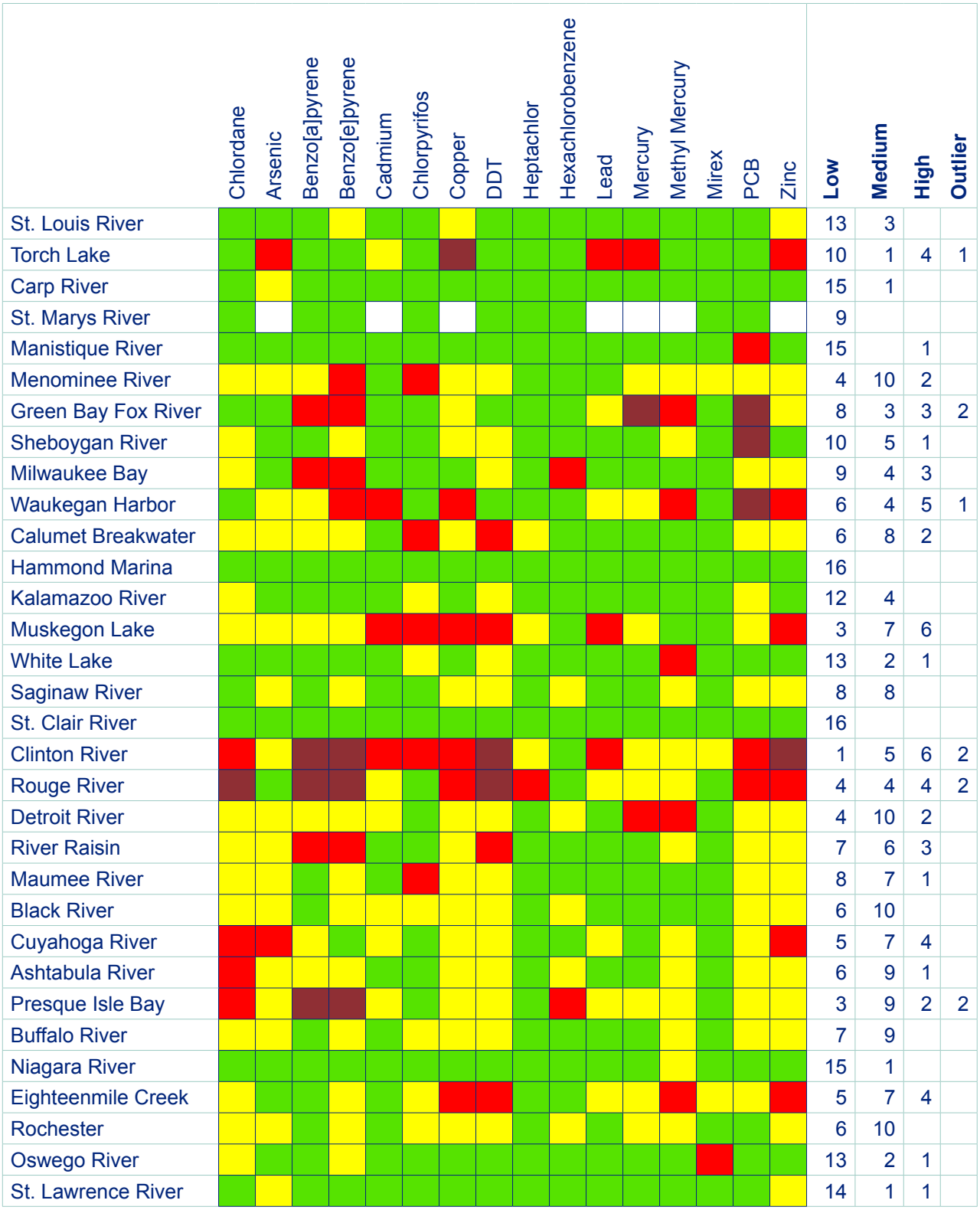
Trace elements are naturally occurring but can have anthropogenic sources as well. Distinguishing the sources of elevated concentrations is beyond the scope of MWP, however, our monitoring data can identify sites with elevated concentrations where further investigation is required.

The organic compound results have two primary patterns of distributions. The first distribution is characterized by the majority of the sites being at or near detection limits with a few sites exhibiting measurements that are elevated, (chlordane, chlorpyrifos, heptachlor, hexachlorobenzene, Mirex); essentially a presence and absence distribution. The second group of organic compounds are more ubiquitous and thus have a "background level" arising from its chemical persistence and also have several outlier measurements that are orders of magnitude higher than the "background" measurements (Benzo [a]pyrene, Benzo[e]pyrene, DDT, and PCB). This second group of organic contaminants approaches a skewed distribution that is similar to the trace element distribution (Site Characterization Section).

Most regulatory controls of chlorinated organics went into effect in the 1970s and 1980s, prior to the initiation of mussel monitoring in the Great Lakes. The tissue trend map for reference sites (Analyte Characterization Section-Page 16) shows historic site measurements for a subset of MWP long-term data. The box and whisker plots for organic contaminants from reference sites show no significant difference between years since 2001 across the entire basin, and is supported by the bar charts in the adjacent map. These results suggest that decreasing organic contaminant trends have reached asymptotic levels and further reductions in these levels by natural means alone will likely take decades.



Tissue heat map. Figure showing outlier (★), high (●), medium (●), and low (●) AOC tissue measurements for all trace elements, and organic contaminants discussed in this report.



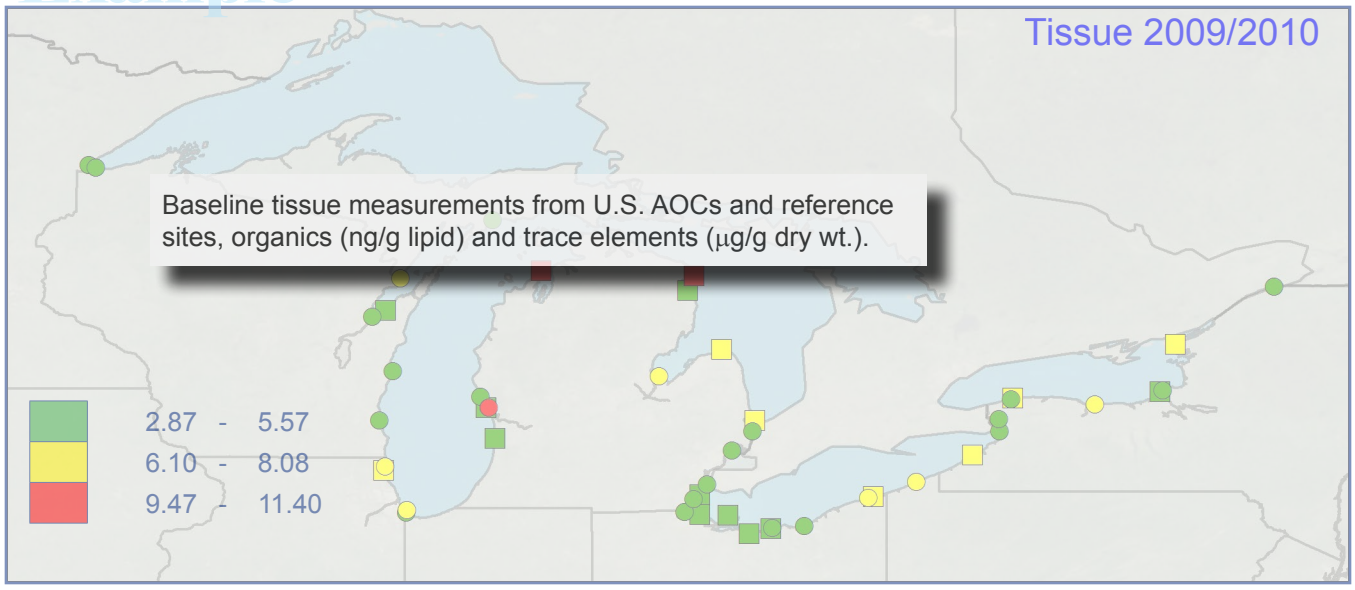
Sediment heat map. Figure showing outlier (★), high (●), medium (●), and low (●) AOC sediment measurements for all trace elements and organic contaminants discussed in this report. Boxes are white when no data is available.

Analyte Characterization

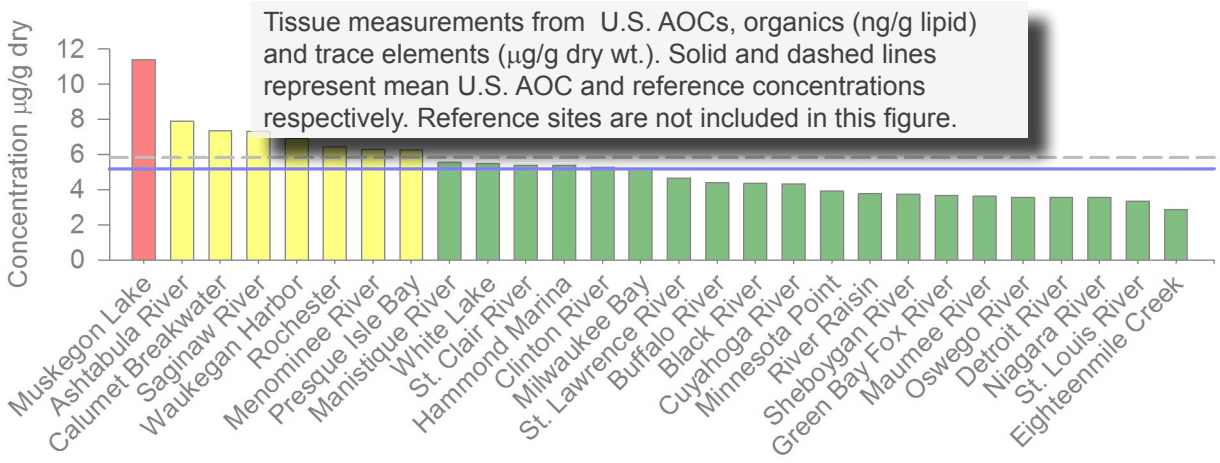
- Great Lakes sediment (U.S. AOC & reference) measurements were found to be significantly higher than national measurements.
- Significant differences between U.S. AOC and reference site tissue measurements were primarily limited to organic contaminants.
- When compared to national and reference site measurements, U.S. AOCs registered a disproportionate number of outlier and high measurements for organic contaminants but not for trace elements.
- Sediment measurements for U.S. AOCs were not significantly different from reference sites sediment measurements.

YAMAHA

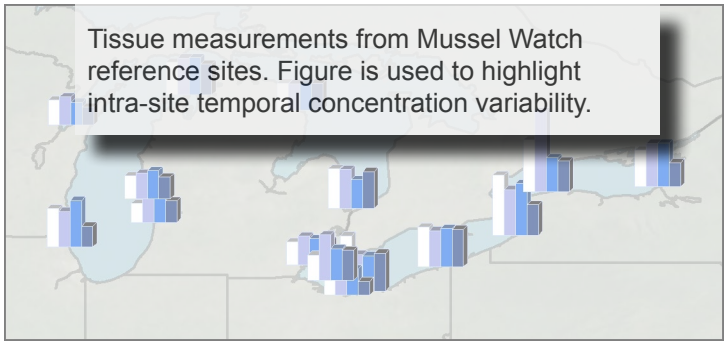
Example

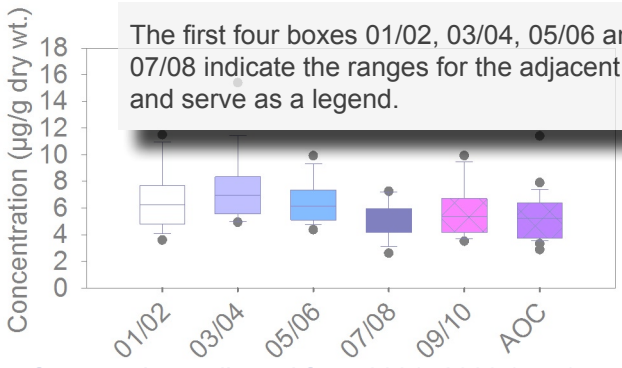


Tissue map: Categories low (●), medium (●) and high (●), and where applicable outlier (★), are used to characterize U.S. AOC (●) and reference (■) site contaminant concentrations (µg/g dry wt.) in dressenid mussels.



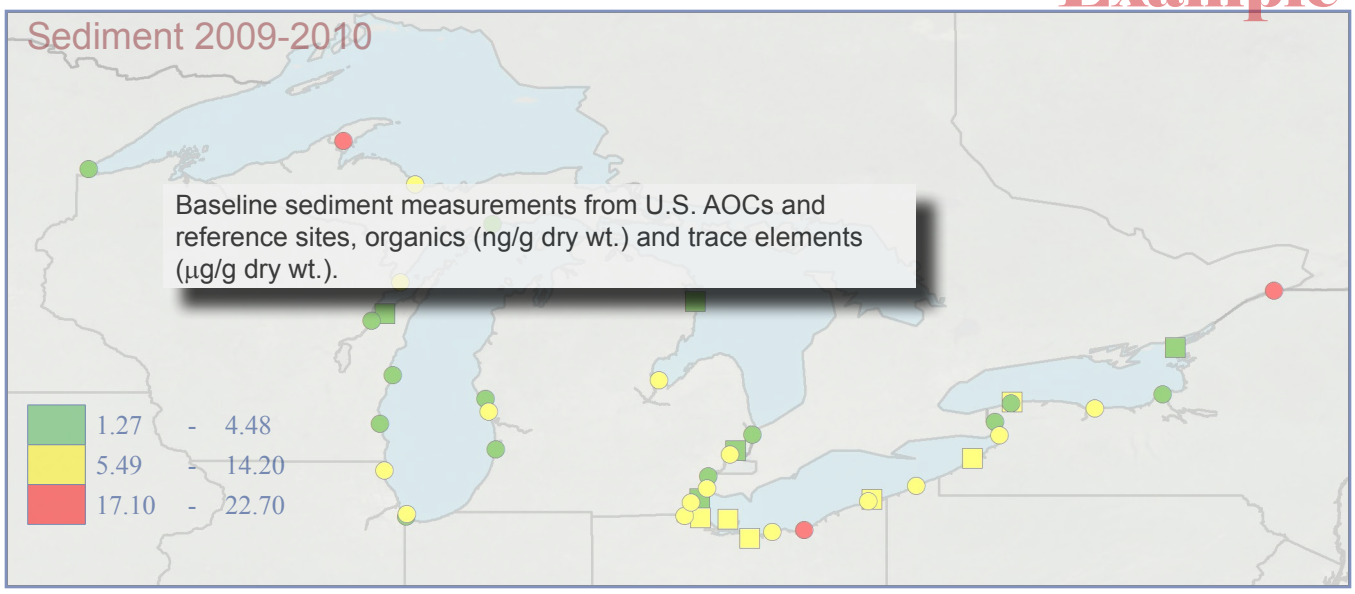
AOC barchart: Comparison of AOC contaminant concentrations in dreissenid mussels (µg/g dry wt.). Reference lines represent mean AOC (solid line) and reference site (dotted line) concentrations.



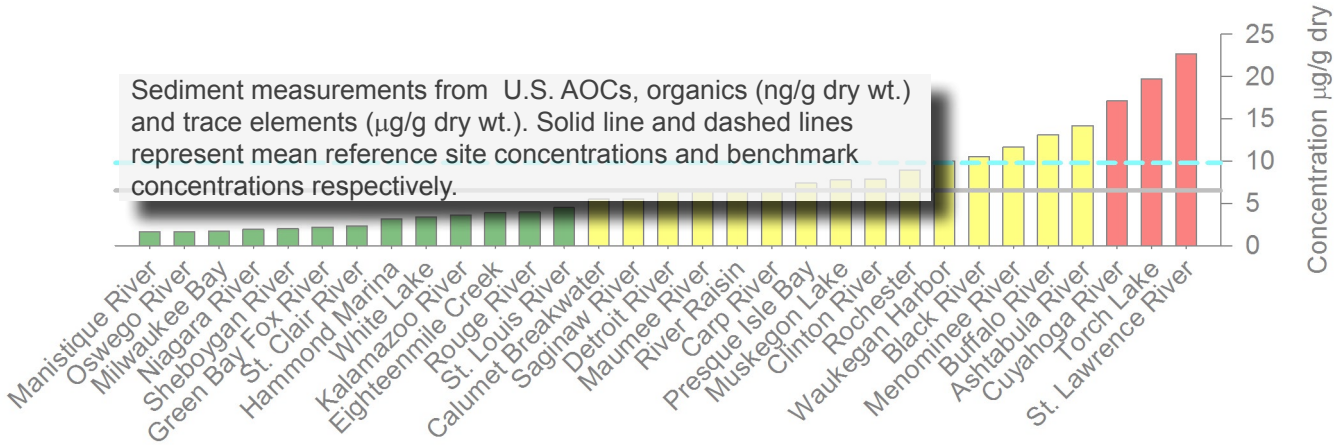


Historic data: Mussel tissue concentration (µg/g dry wt.) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and U.S. AOC sites collected in 2009/2010.

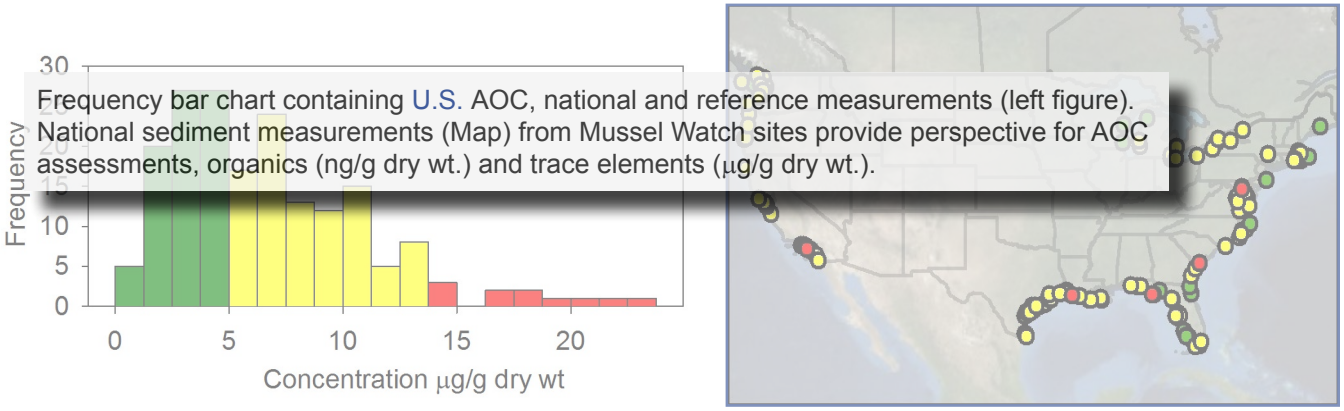
Example



Sediment map: Categories low (●), medium (●) and high (●), and where applicable outlier (★), are used to characterize U.S. AOC (●) and reference (■) site sediment concentrations (μg/g dry wt.).

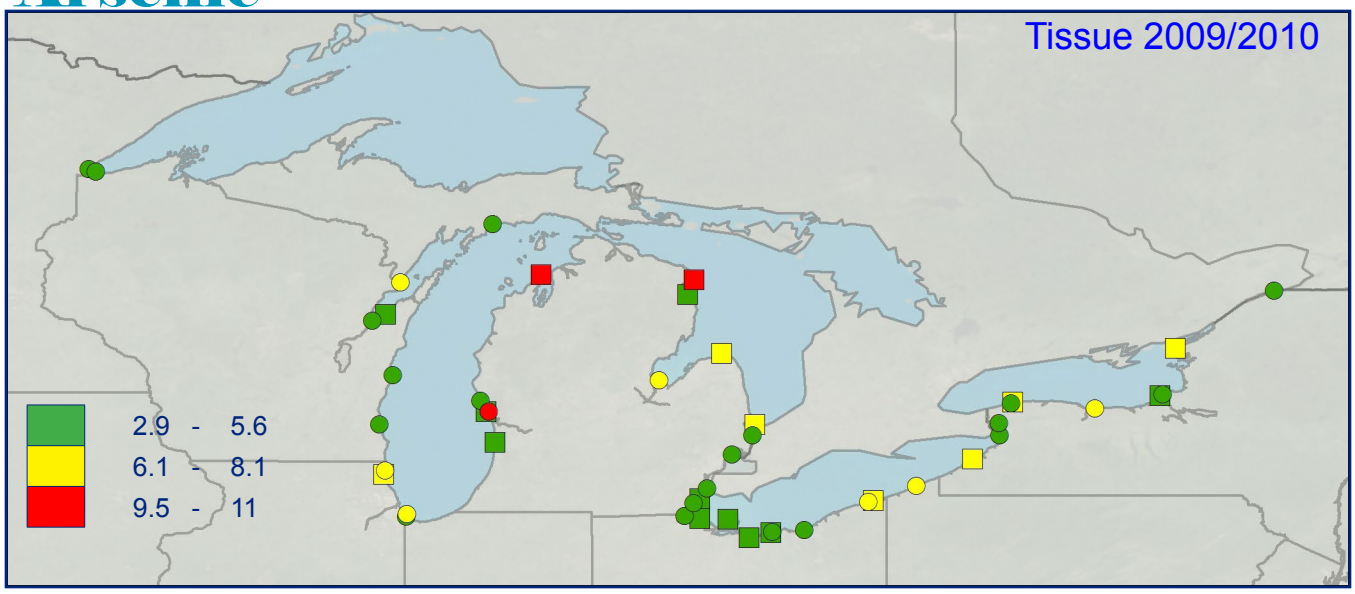


AOC barchart: Comparison of AOC contaminant concentrations in sediment (μg/g dry wt.). Where available, reference lines representing PEC (black dashed line), TEC (blue dashed line), and reference site mean (gray solid line) are given.

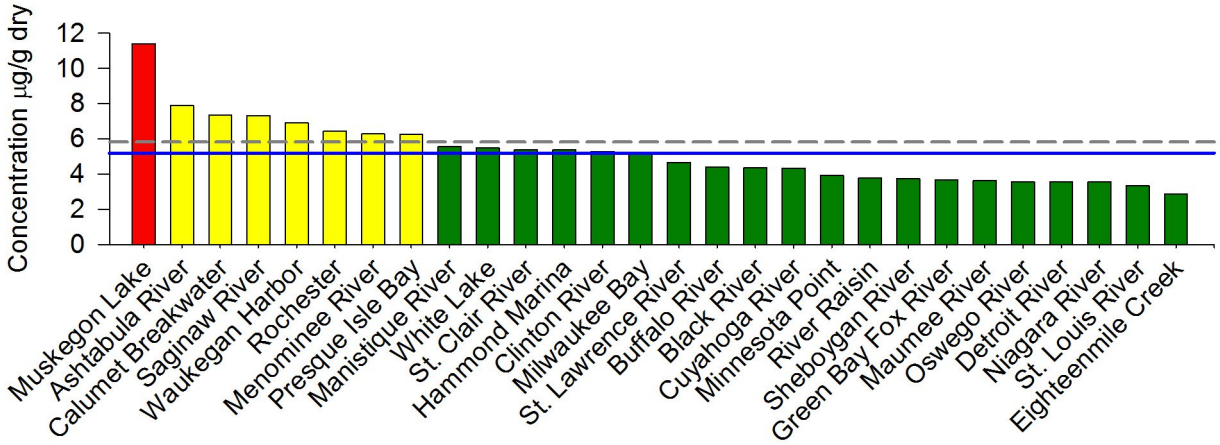


National frequency plot and sediment map: Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; μg/g dry wt.).

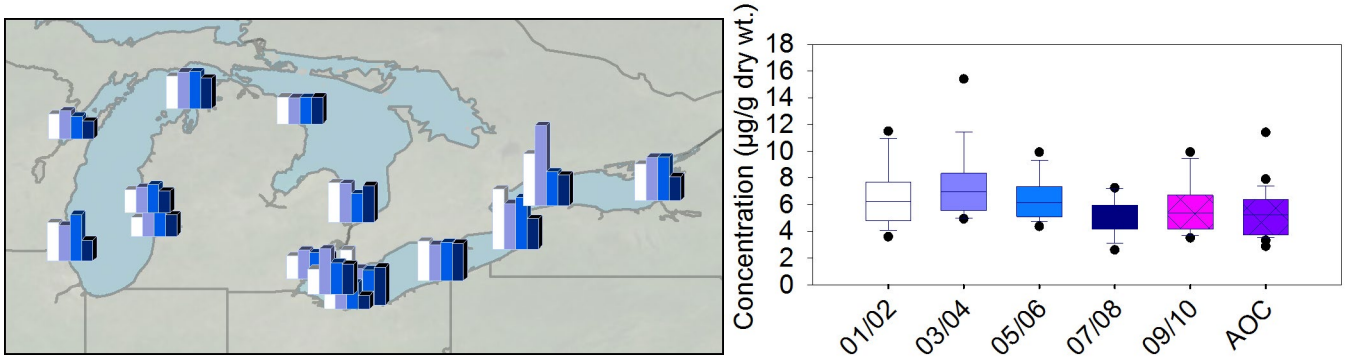
Arsenic



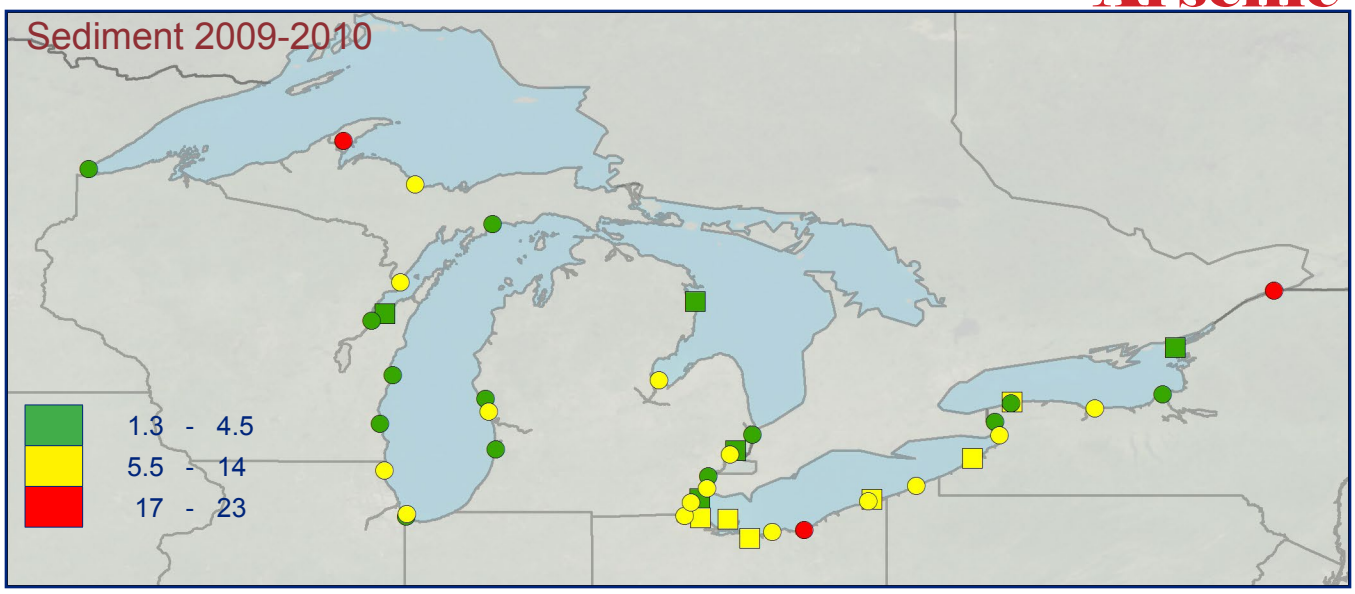
Tissue map: Categories low (●), medium (●) and high (●), and where applicable outlier (★), are used to characterize U.S. AOC (●) and reference (■) site contaminant concentrations (µg/g dry wt.) in dressenid mussels.



AOC barchart: Comparison of AOC contaminant concentrations in dreissenid mussels (µg/g dry wt.). Reference lines represent mean AOC (solid line) and reference site (dashed line) concentrations.



Historic data: Mussel tissue concentration (µg/g dry wt.) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and AOC sites collected in 2009/2010.



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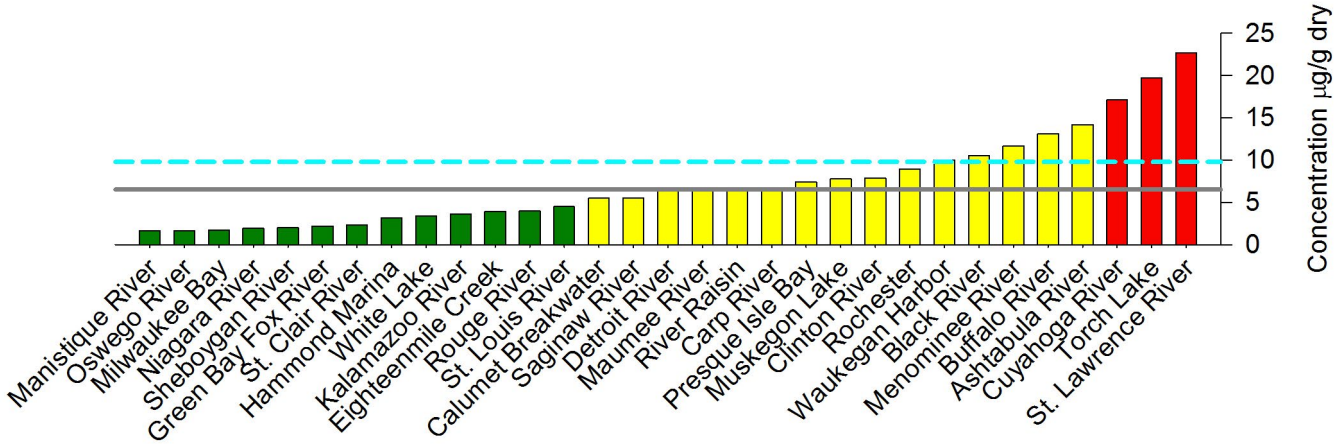

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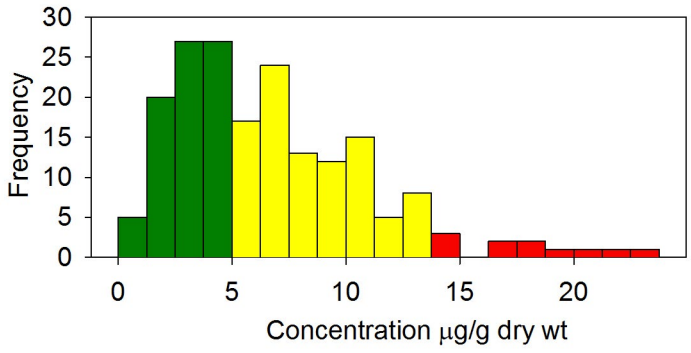
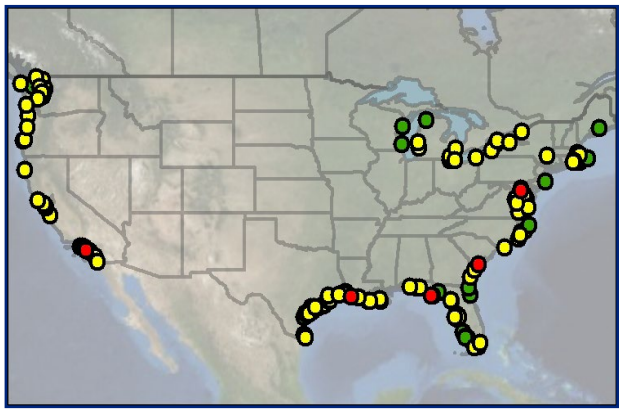
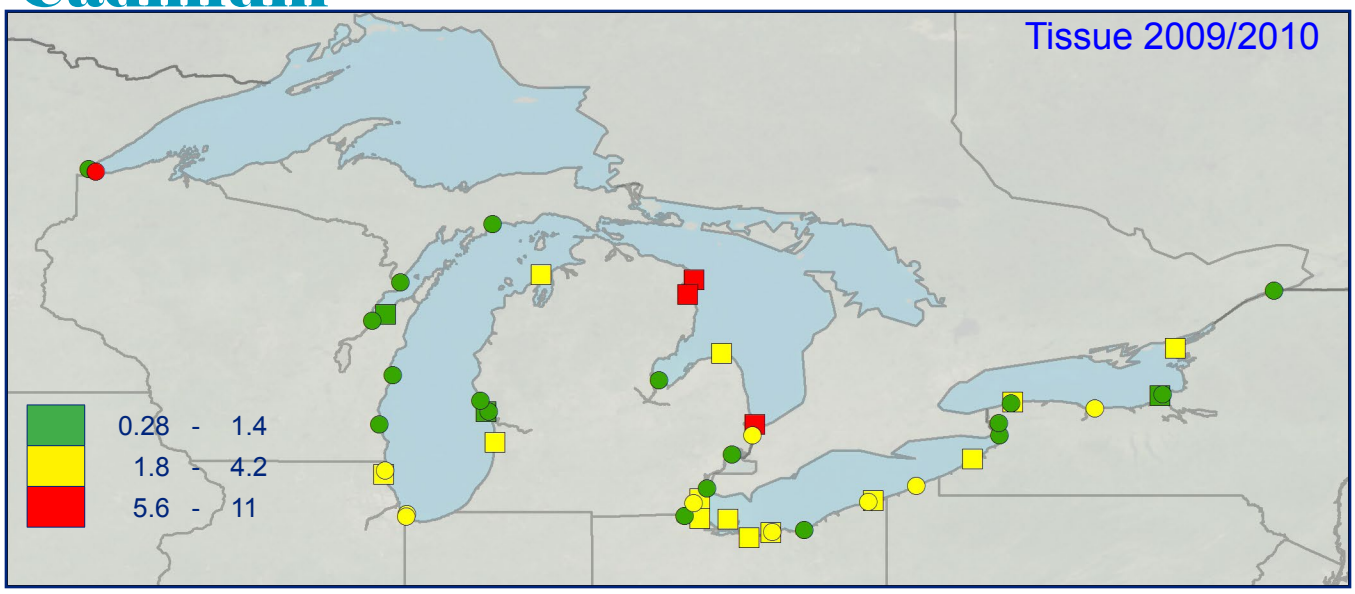




National frequency plot and sediment map: Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; µg/g dry wt.).

Cadmium



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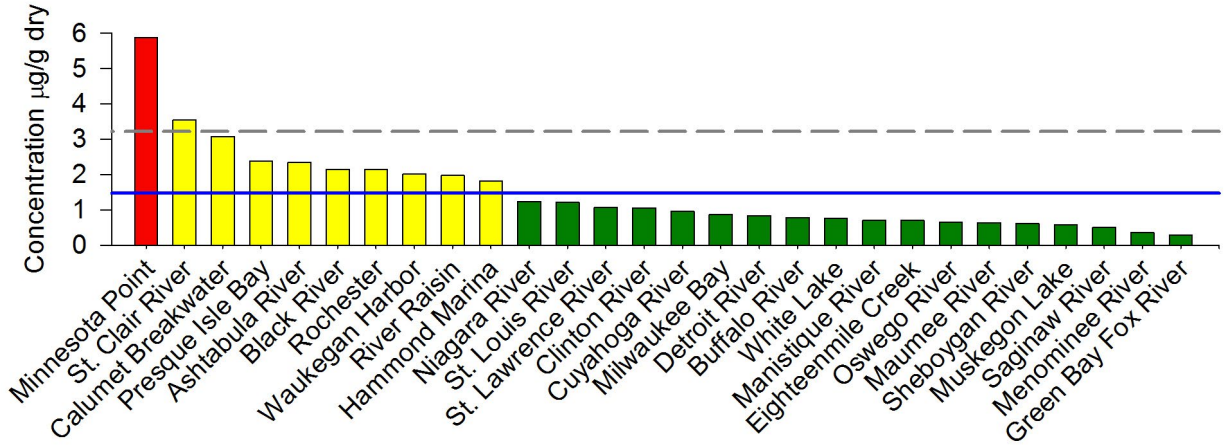

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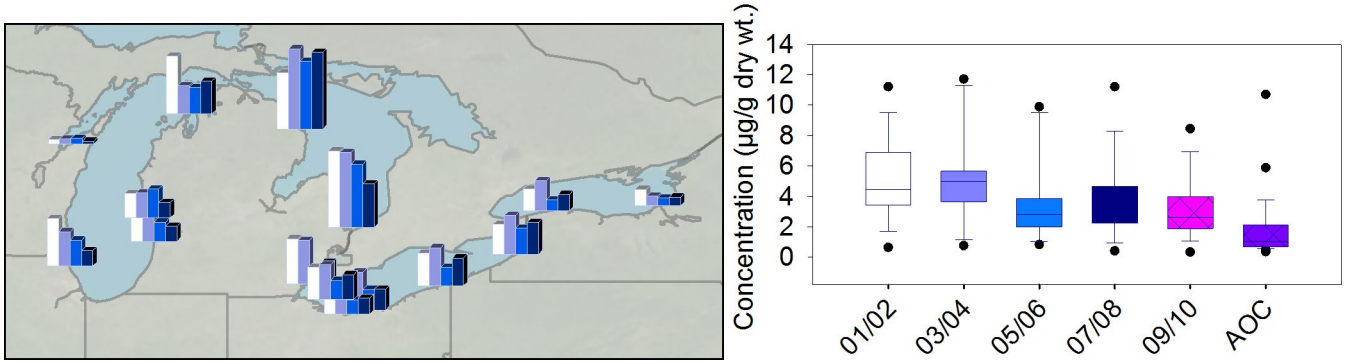

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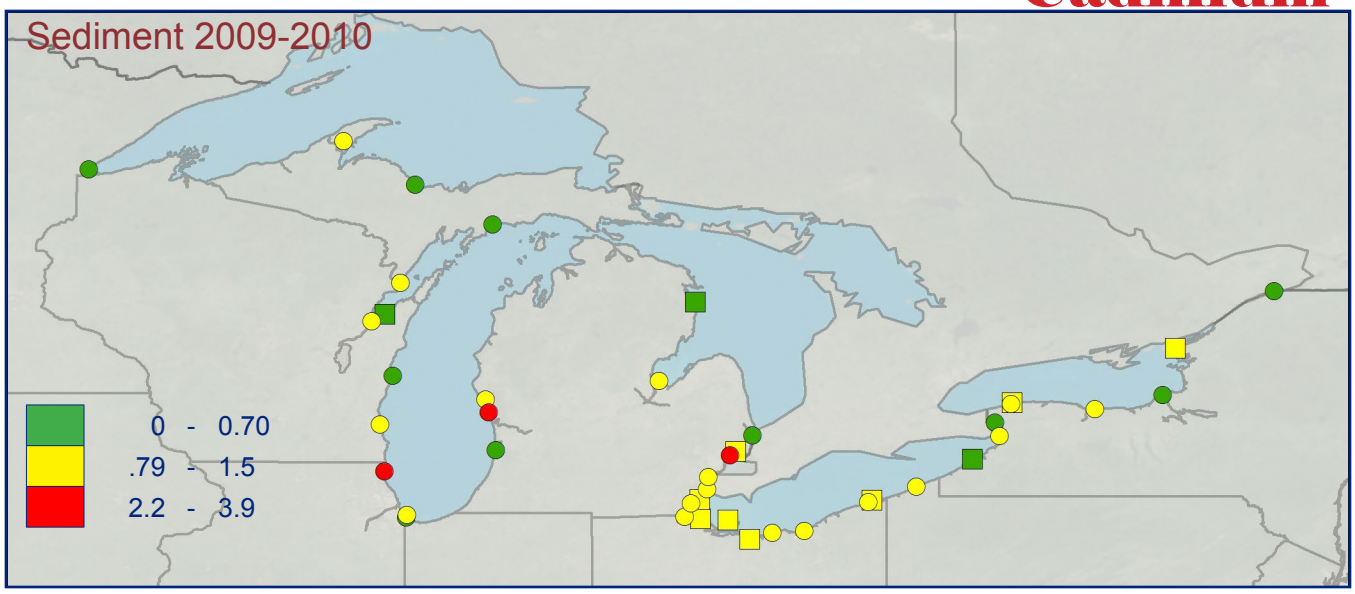
Cadmium



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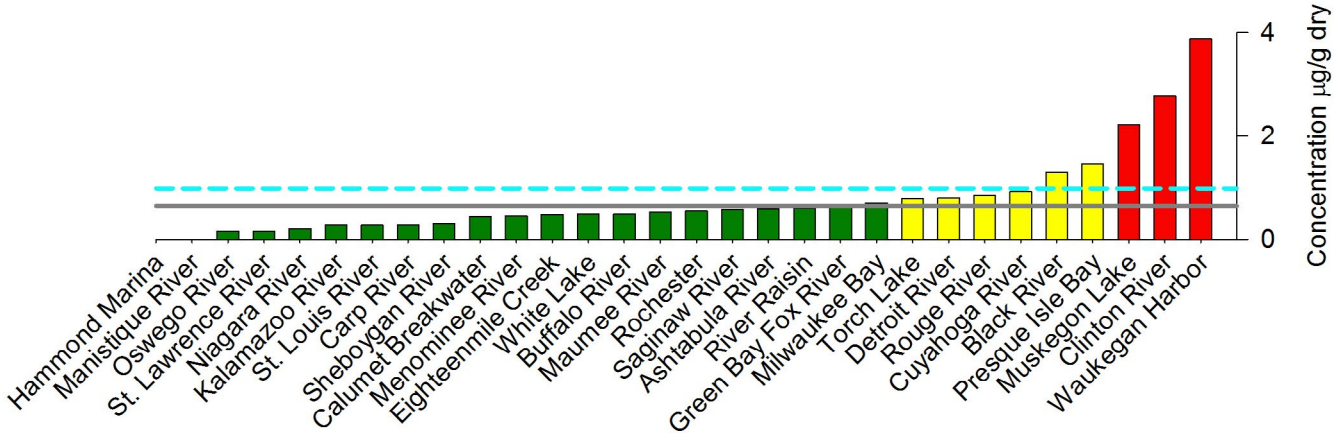

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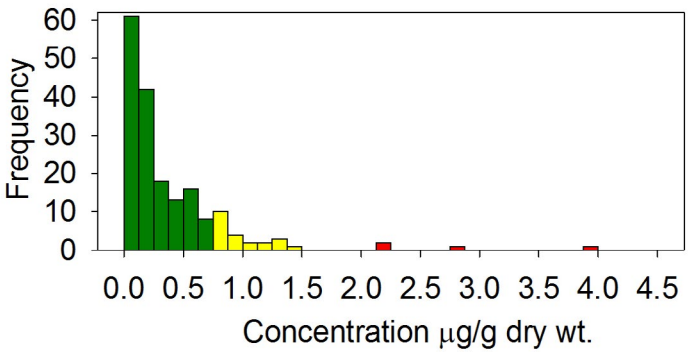
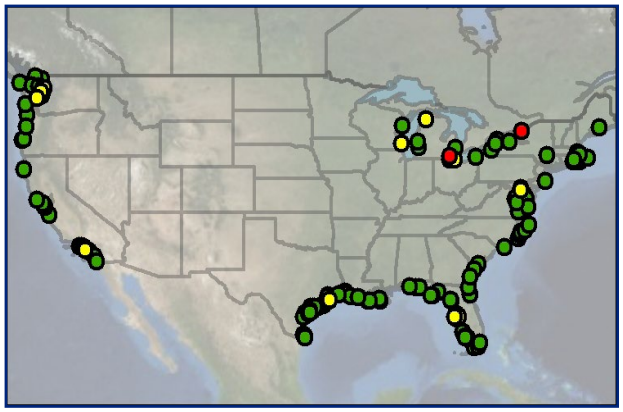
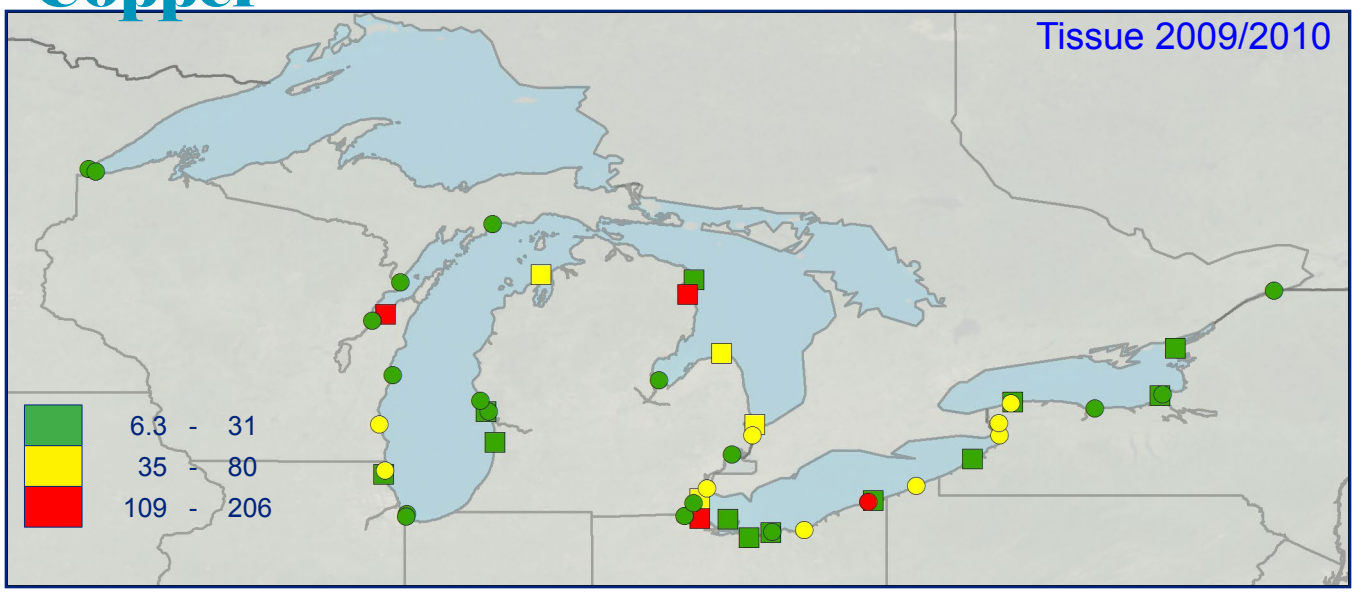


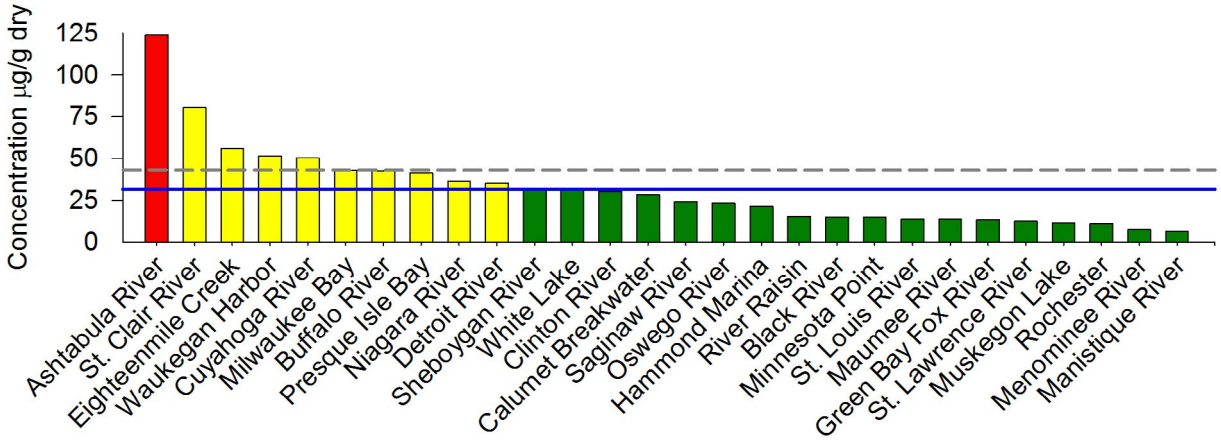


National frequency plot and sediment map: Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; µg/g dry wt.).

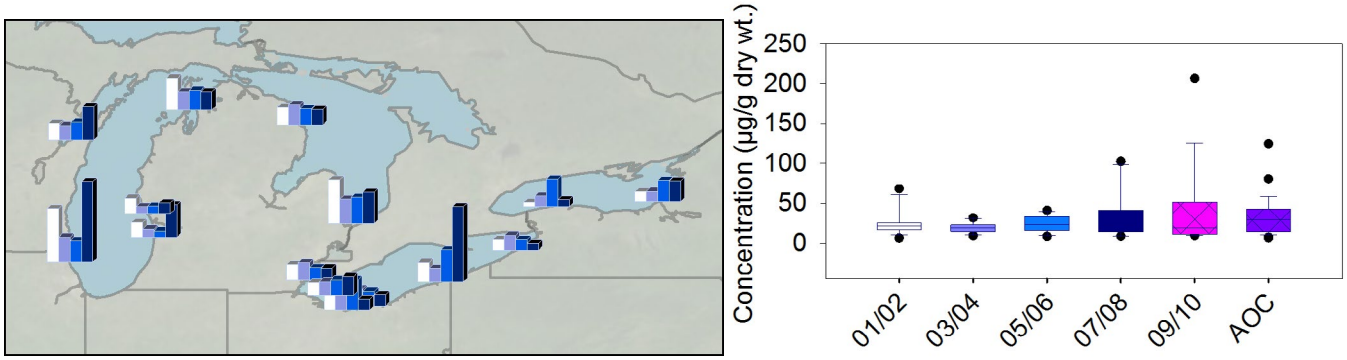
Copper



Tissue map: Categories low (●), medium (●) and high (●), and where applicable outlier (★), are used to characterize U.S. AOC (●) and reference (■) site contaminant concentrations (ng/g lipid) in dressenid mussels.

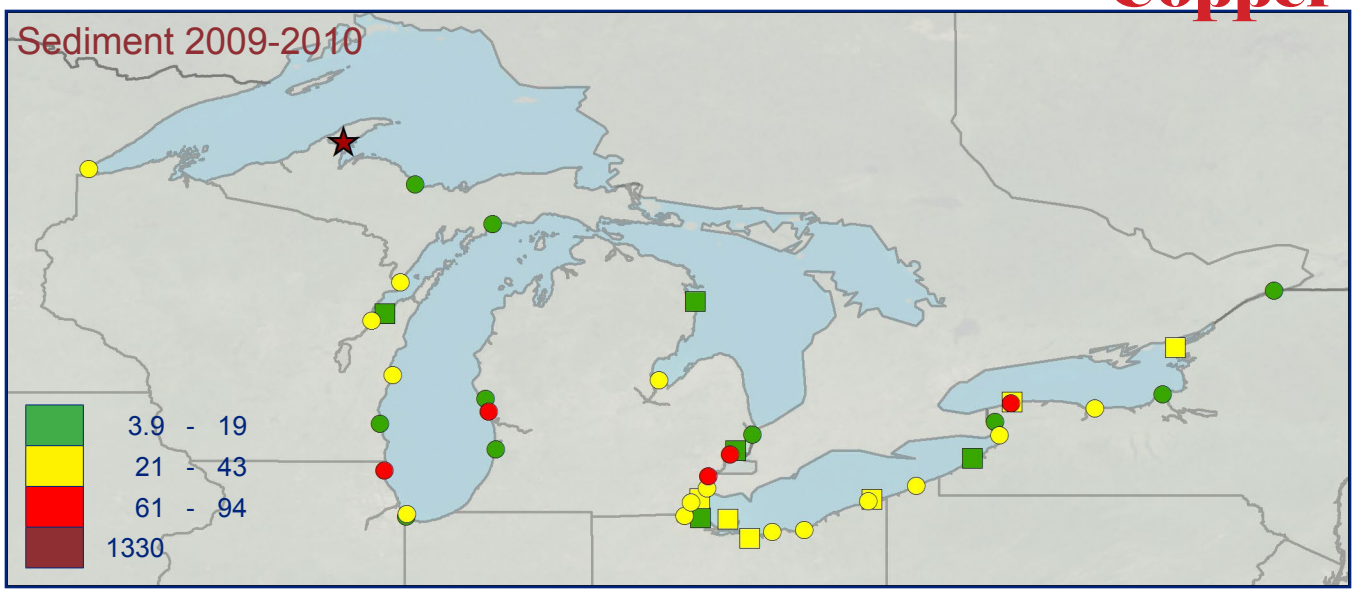


AOC Barchart: Comparison of AOC contaminant concentrations in dreissenid mussels (ng/g lipid) among AOCs. Reference lines represent mean AOC (solid line) and reference site (dashed line) concentrations.



Historic data. Mussel tissue concentration (ng/g lipid) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and AOC sites collected in 2009/2010.

Copper



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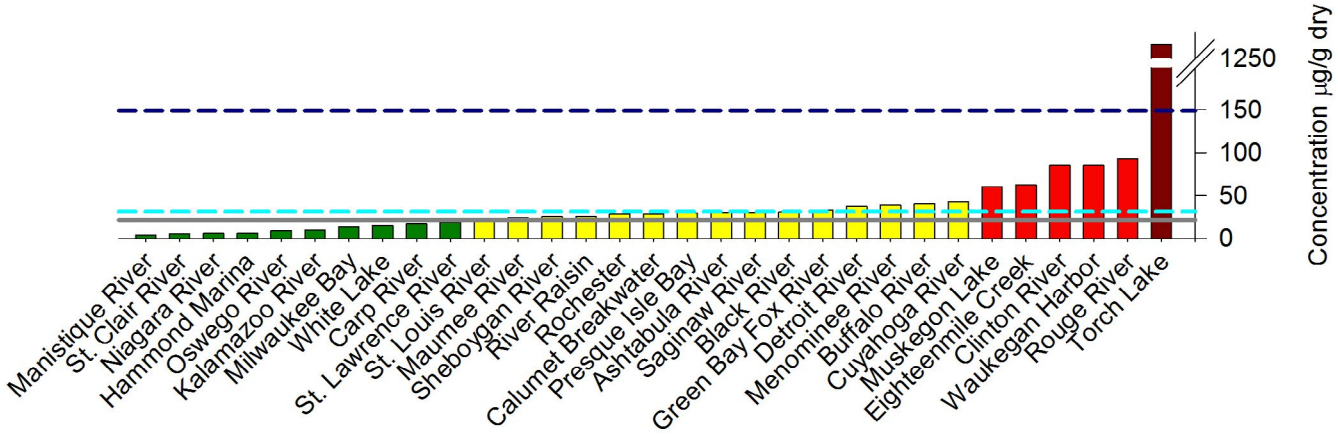
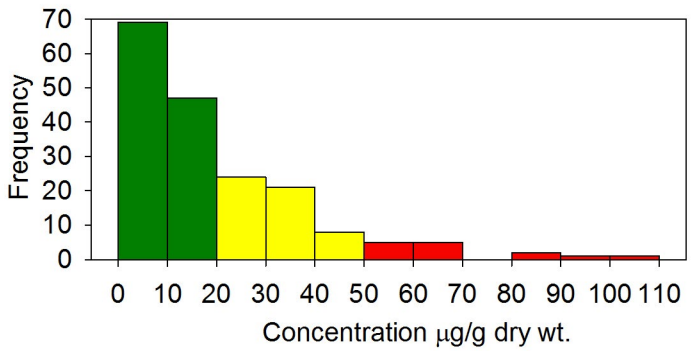
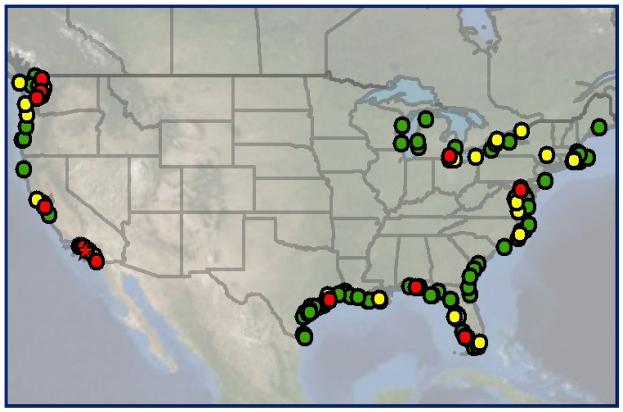


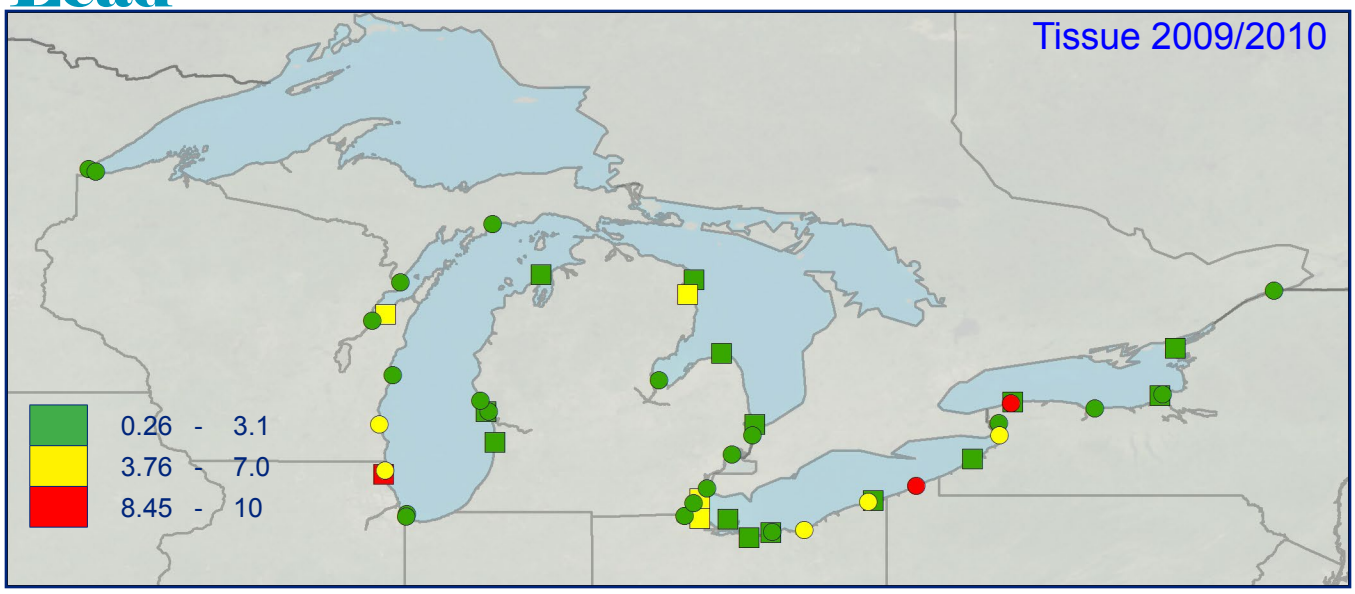
AOC barchart: Comparison of AOC contaminant concentrations in sediment (ng/g dry wt.). Where relevant reference lines representing PEC (black dashed line), TEC (blue dashed line), and reference site mean (gray solid line) are given.





National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.). Extreme outliers omitted.

Lead



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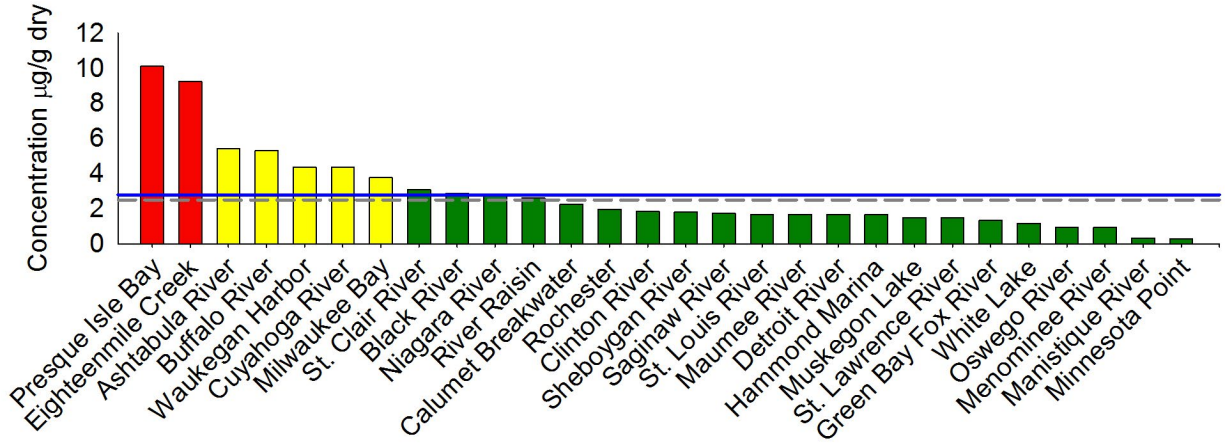
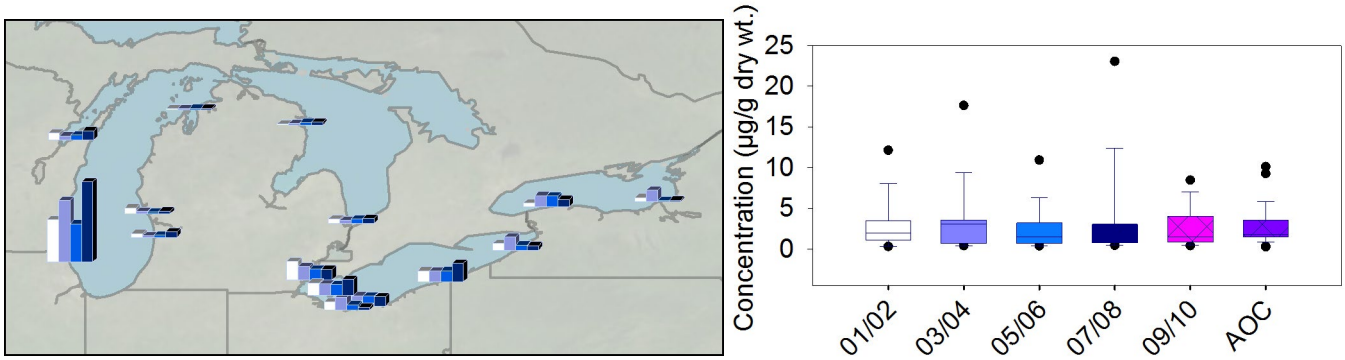
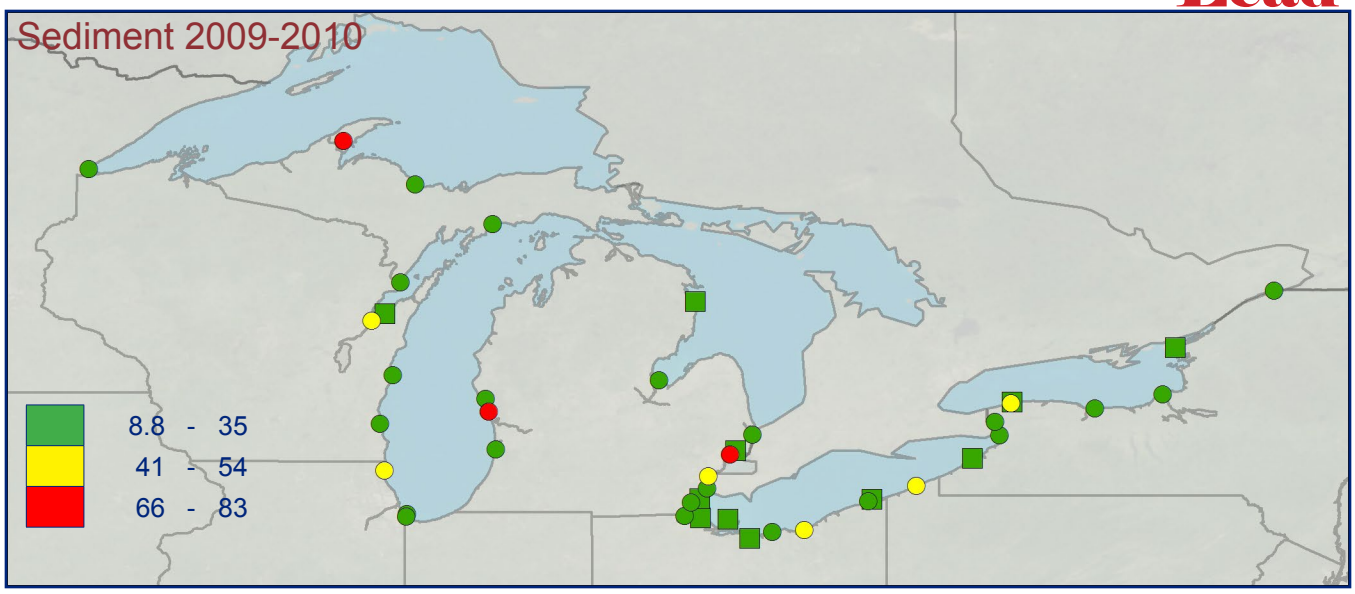


AOC barchart: Comparison of AOC contaminant concentrations in dreissenid mussels (µg/g dry wt.). Reference lines represent mean AOC (solid line) and reference site (dashed line) concentrations.



Historic data: Mussel tissue concentration (µg/g dry wt.) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and AOC sites collected in 2009/2010.



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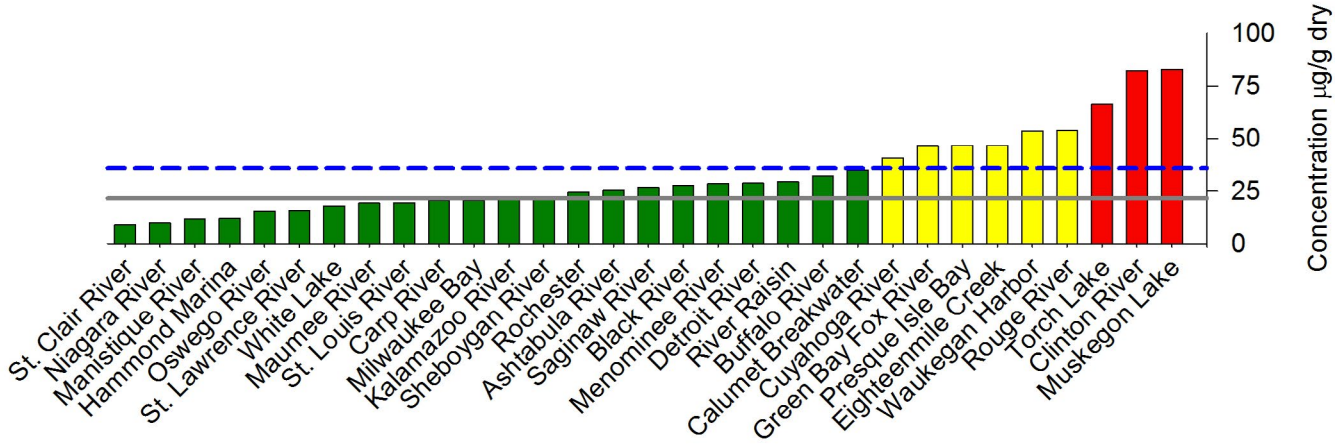

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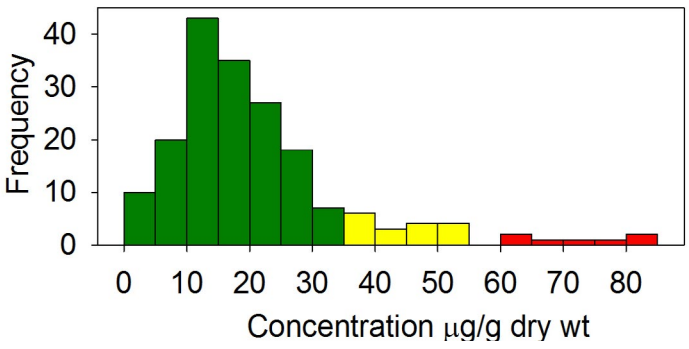
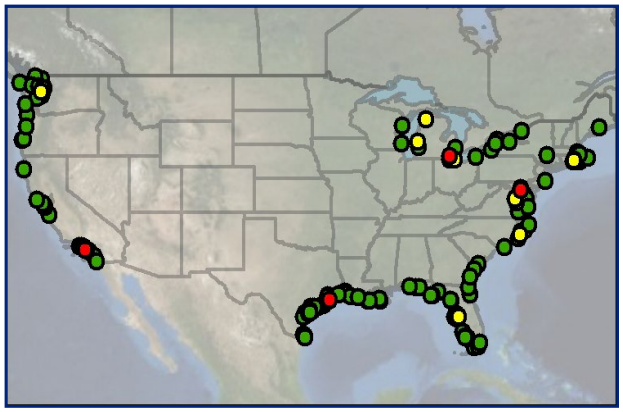
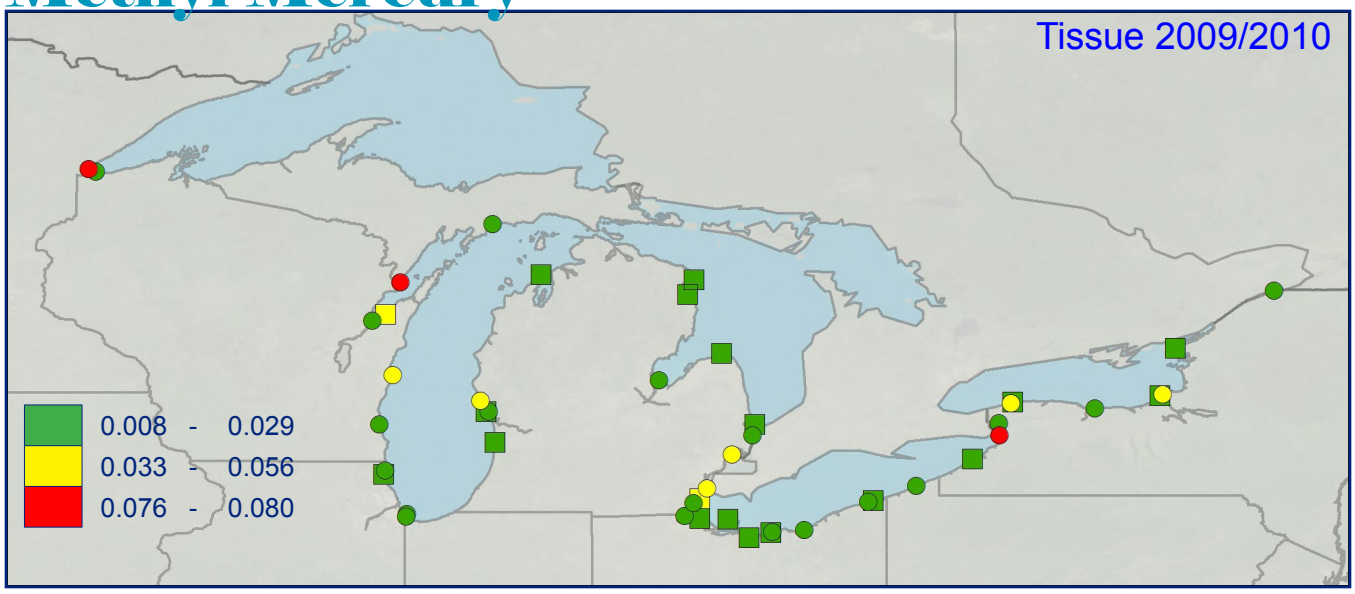




National frequency plot and sediment map: Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; µg/g dry wt.).

Methyl Mercury



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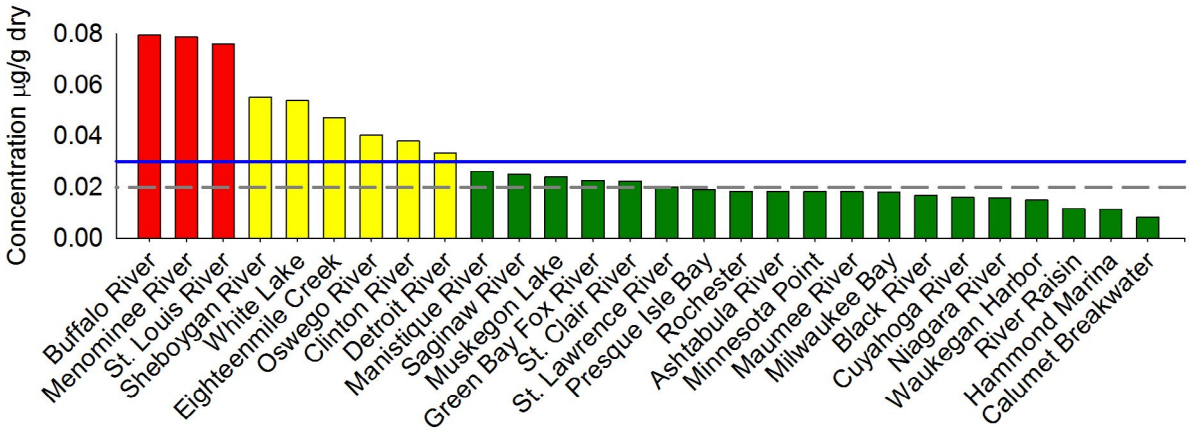
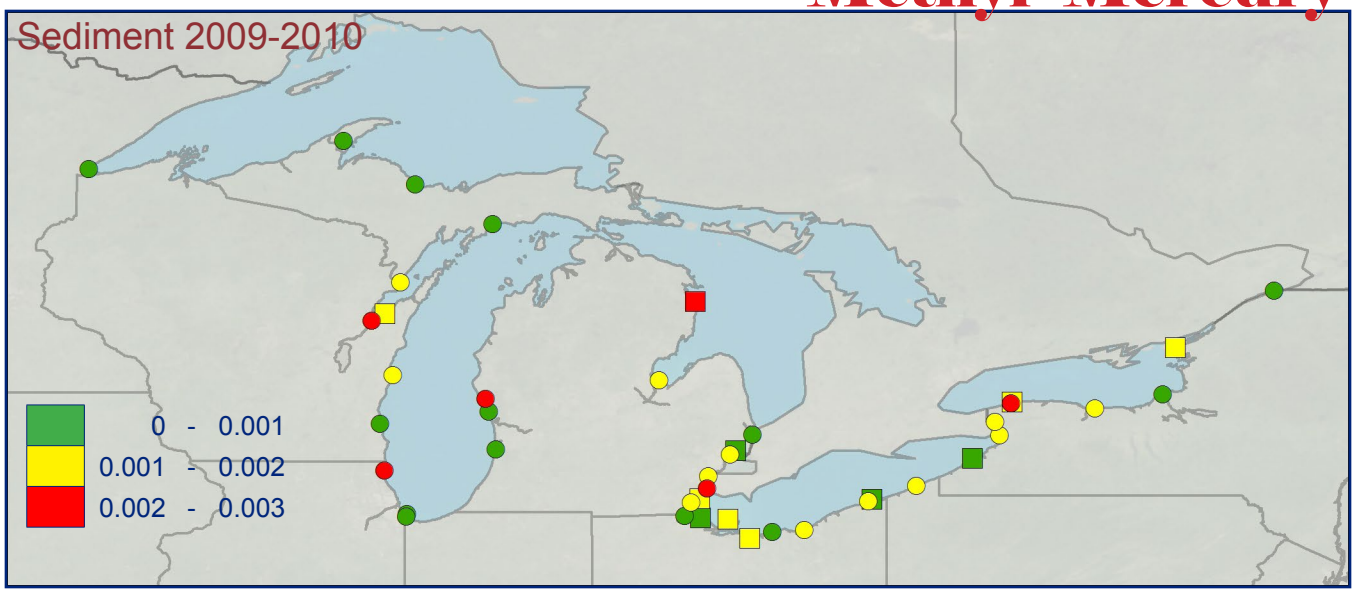
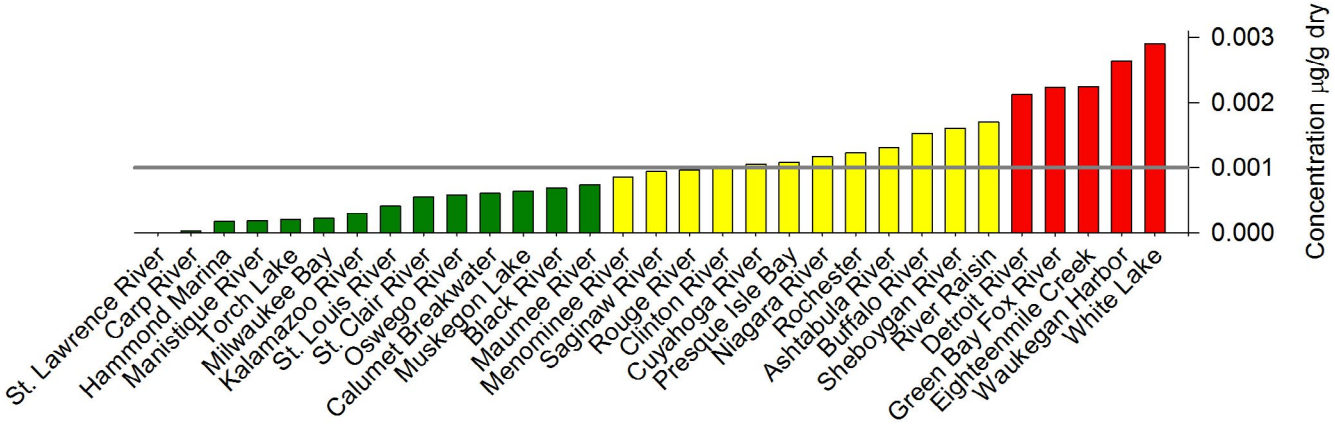


AOC barchart: Comparison of AOC contaminant concentrations in dreissenid mussels (µg/g dry wt.). Reference lines represent mean AOC (solid line) and reference site (dashed line) concentrations.

Methyl Mercury



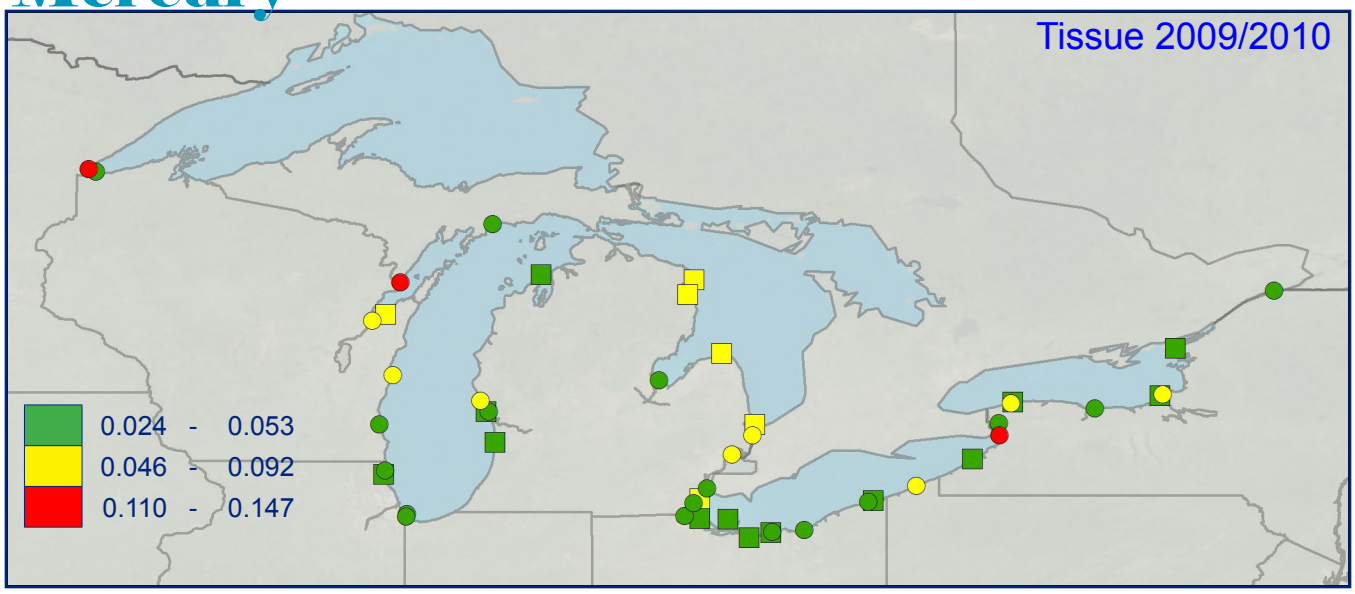
Sediment map: Categories low (●), medium (●) and high (●), and where applicable outlier (★), are used to characterize U.S. AOC (●) and reference (■) site sediment concentrations (µg/g dry wt.).



AOC barchart: Comparison of AOC contaminant concentrations in sediment (µg/g dry wt.). Where relevant, reference lines representing PEC (black dashed line), TEC (blue dashed line), and reference site mean (gray solid line) are given.

and

Mercury



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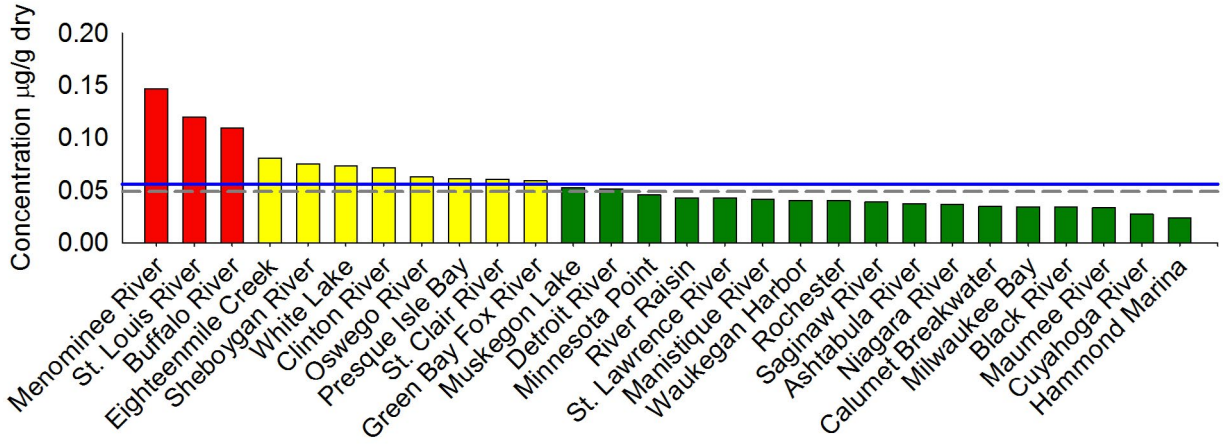

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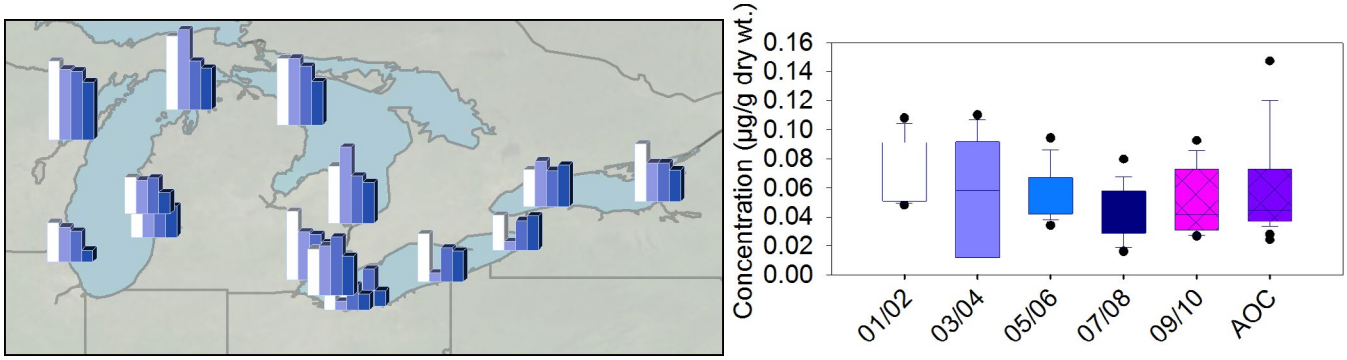
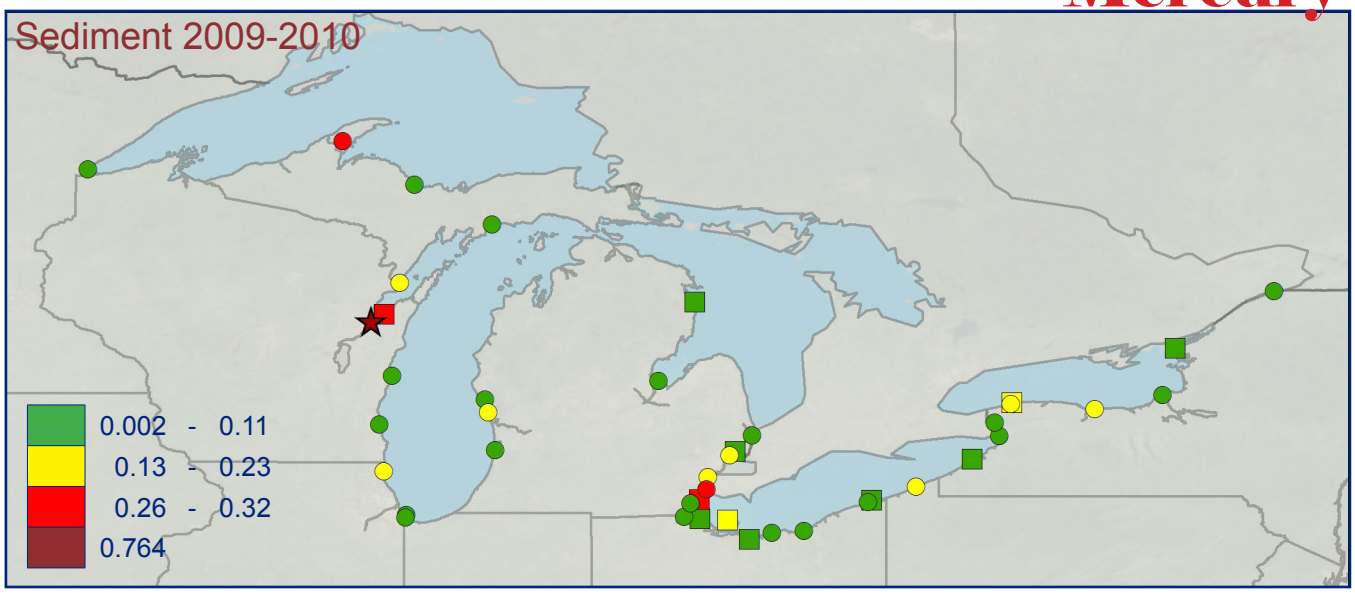


Historic data: Mussel tissue concentration (µg/g dry wt.) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and AOC sites collected in 2009/2010.



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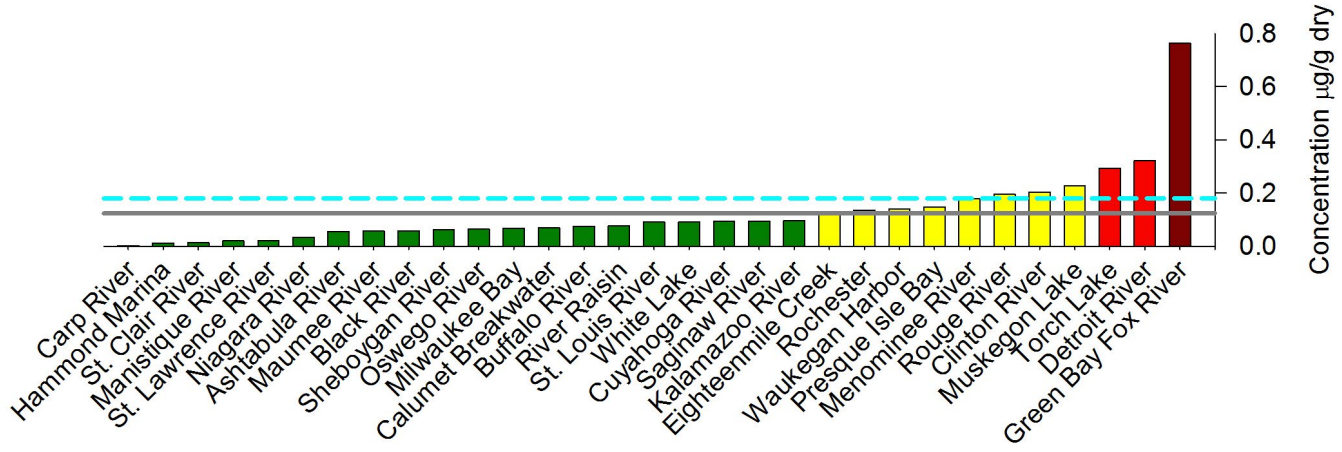

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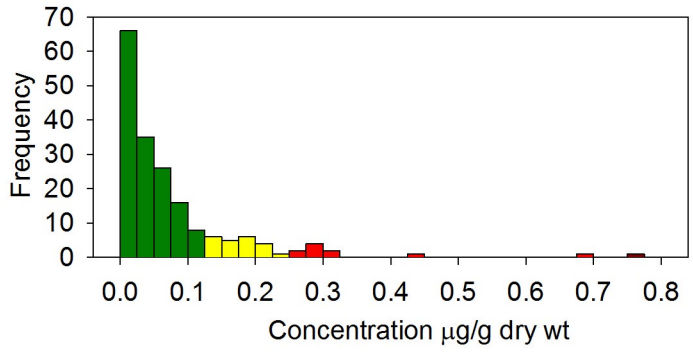
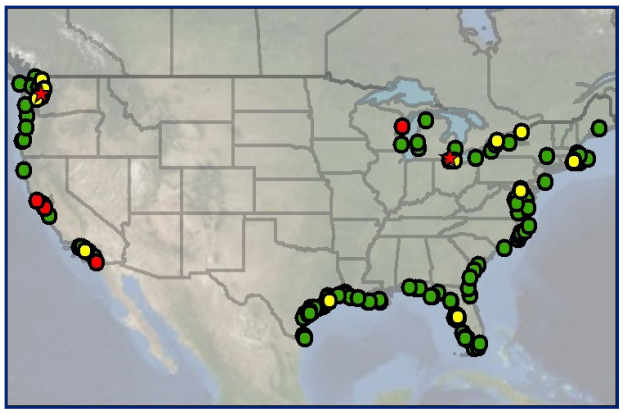
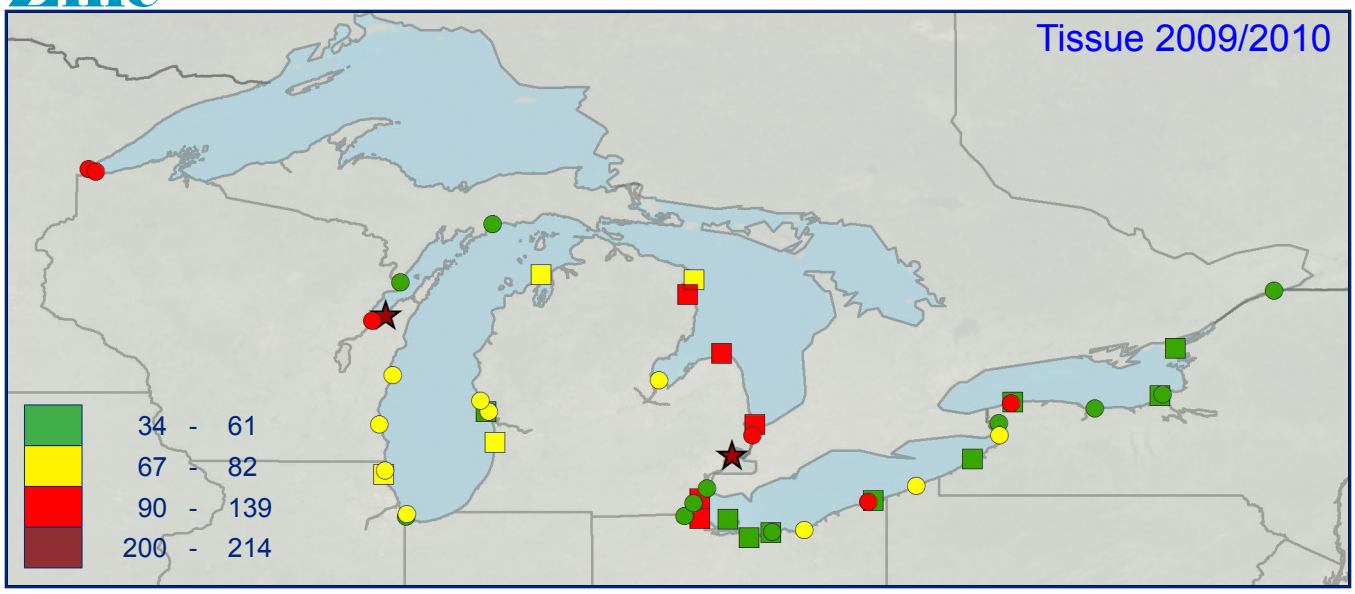




National frequency plot and sediment map: Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; µg/g dry wt.).

Zinc



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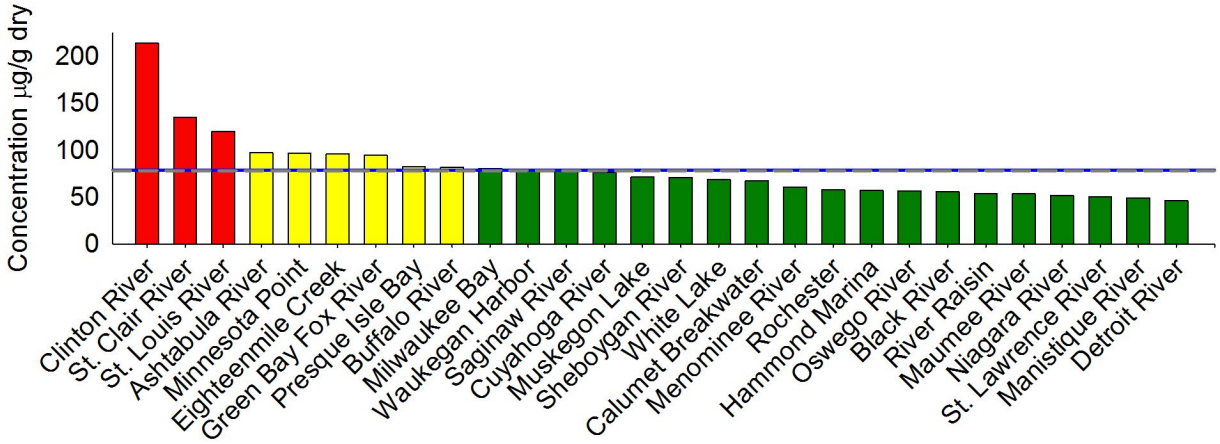

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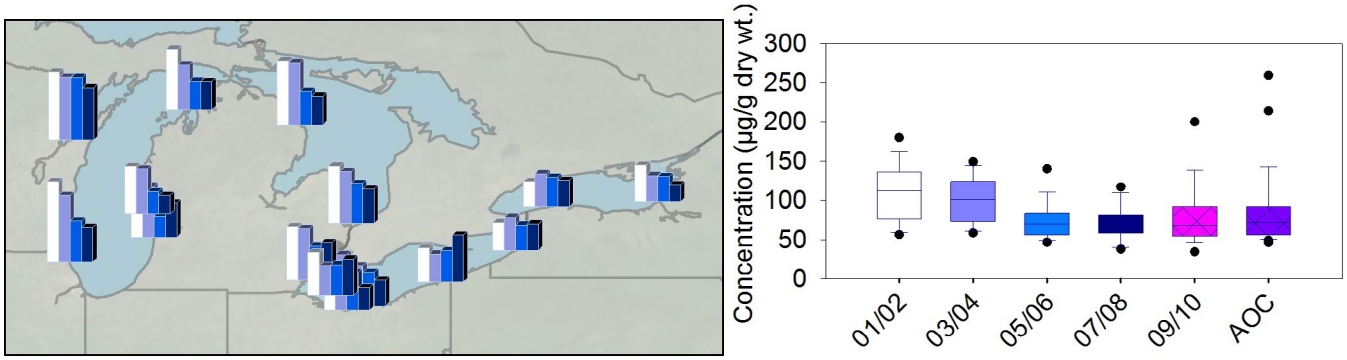
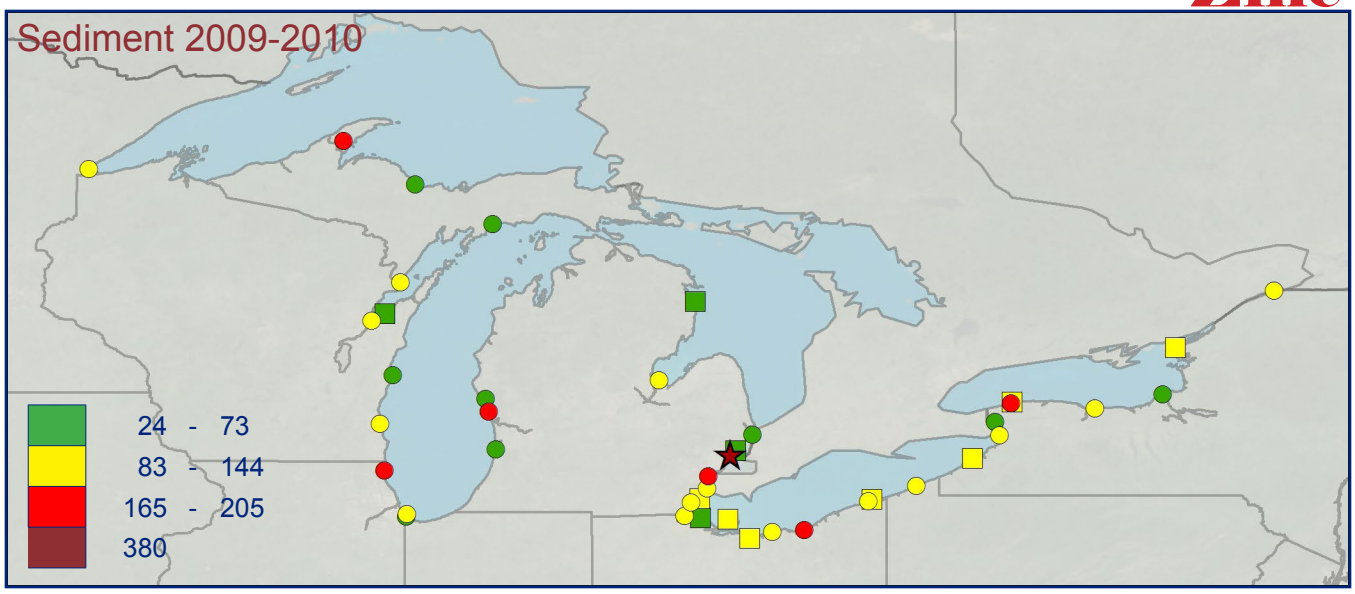


Historic data: Mussel tissue concentration (µg/g dry wt.) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and AOC sites collected in 2009/2010.



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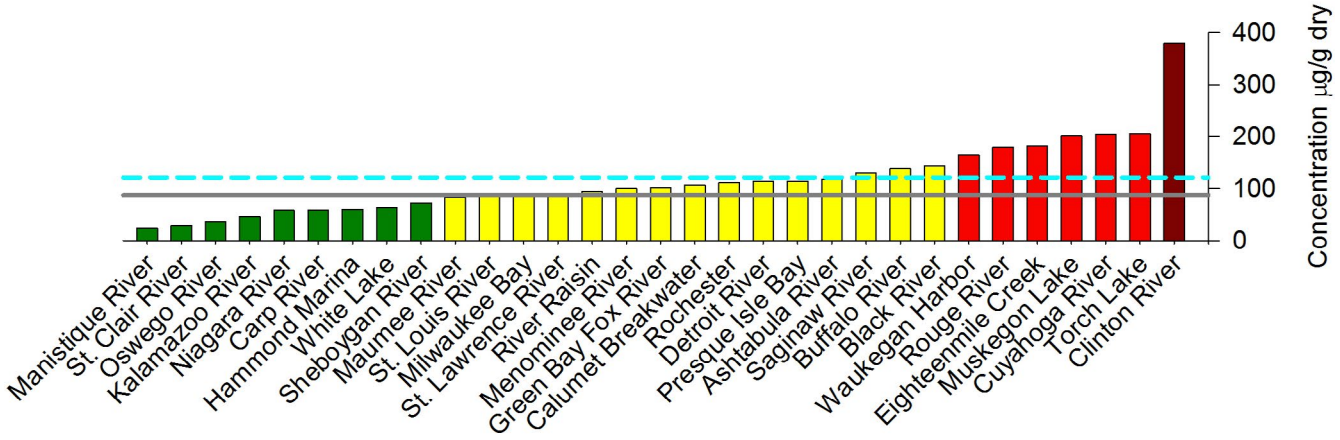

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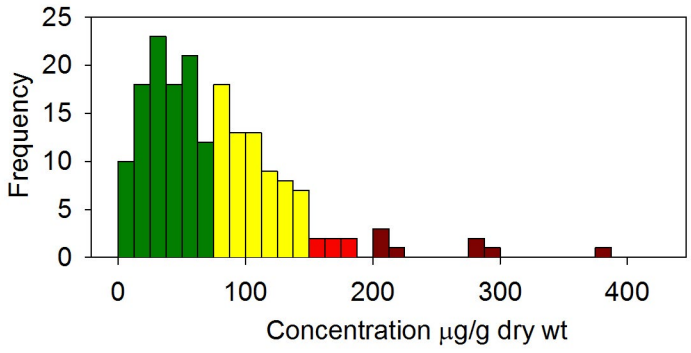
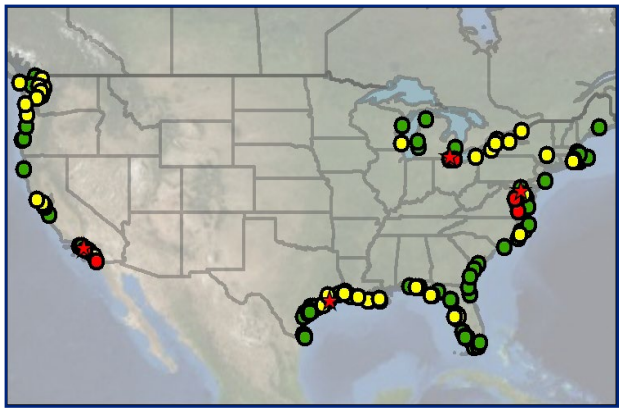
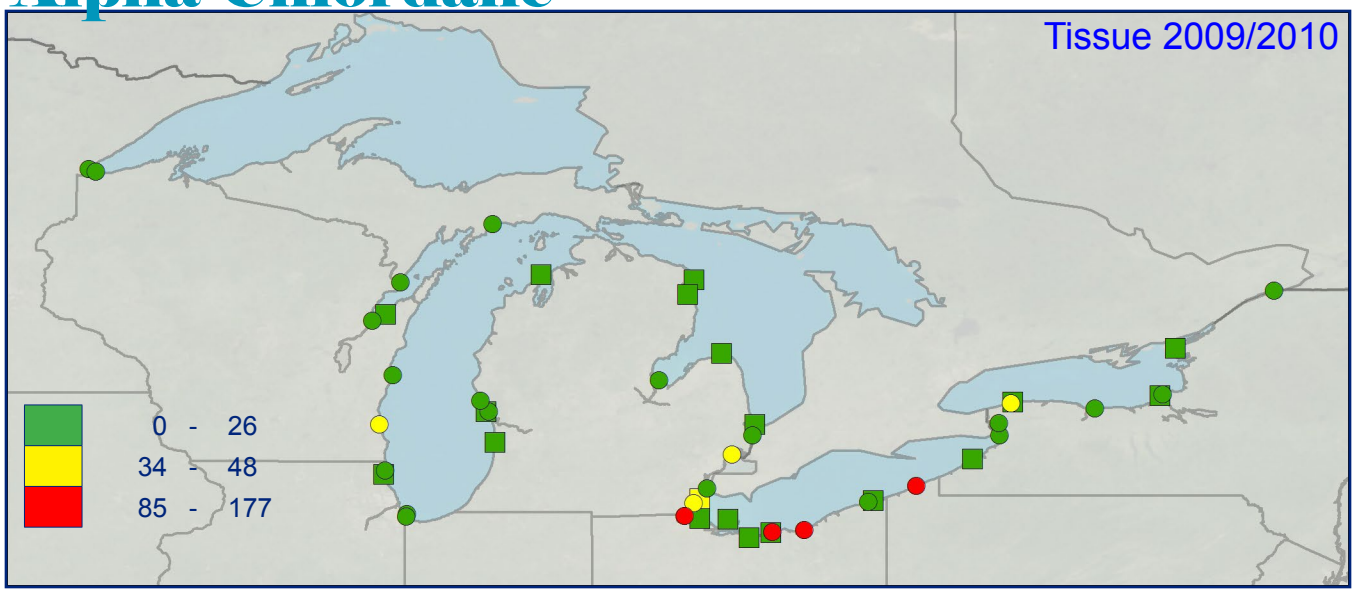


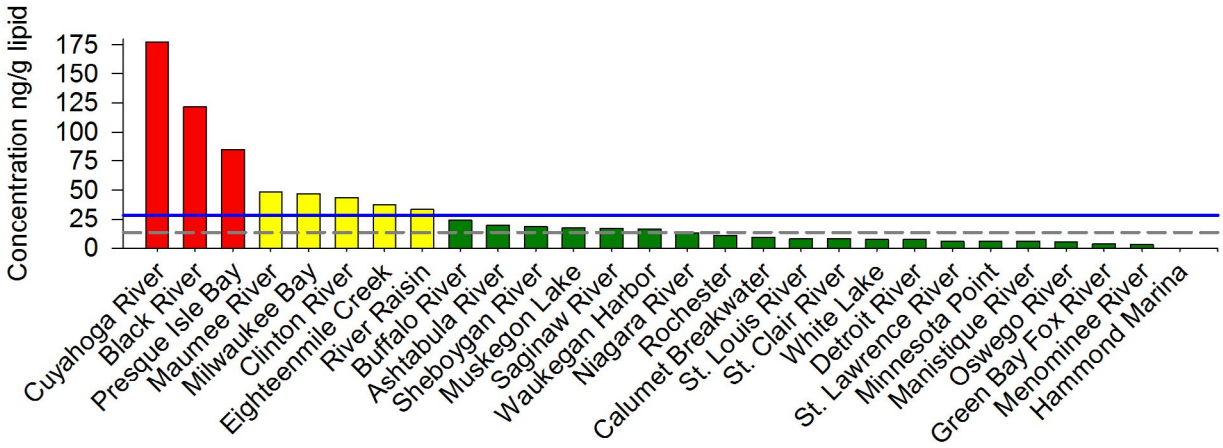


National frequency plot and sediment map: Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; µg/g dry wt.).

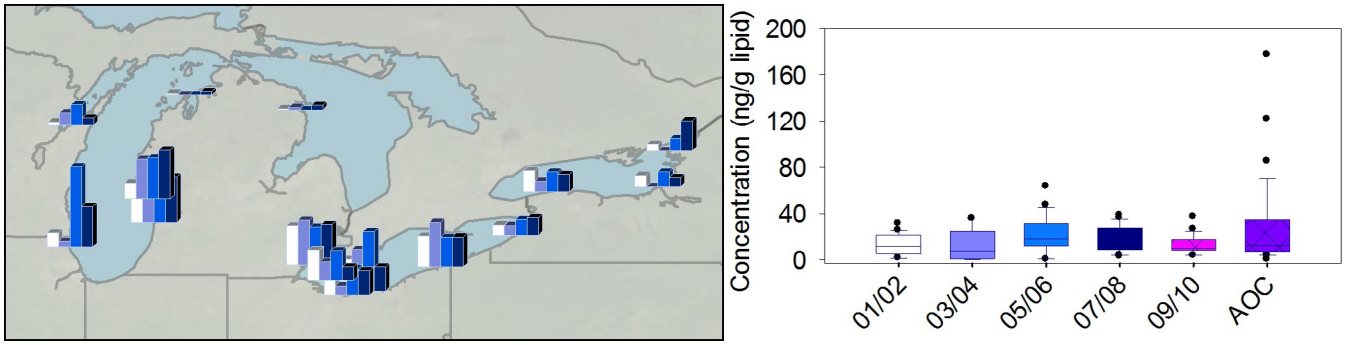
Alpha-Chlordane



Tissue map: Categories low (●), medium (●) and high (●), and where applicable outlier (★), are used to characterize U.S. AOC (●) and reference (■) site contaminant concentrations (ng/g lipid) in dressenid mussels.

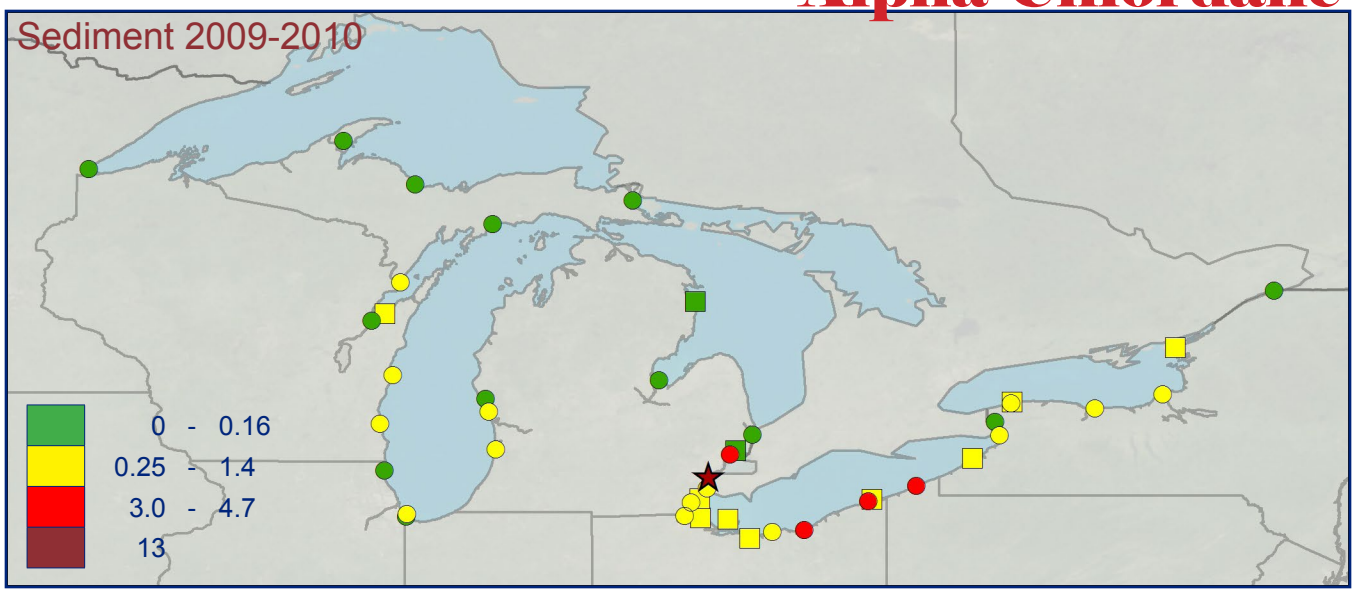


AOC Barchart: Comparison of AOC contaminant concentrations in dreissenid mussels (ng/g lipid) among AOCs. Reference lines represent mean AOC (solid line) and reference site (dashed line) concentrations.



Historic data. Mussel tissue concentration (ng/g lipid) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and AOC sites collected in 2009/2010.

Alpha-Chlordane



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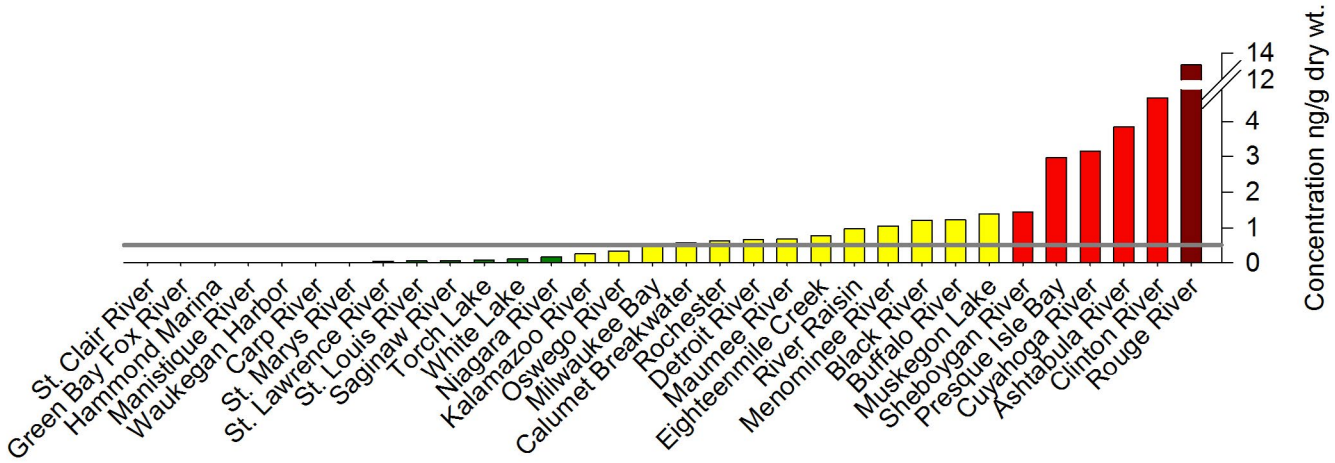

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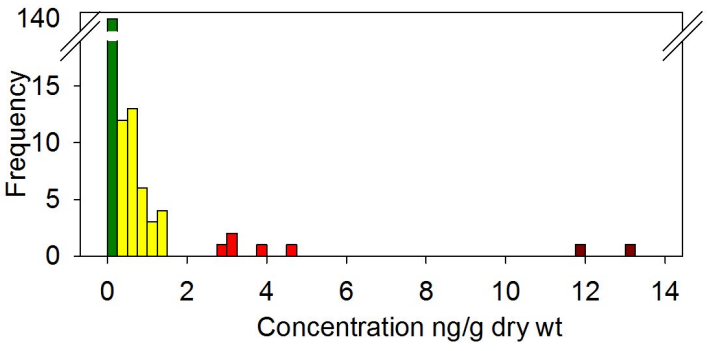
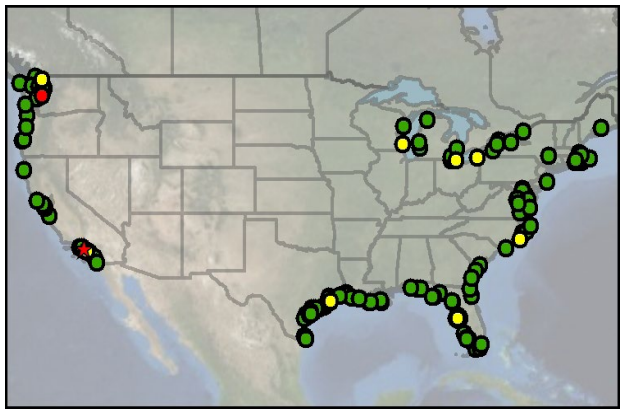
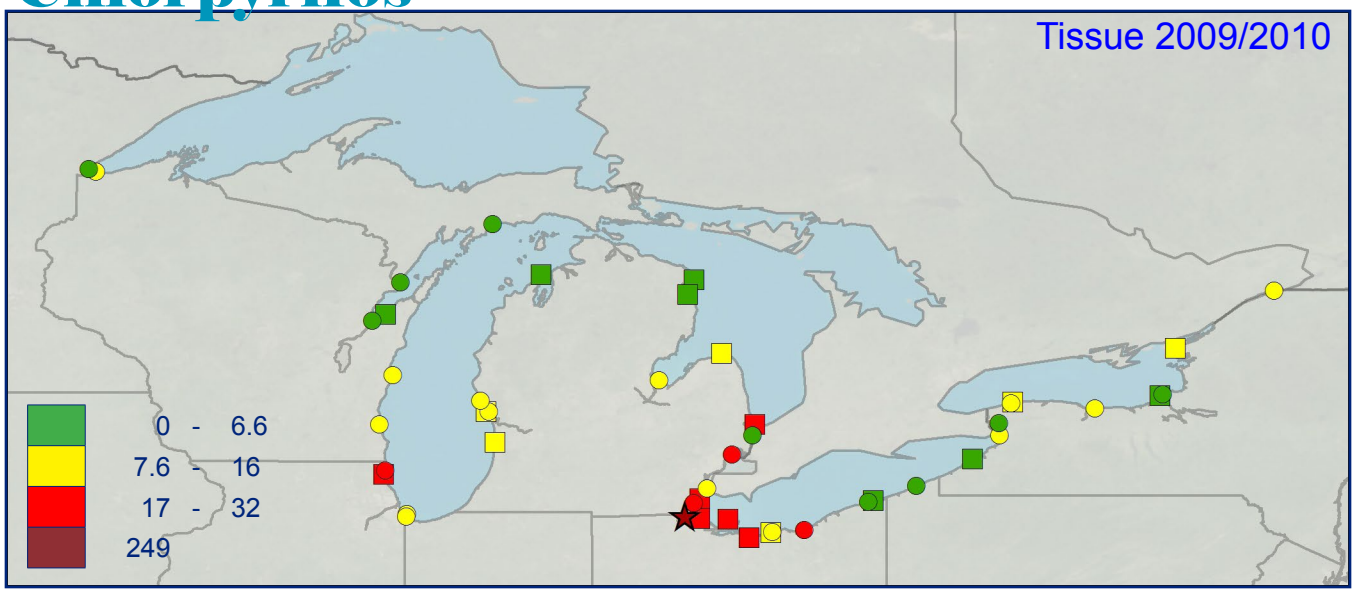




National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.).

Chlorpyrifos



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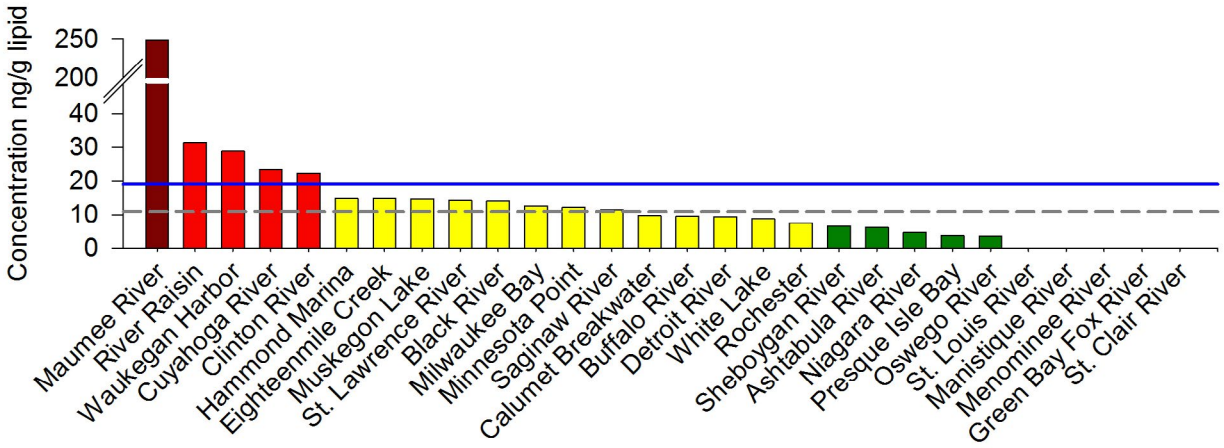

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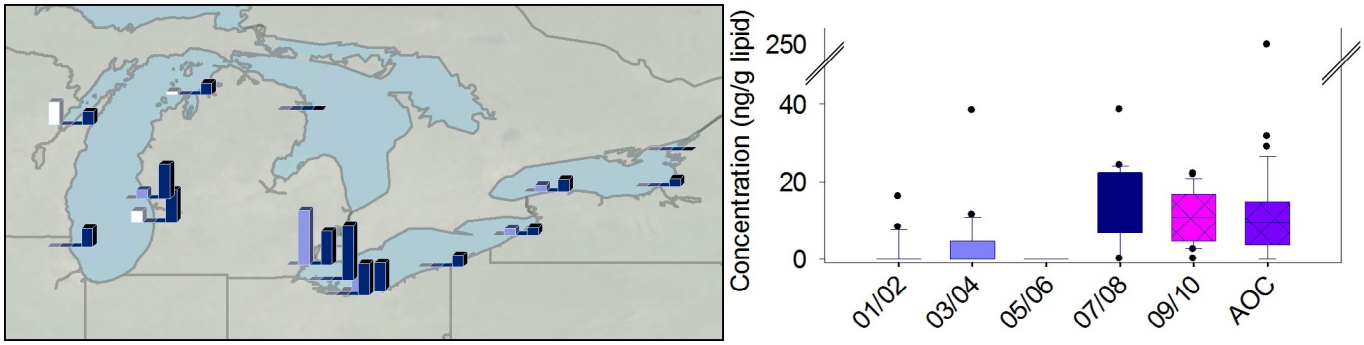
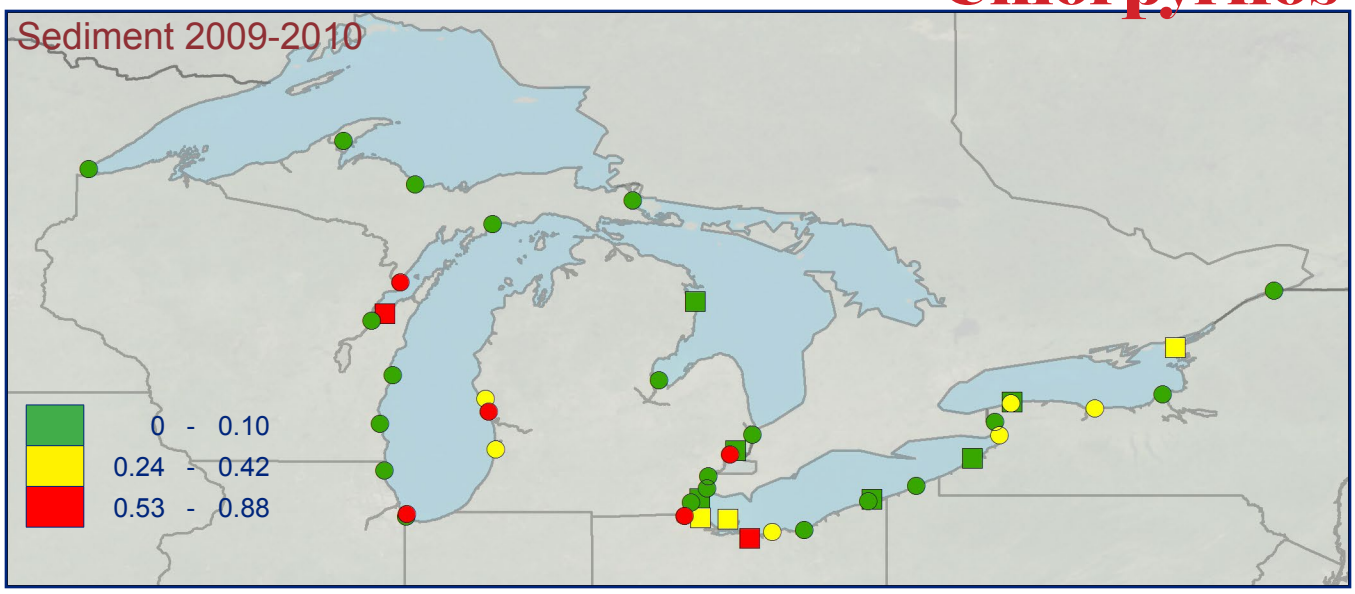


Historic data. Mussel tissue concentration (ng/g lipid) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and AOC sites collected in 2009/2010.

Chlorpyrifos



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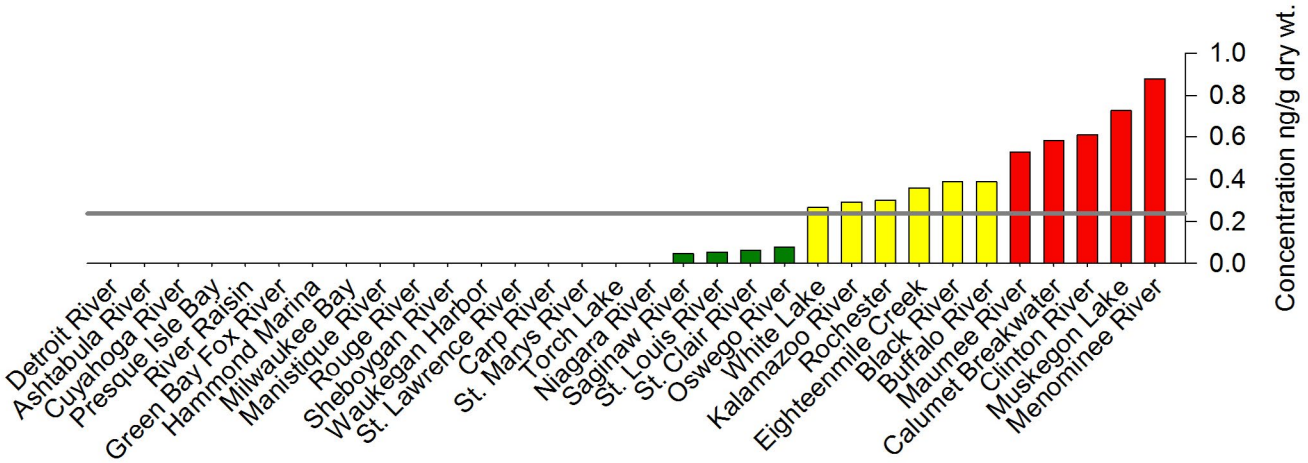

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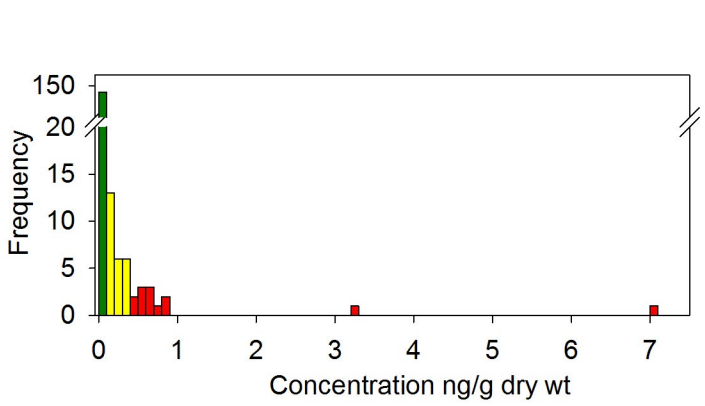
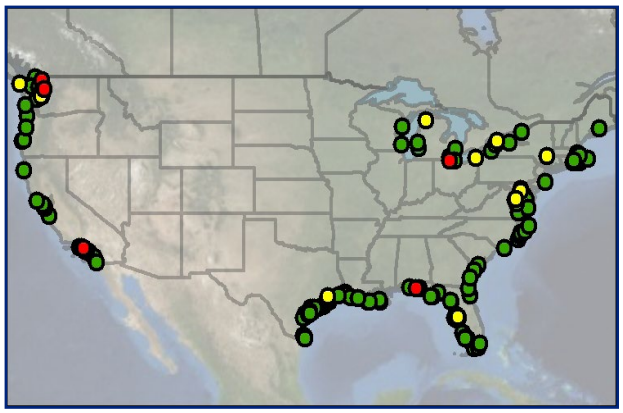
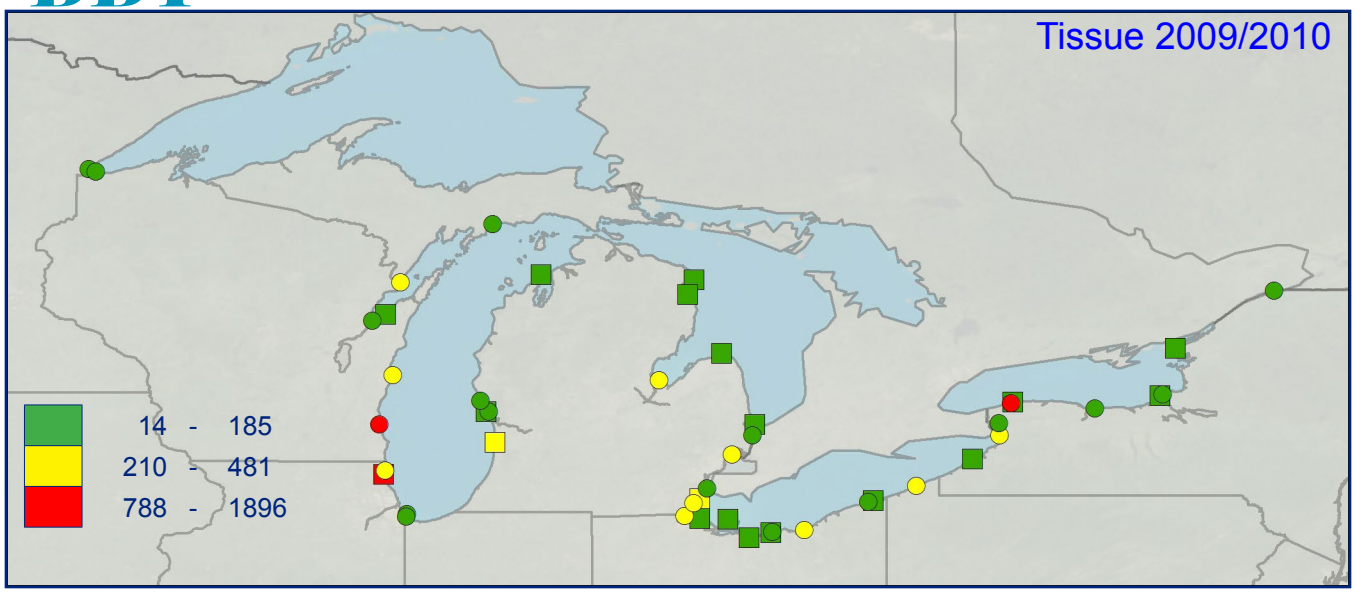




National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.).

DDT



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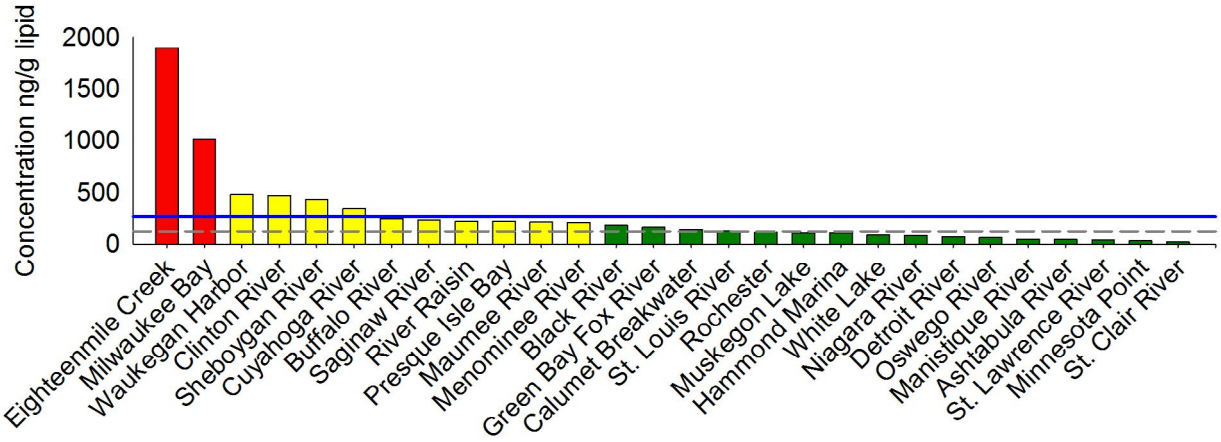

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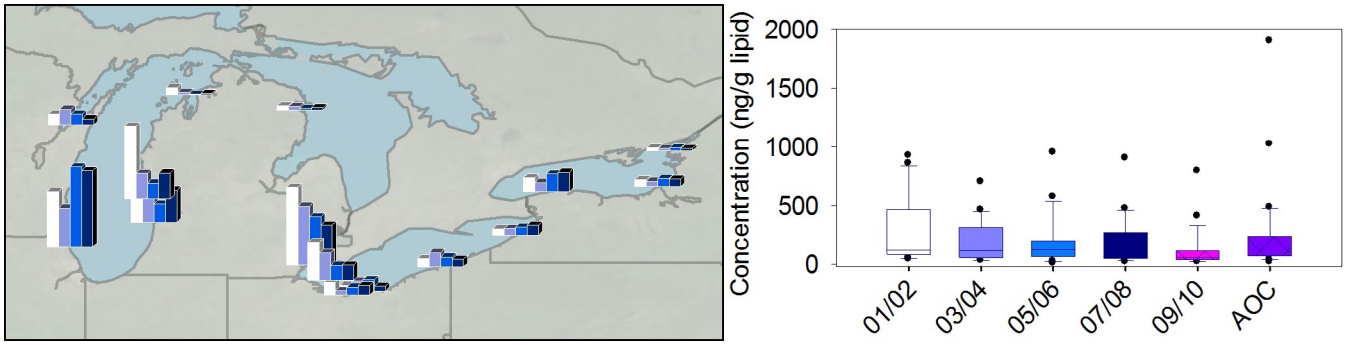

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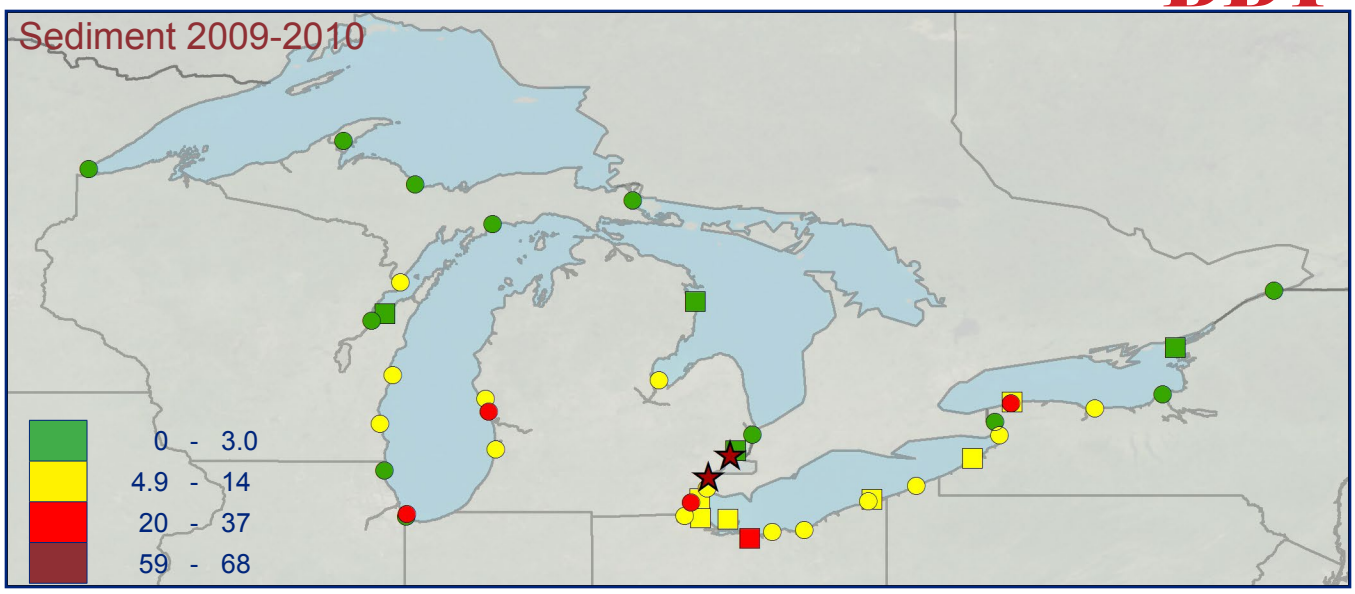

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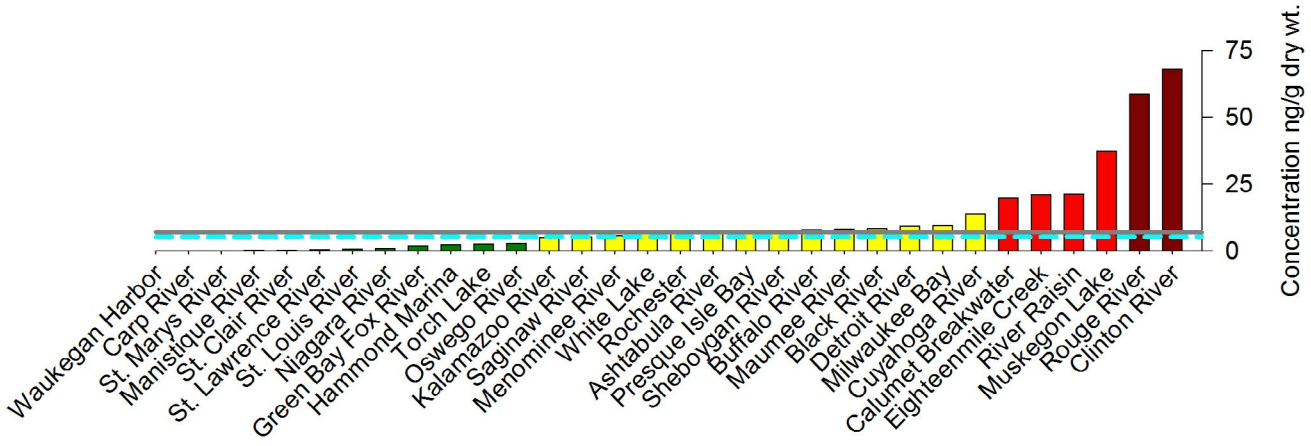

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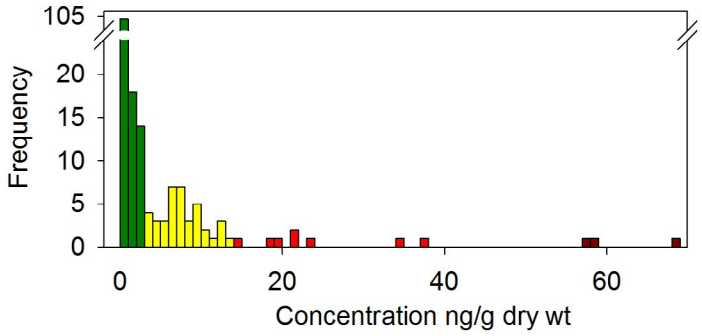
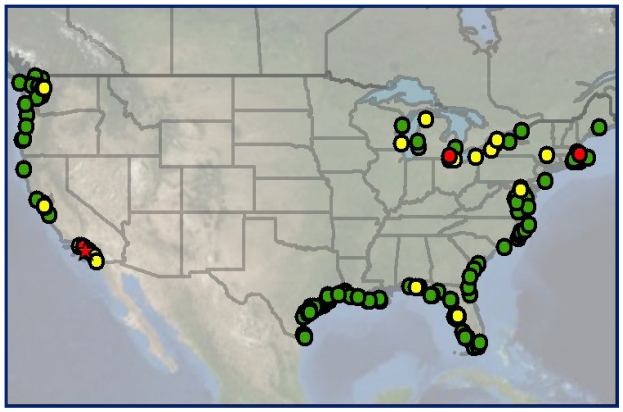
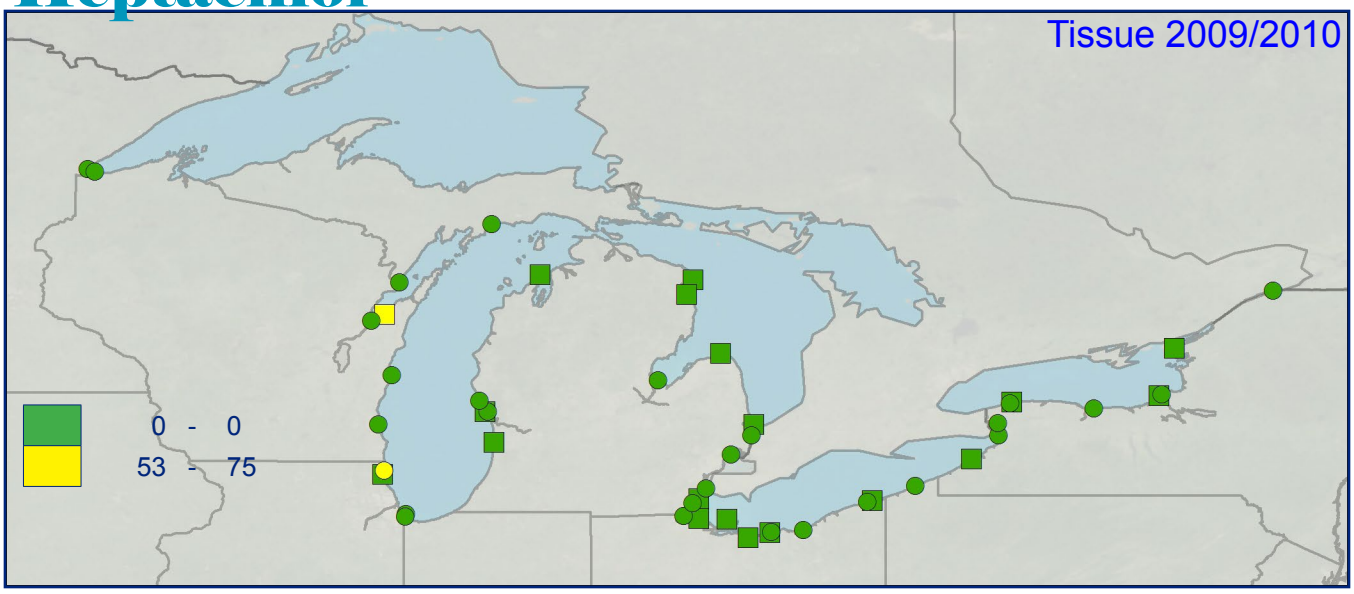




National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.).

Heptachlor



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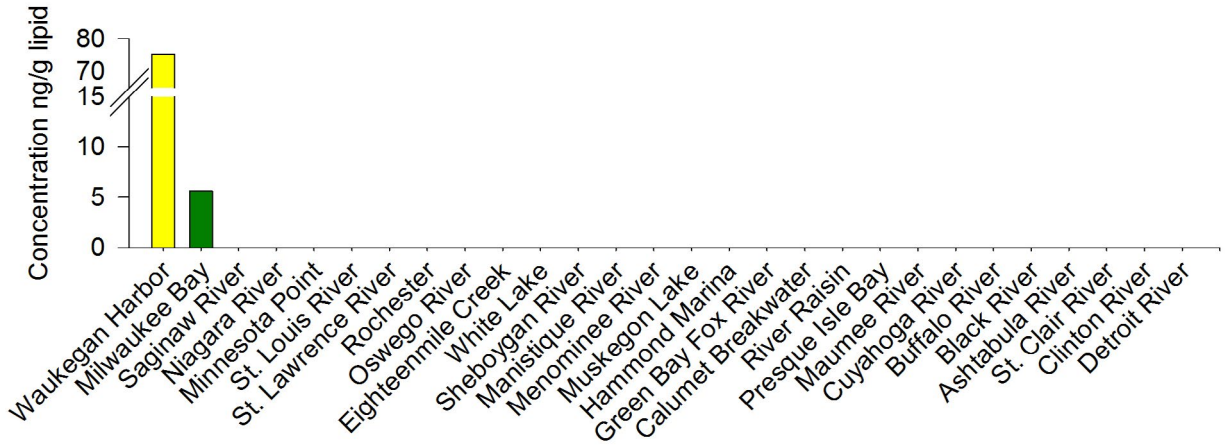

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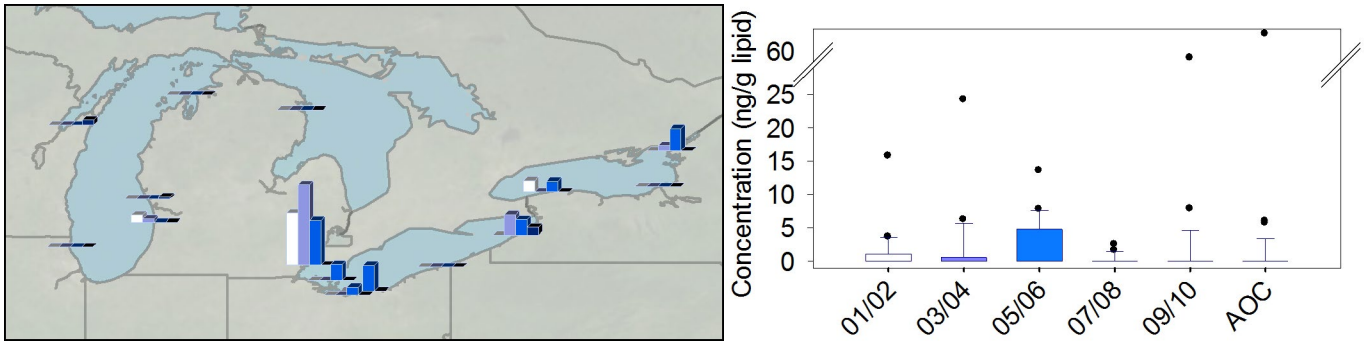

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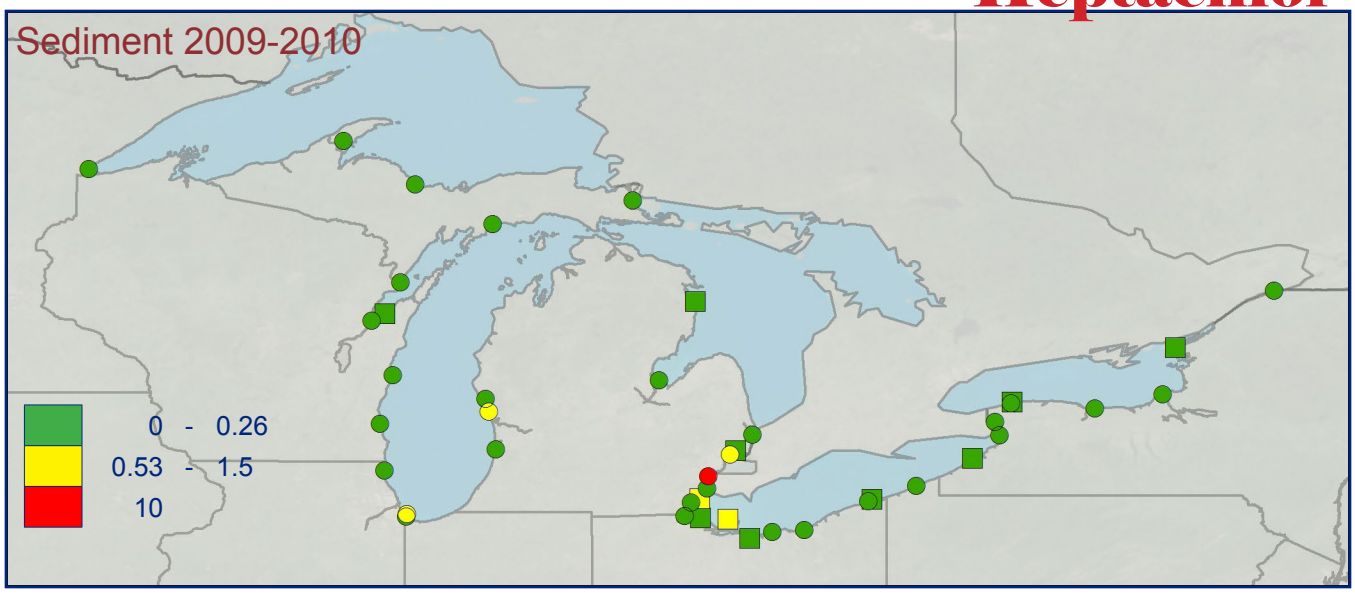
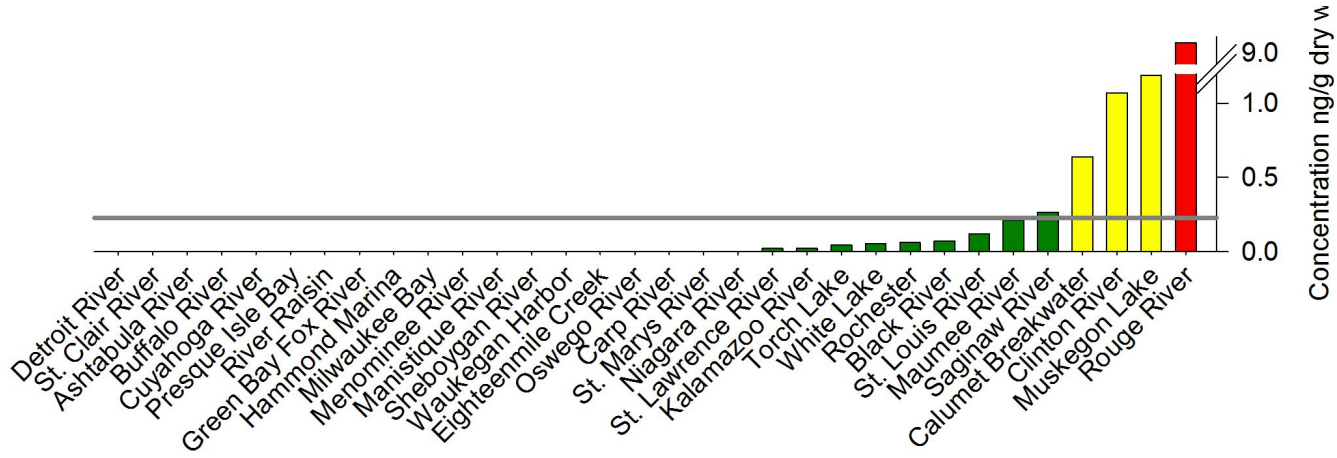
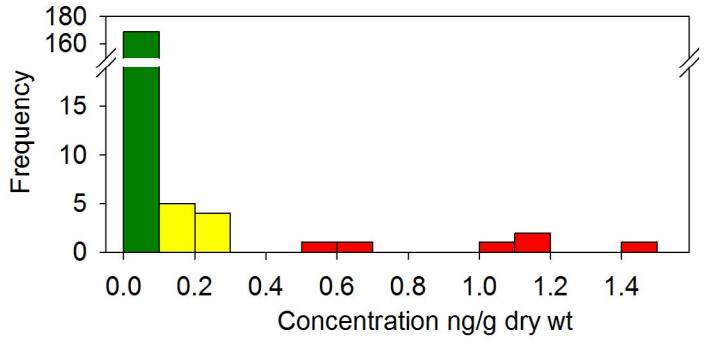
Heptachlor

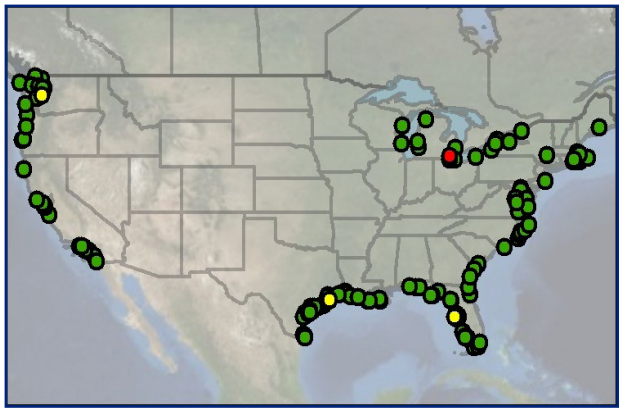


Sediment map: Categories low (●), medium (●) and high (●), and where applicable outlier (★), are used to characterize U.S. AOC (●) and reference (■) site sediment concentrations (ng/g dry wt.).



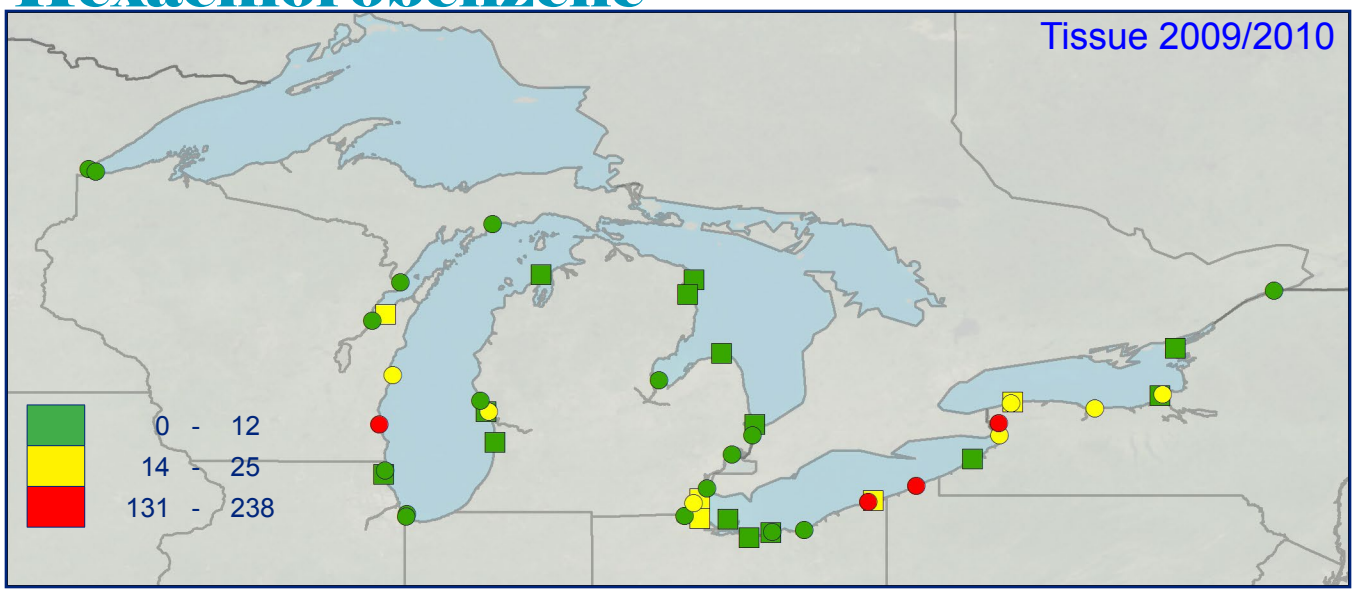
AOC barchart: Comparison of AOC contaminant concentrations in sediment (ng/g dry wt.). Where relevant reference lines representing PEC (black dashed line), TEC (blue dashed line), and reference site mean (gray solid line) are given.





National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.). Extreme outliers omitted.

Hexachlorobenzene



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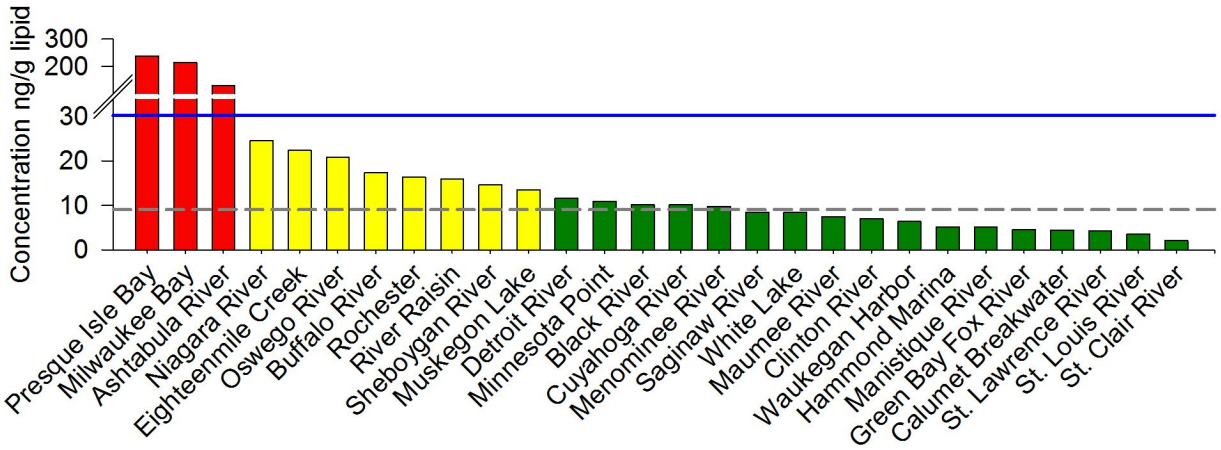

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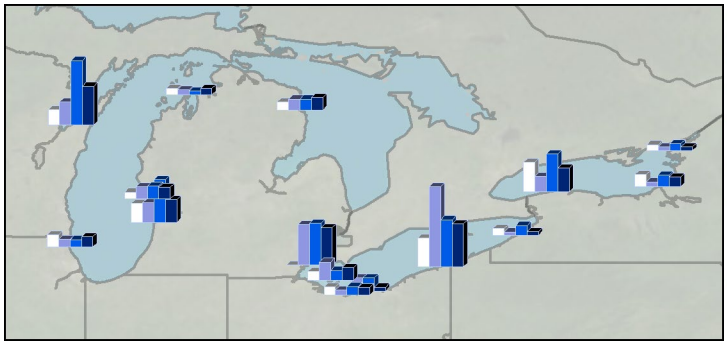
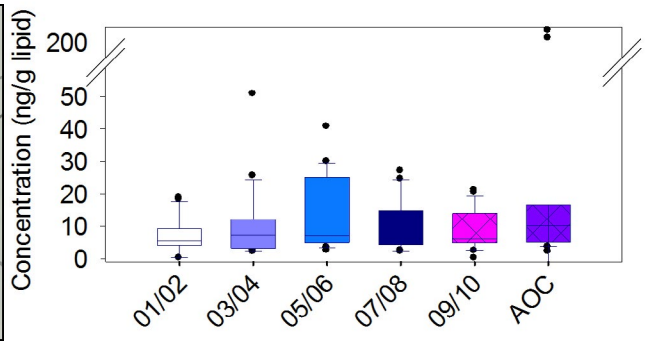
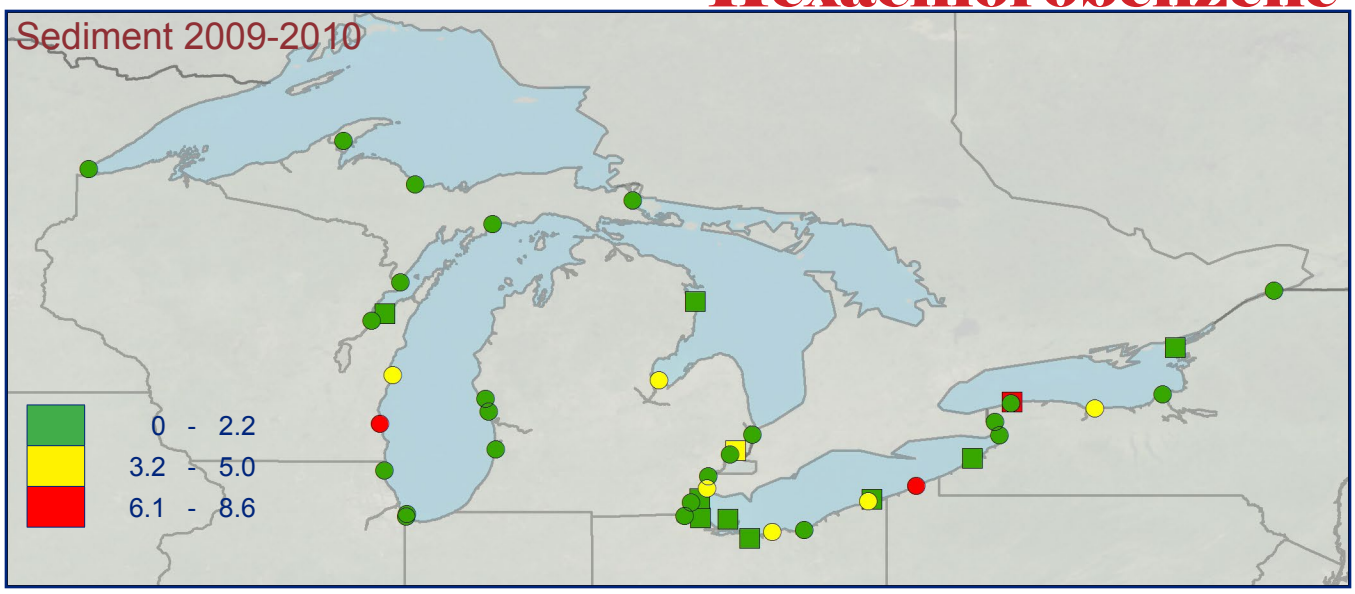




Historic data. Mussel tissue concentration (ng/g lipid) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and AOC sites collected in 2009/2010.

Hexachlorobenzene



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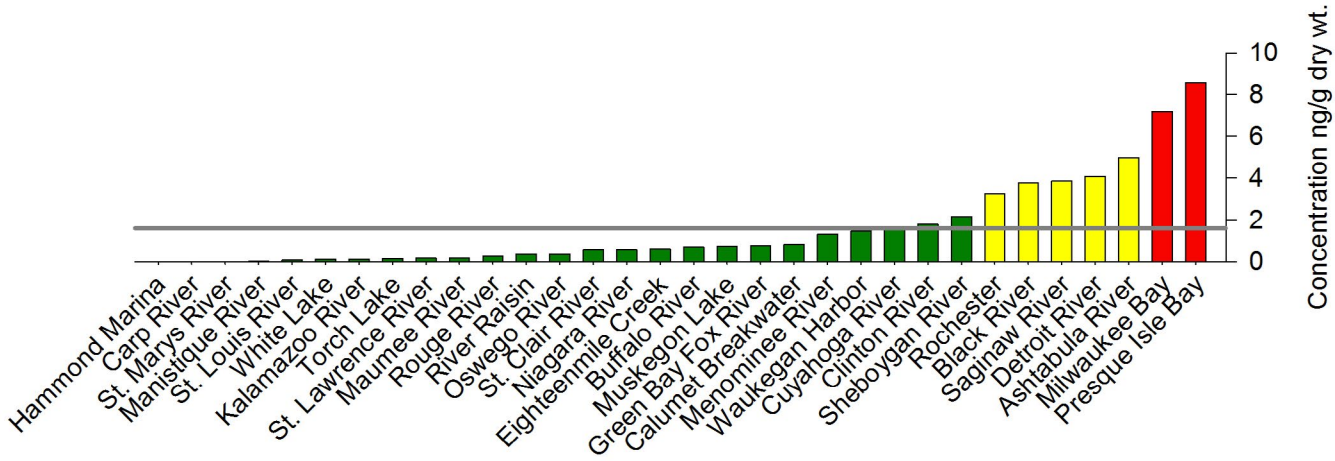

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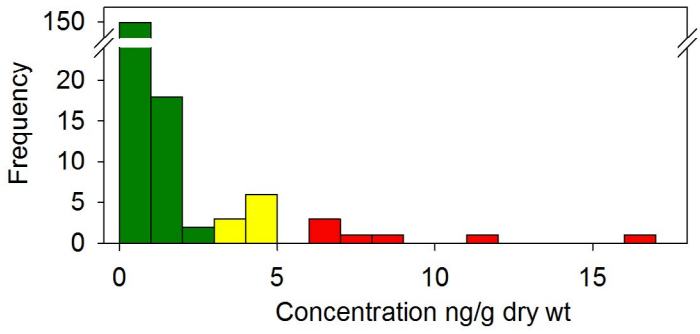
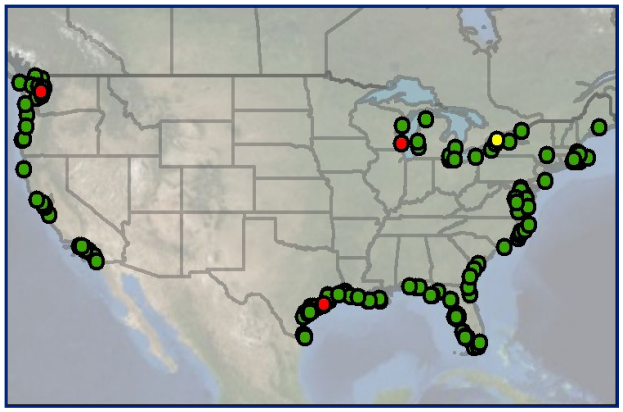
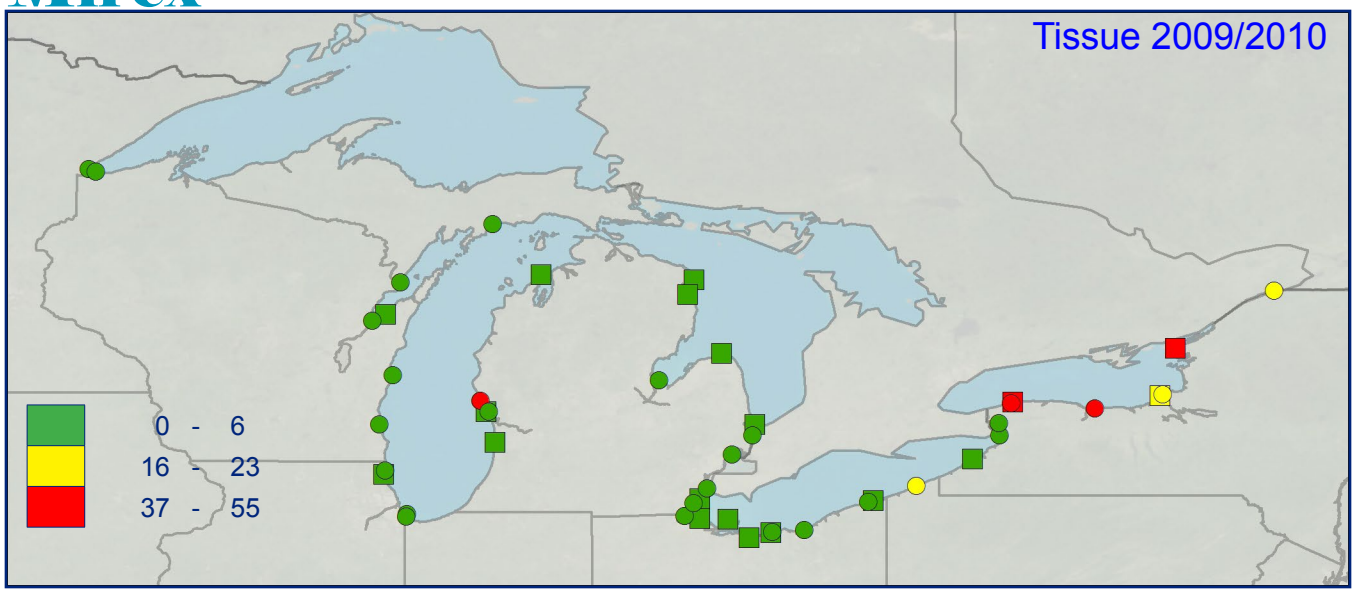




National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.).

Mirex



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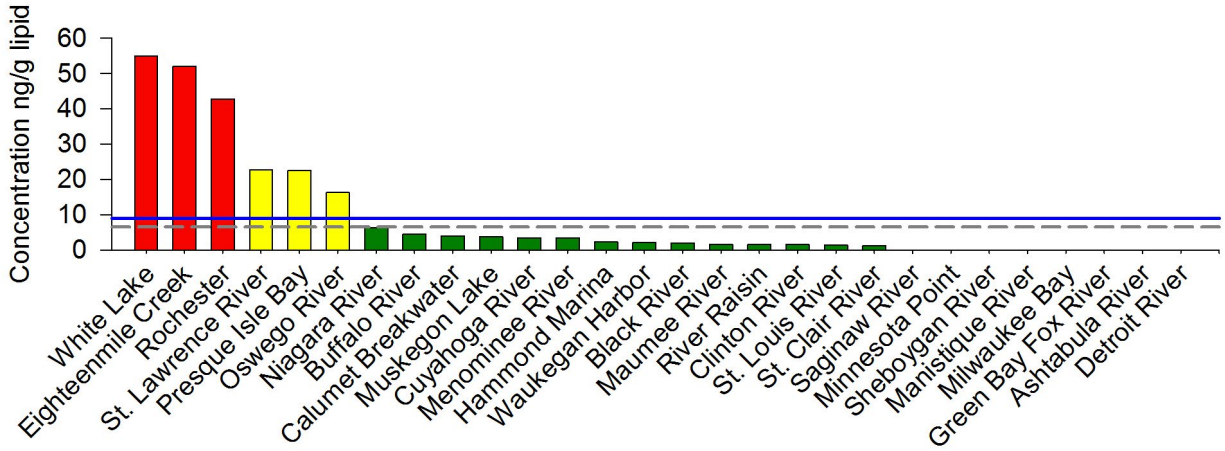

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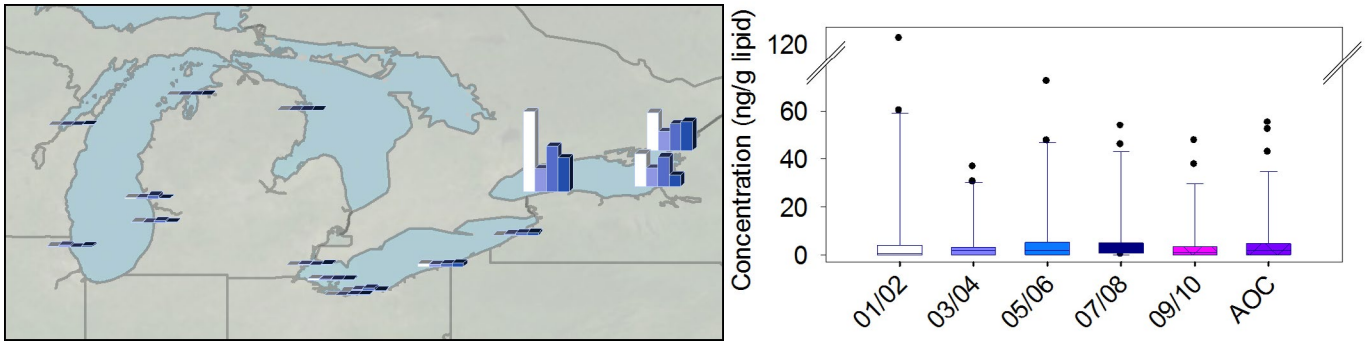

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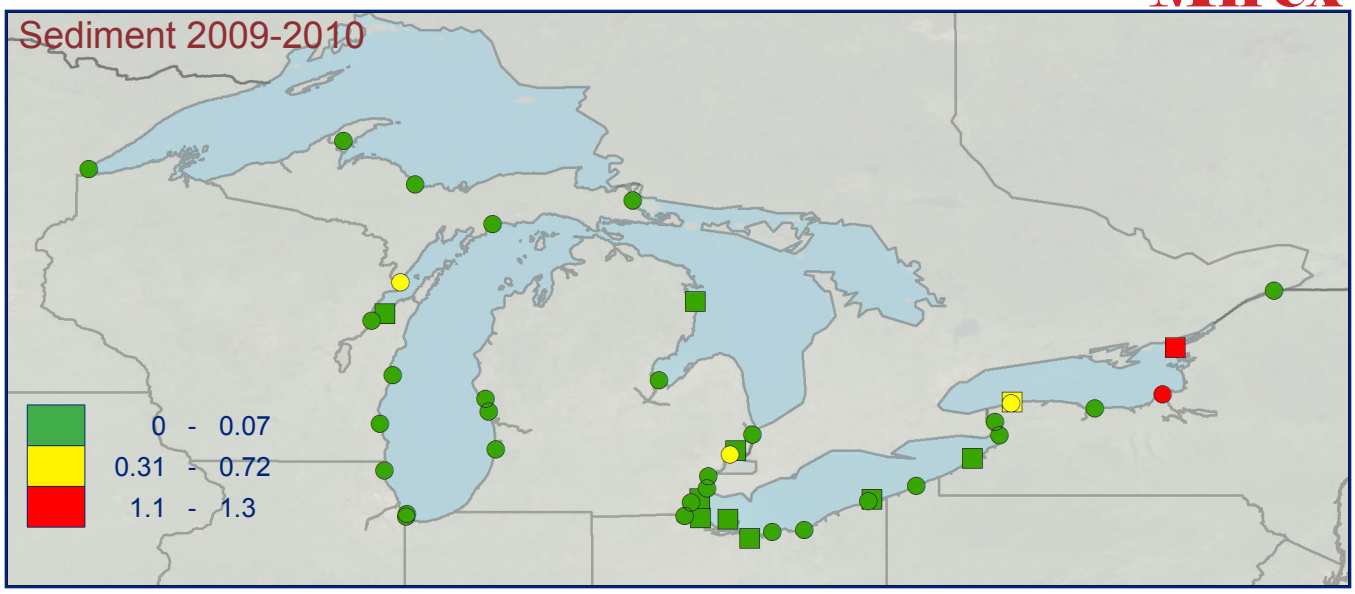

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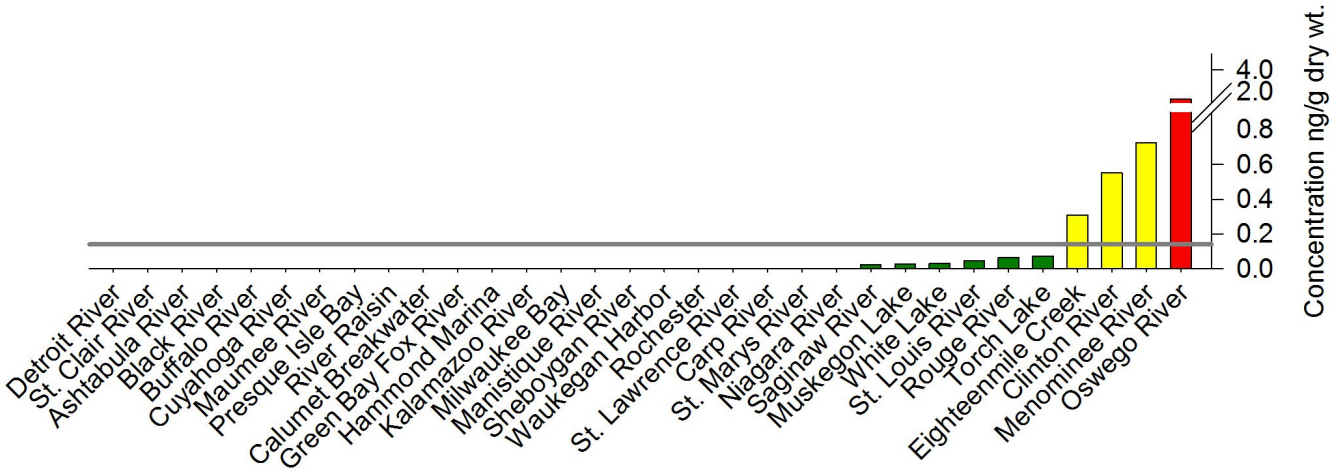

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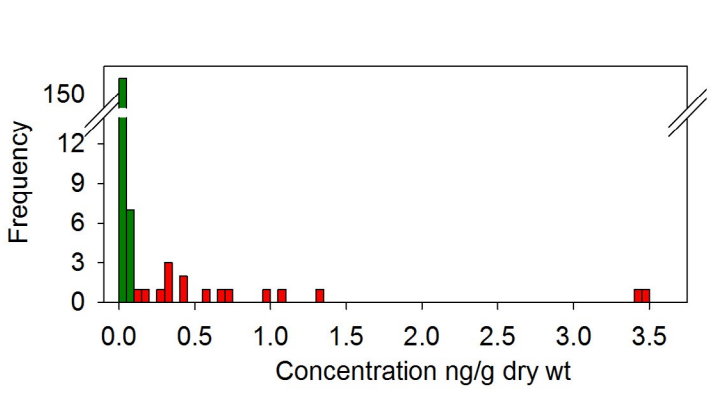
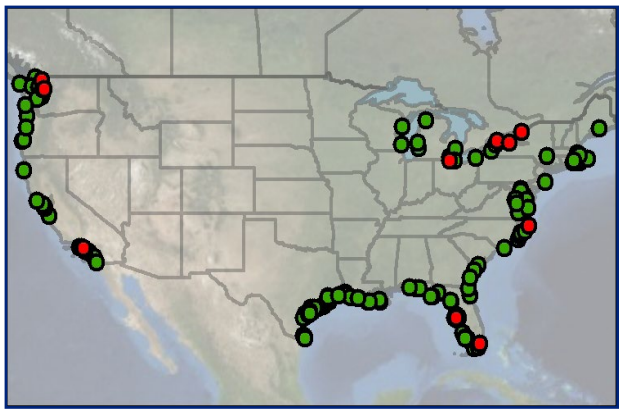
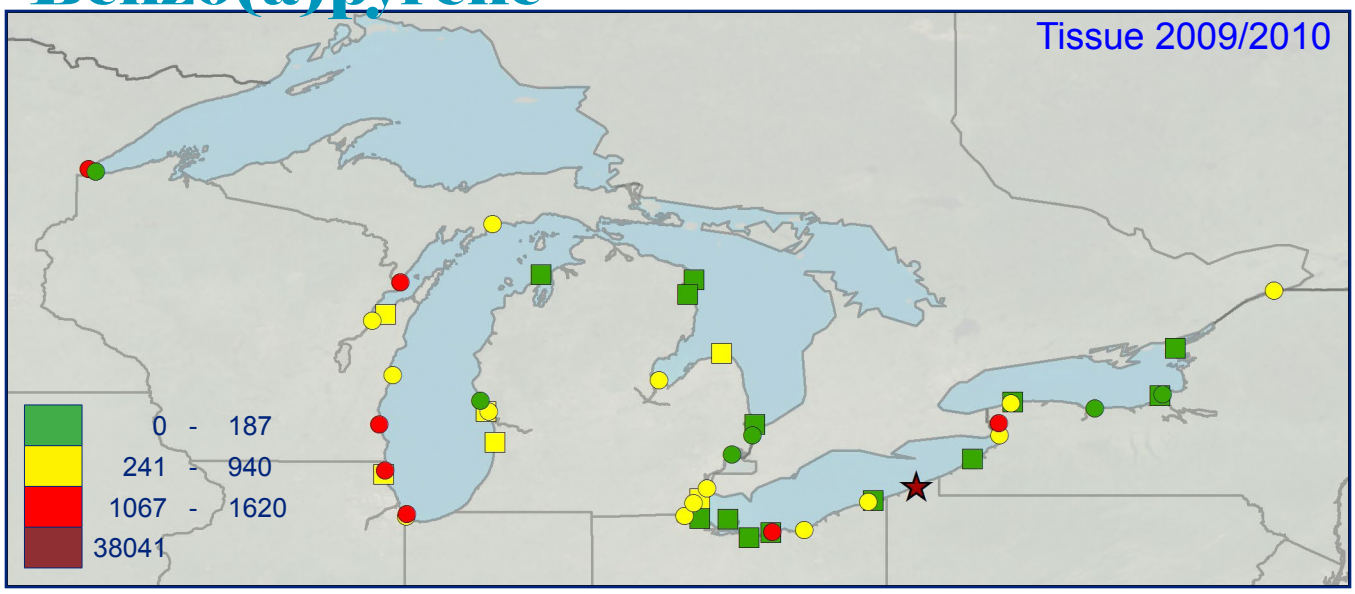




National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.).

Benzo(a)pyrene



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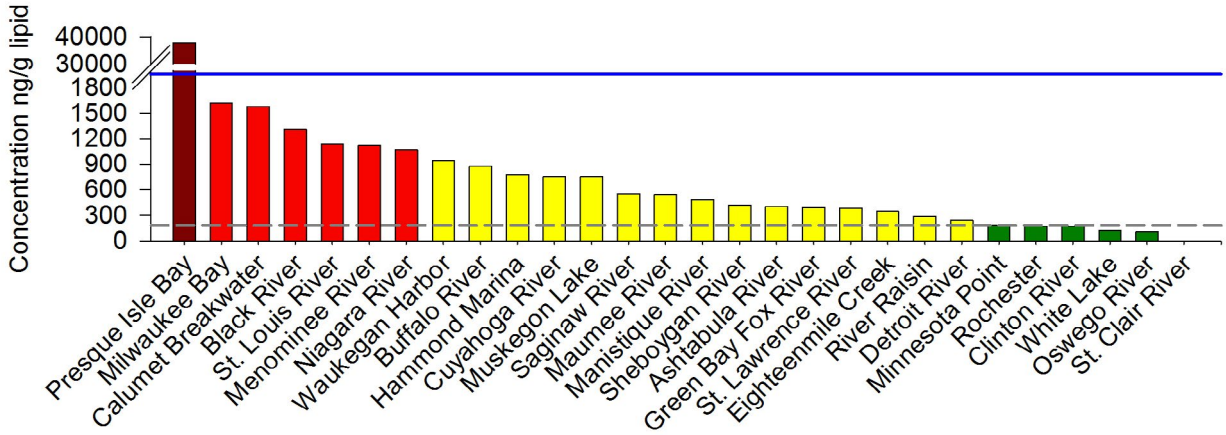

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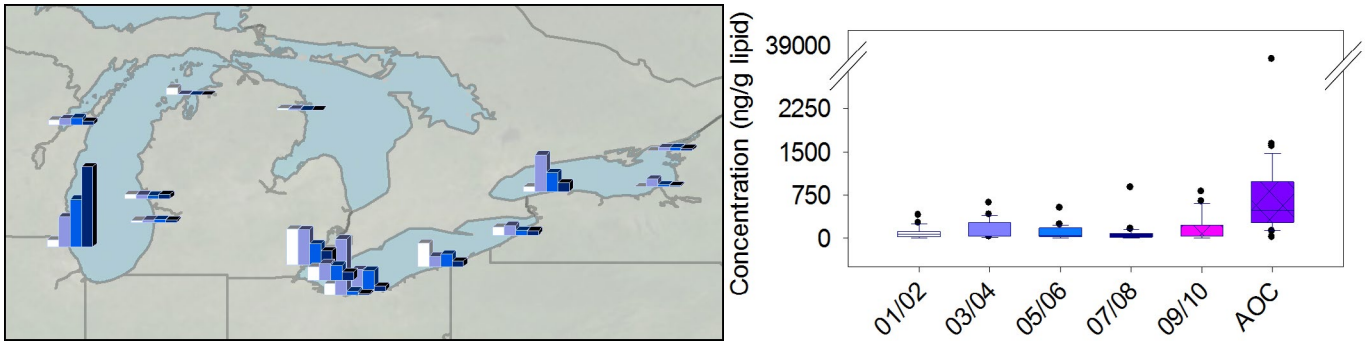

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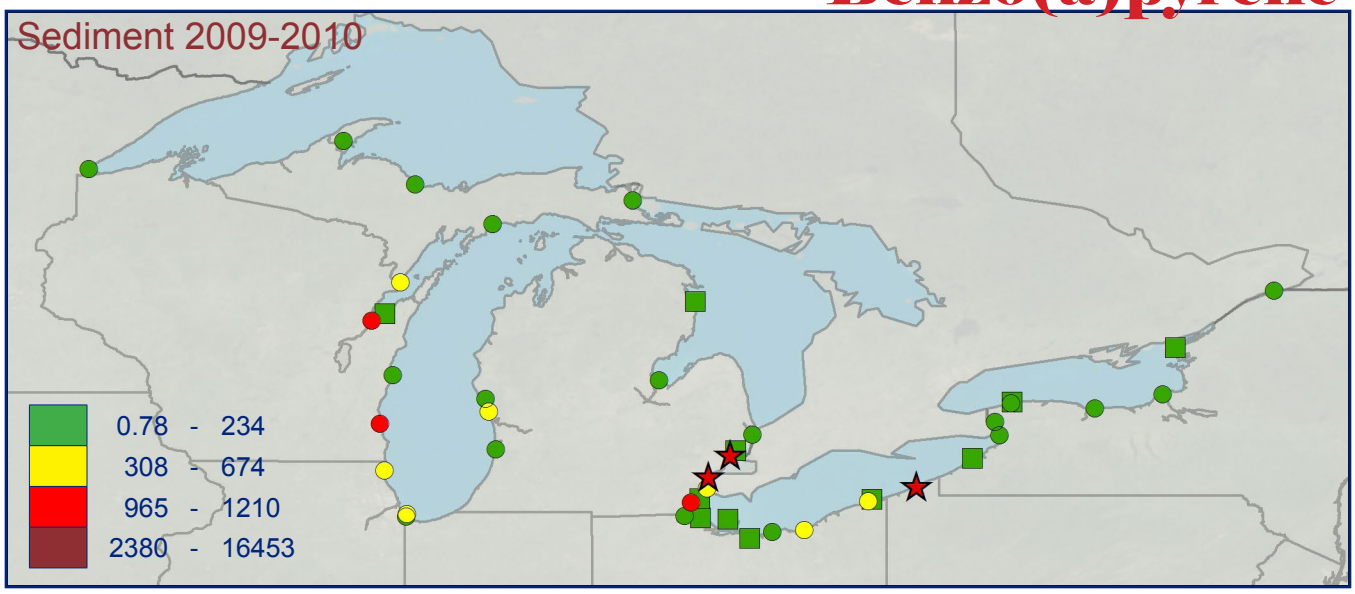
Benzo(a)pyrene



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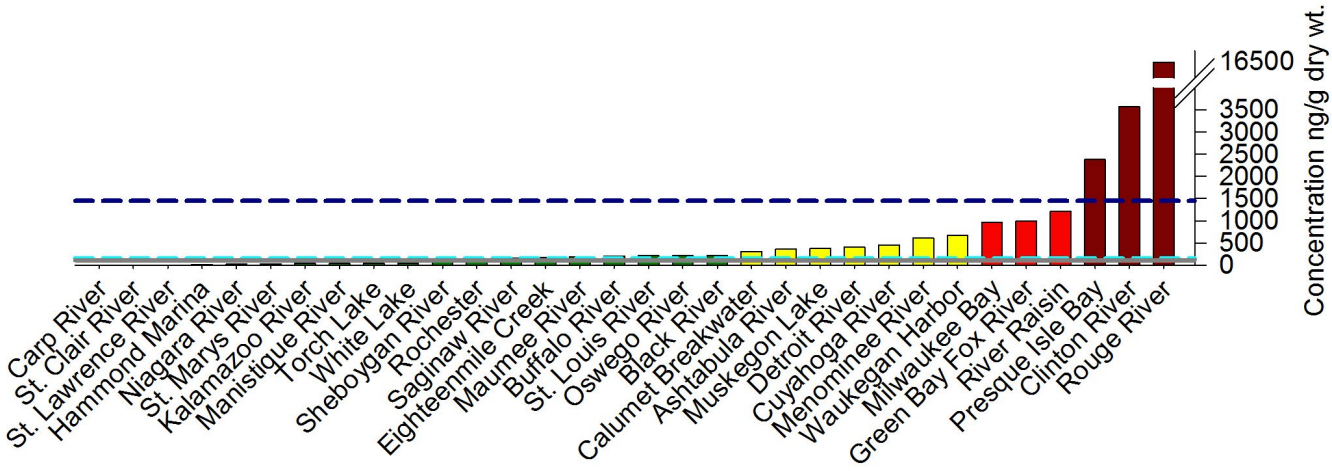

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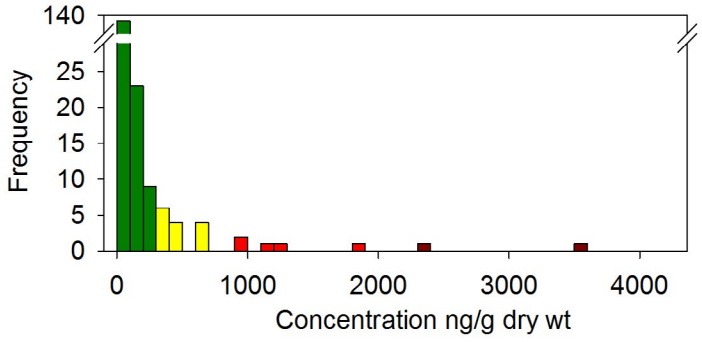
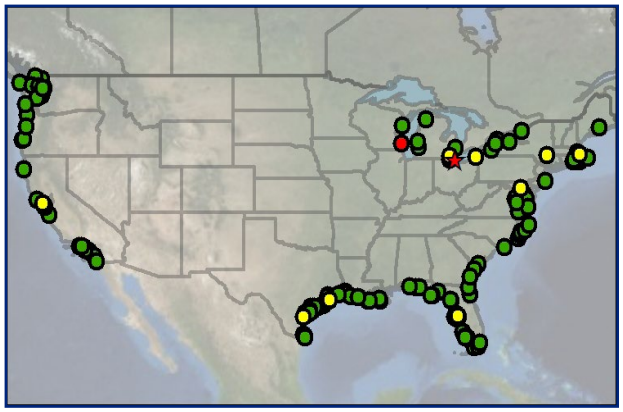
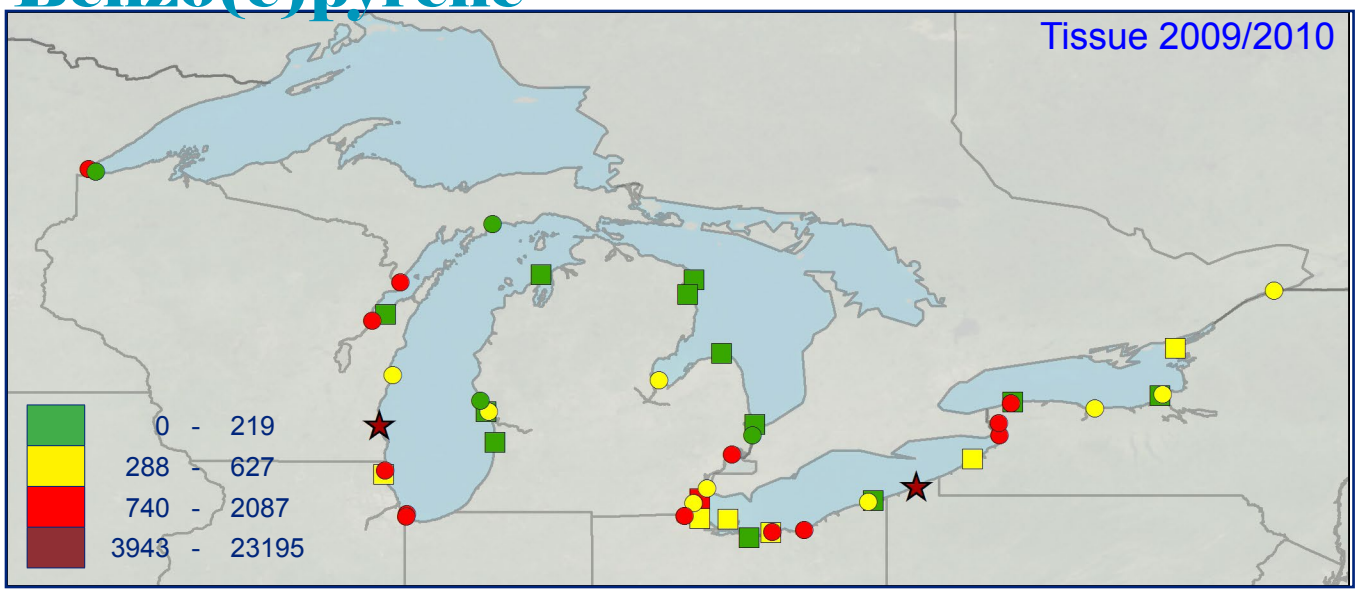




National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.). Extreme outliers omitted.

Benzo(e)pyrene



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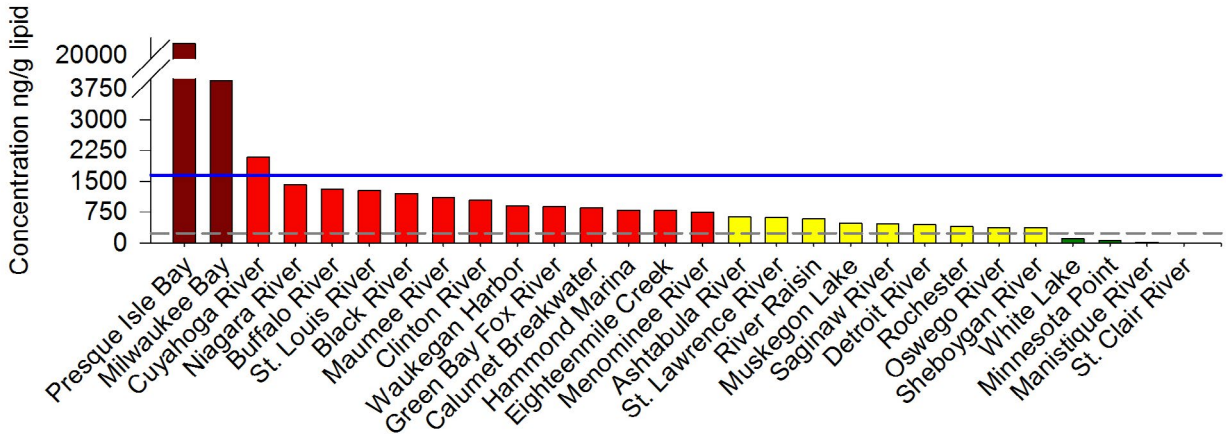

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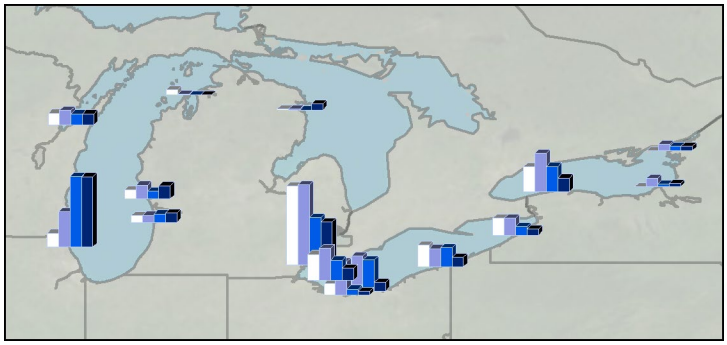

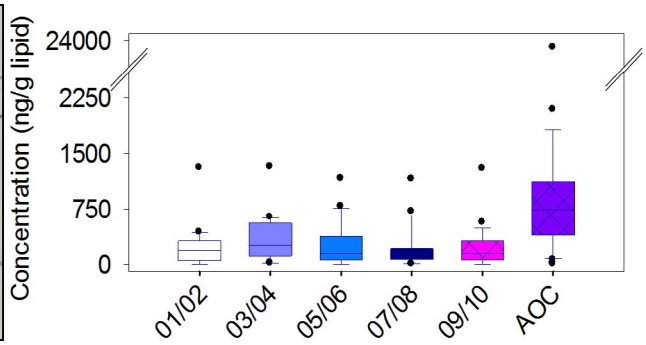

Historic data. Mussel tissue concentration (ng/g lipid) from reference sites collected from 2001- 2008 (map), and whisker plot of the mapped data in addition to reference and AOC sites collected in 2009/2010.

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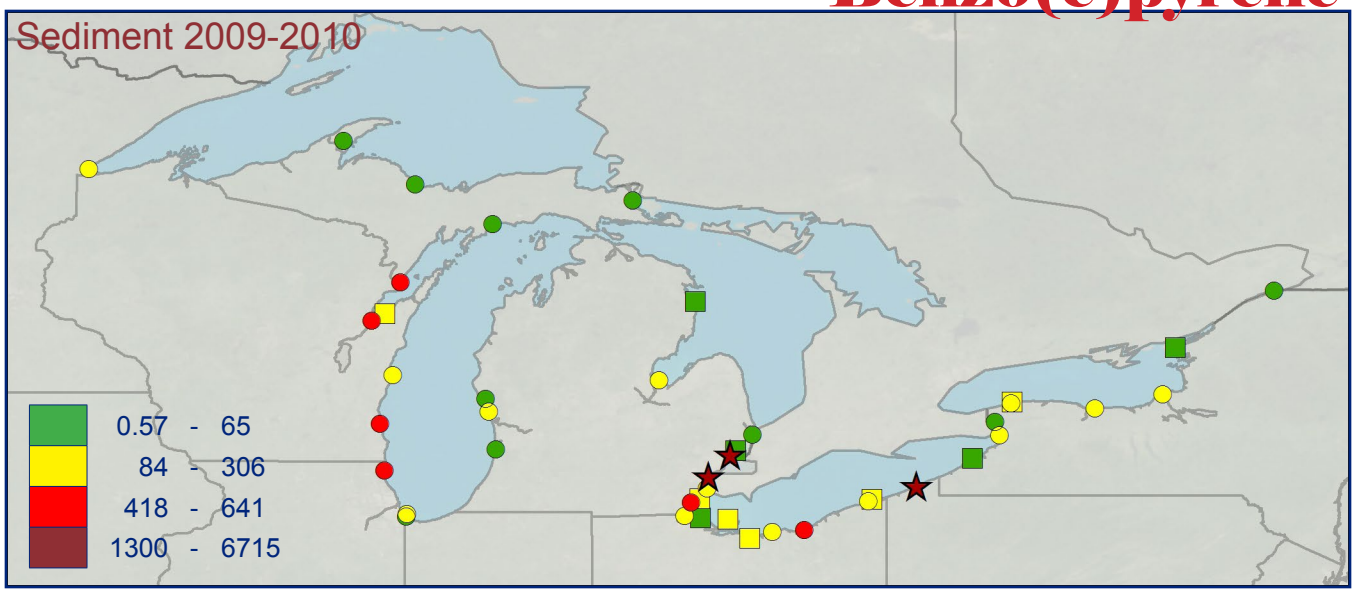

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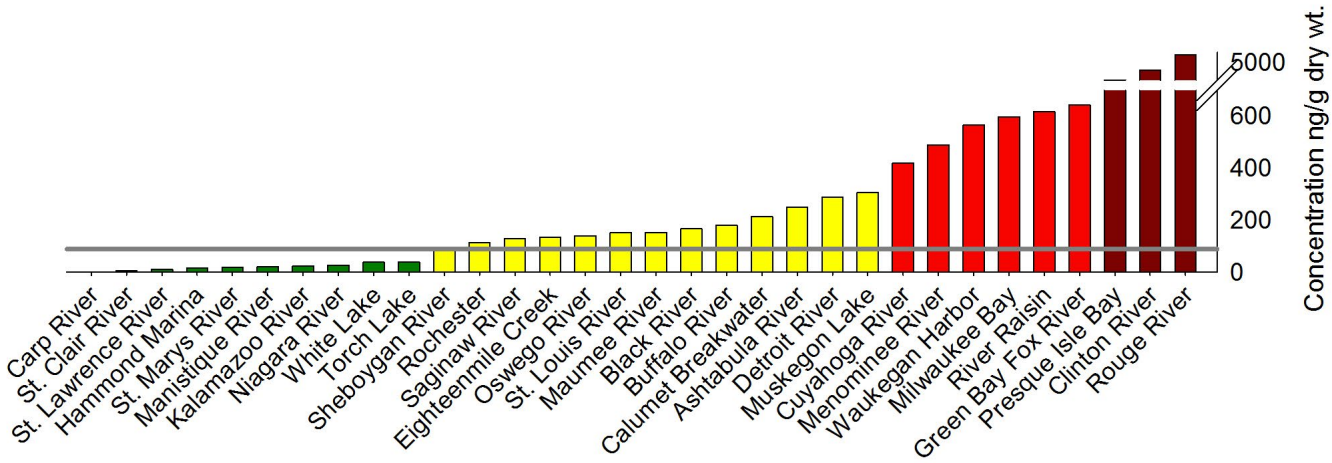

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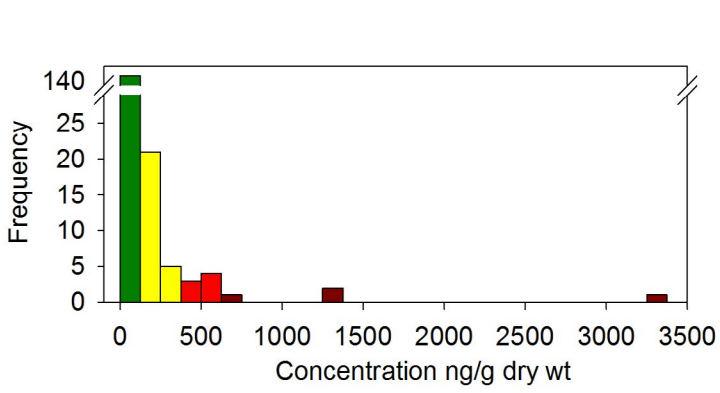
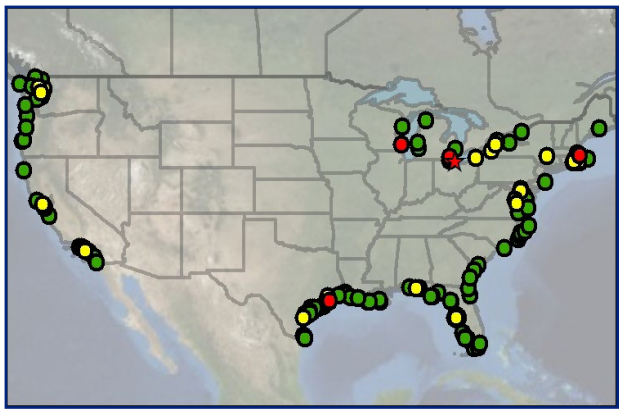
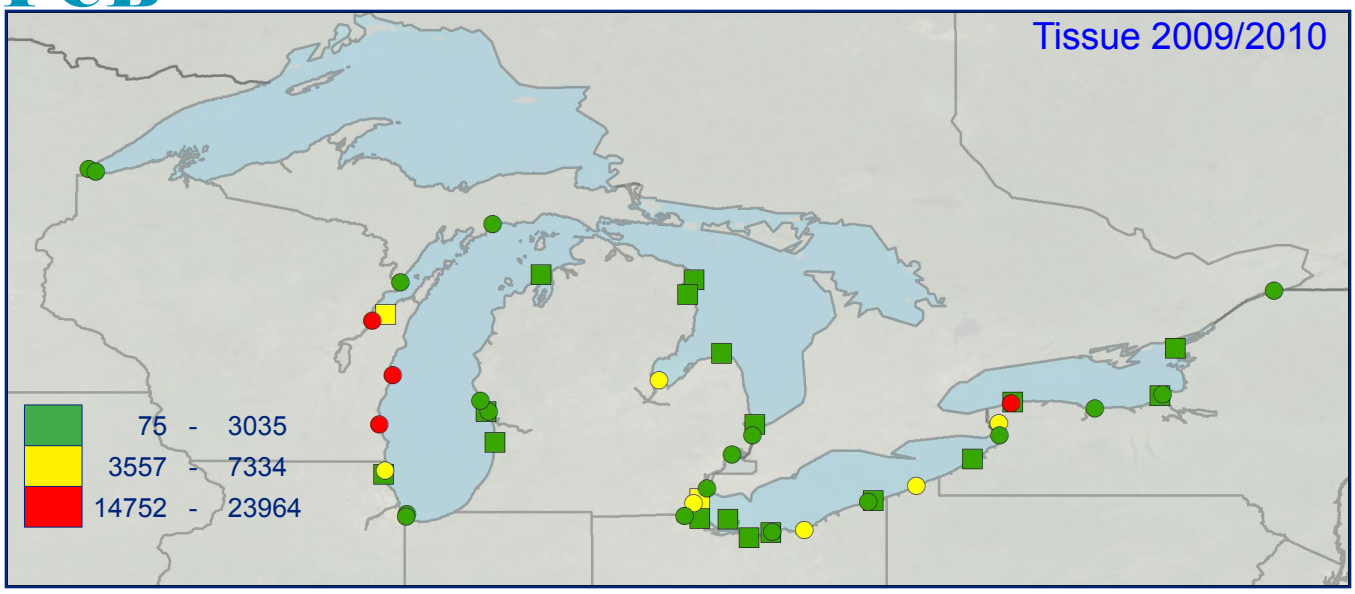




National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.). Extreme outliers omitted.

PCB



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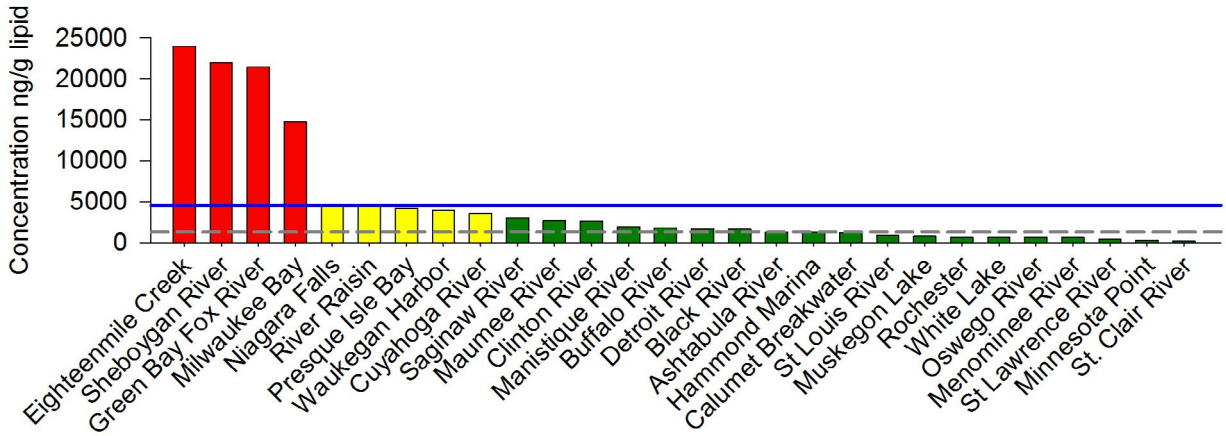

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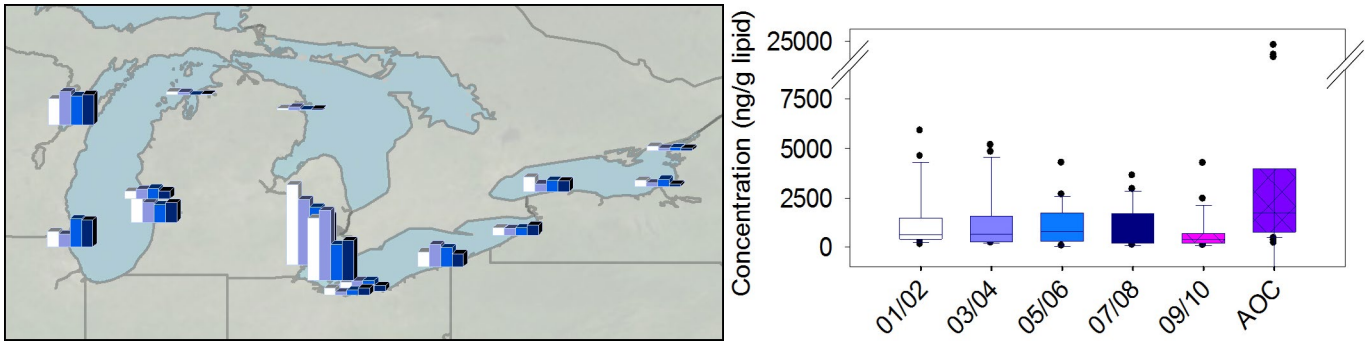

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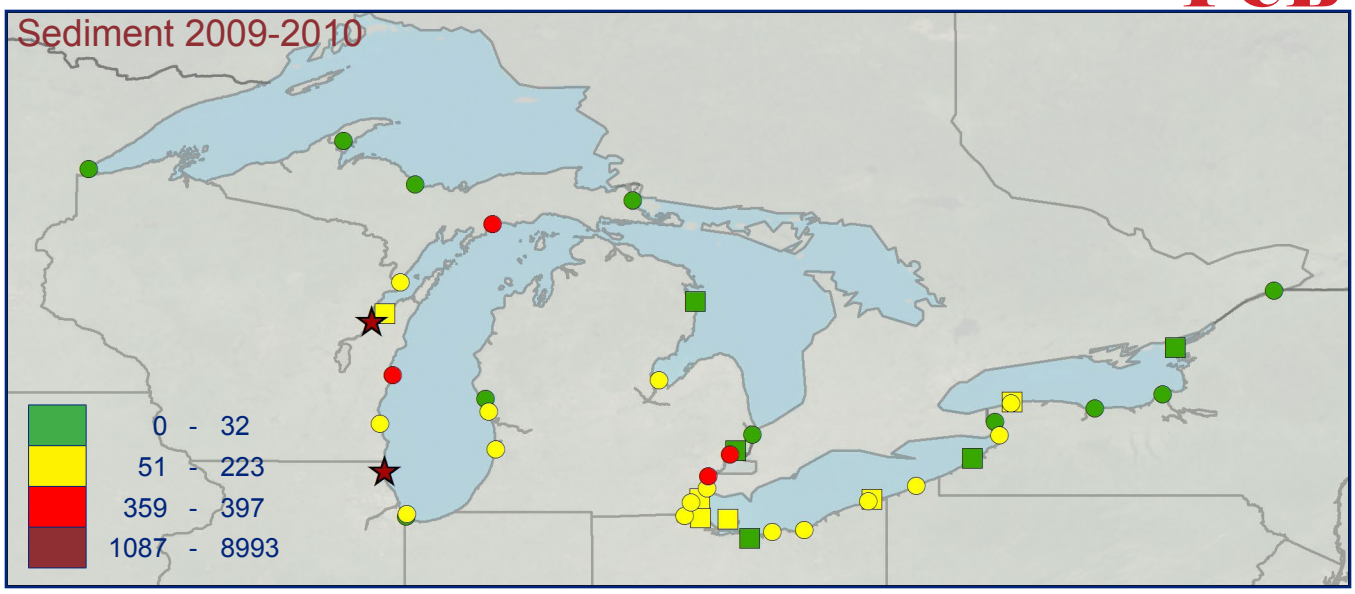

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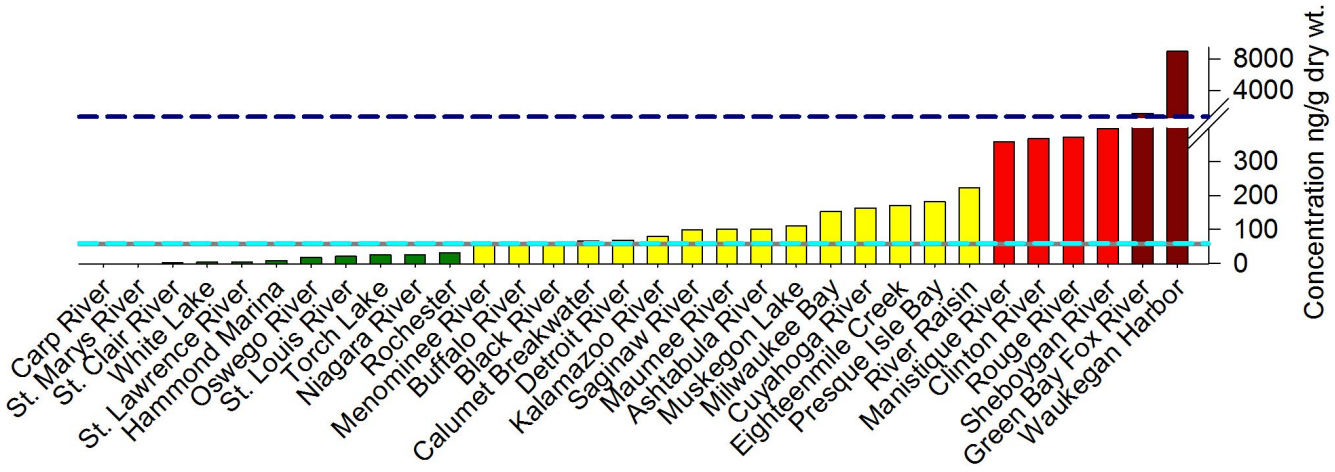

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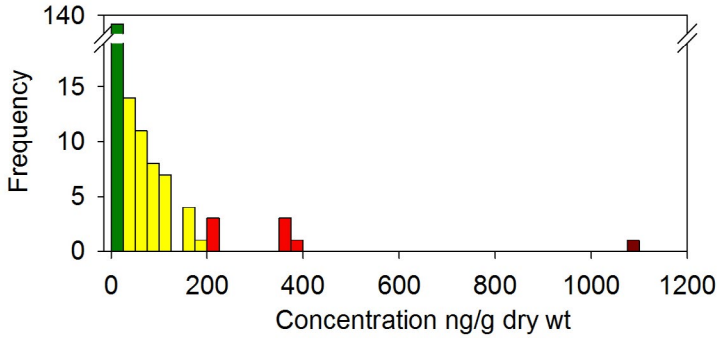
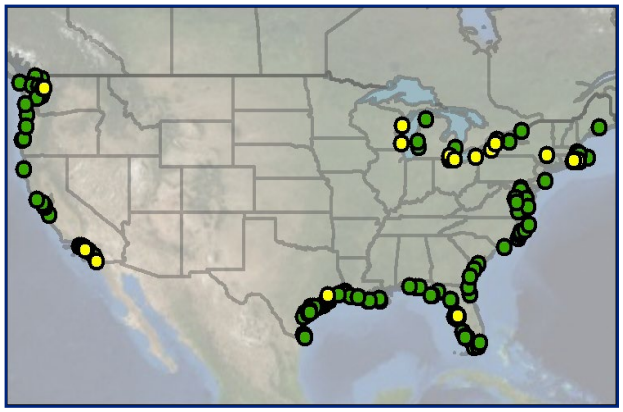




National frequency plot and sediment map. Frequency plot of national (2006/2007) and Great Lakes (AOC and reference; 2009/2010) sediment data, and map of national sediment concentrations (2006/2007; ng/g dry wt.). Extreme outliers omitted.

Section 3: Site characterization

- All available tissue and sediment chemistry data obtained since 2009 was presented, providing a detailed chemical characterization of U.S. AOCs and reference sites.
- Harbor and tributary mouth measurements were used to characterize U.S. AOCs with respect to Great Lakes reference sites and provided the first step in a basin-wide, pre-remediation, baseline assessment of AOCs.
- Multiple tissue stations in the harbor area of priority AOCs provided a more robust baseline measurement for remediation.

Site Example

Legend

Low ● Medium ● High ● Outlier ★

Basin location map: Depicts the location of a U.S. AOC with respect to the Great Lakes basin.

Each tissue station represents data from a composite of 50 -100 mussels.

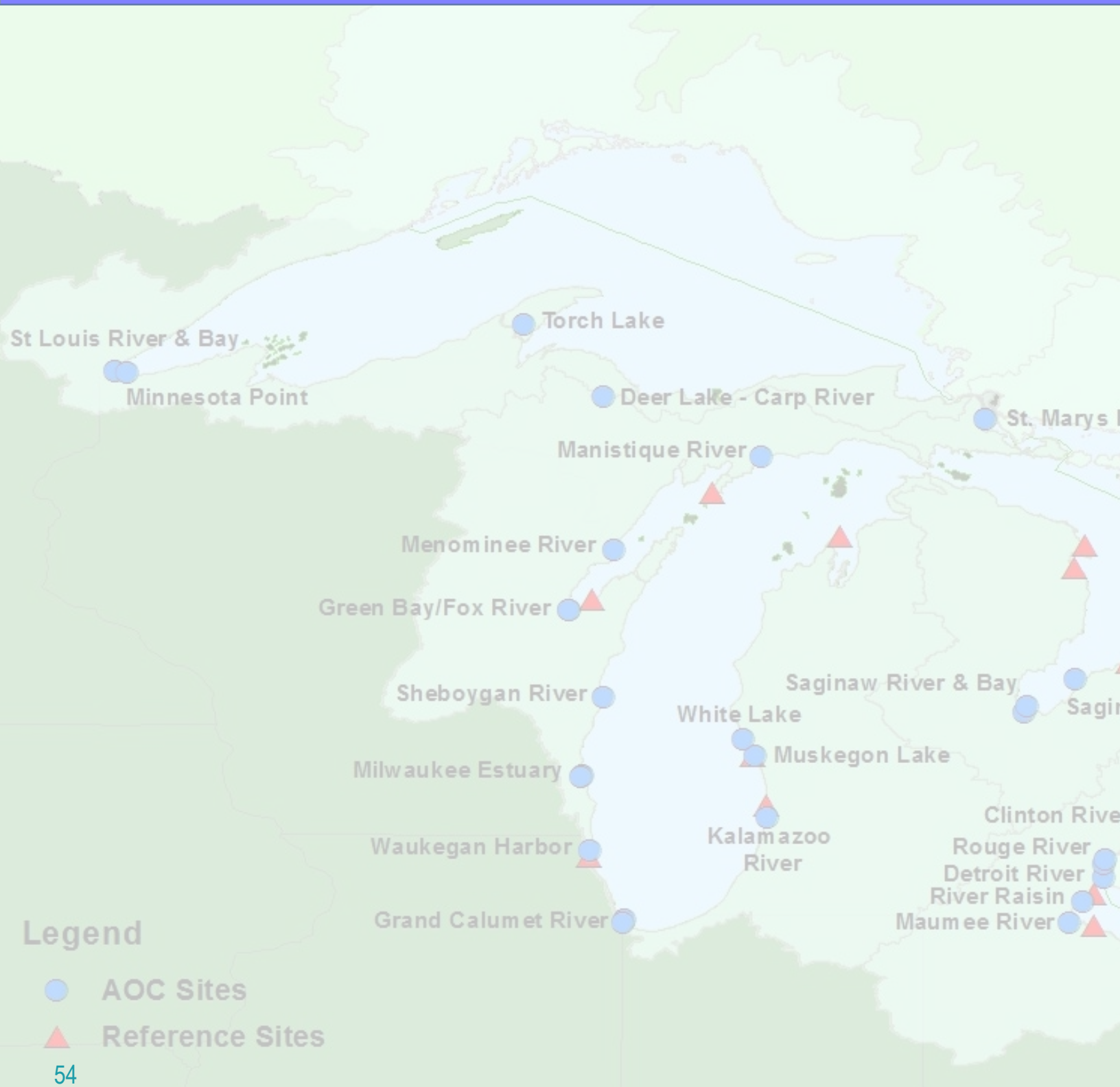
Analyte tables: Concentrations and associated ranking from the previous section for baseline tissue and sediment sites are presented along with all additional measurements from 2010 (2 sediment stations for some U.S. AOCs in western Great Lakes) and from 2011 (additional tissue stations in priority U.S. AOCs).

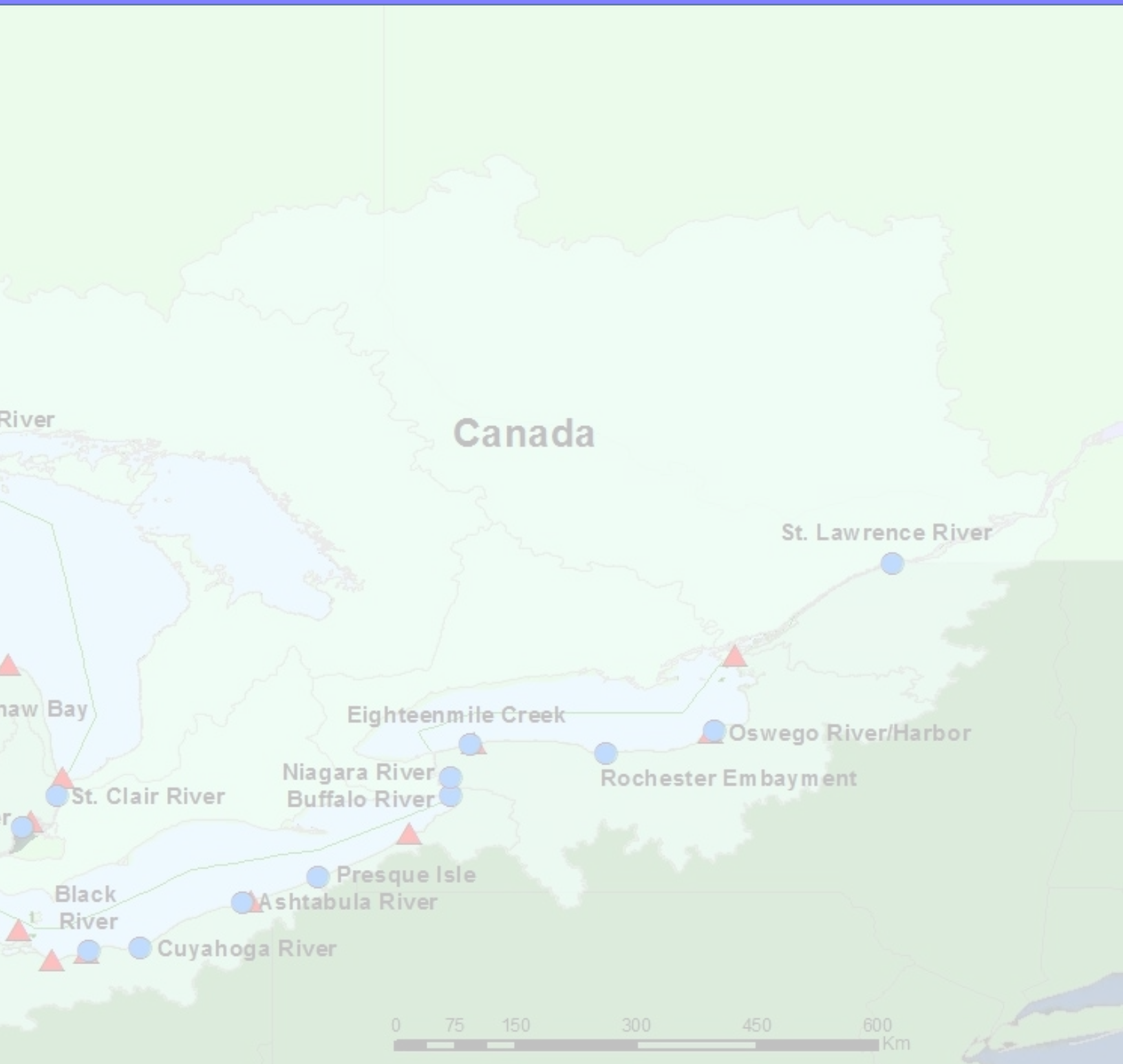
Analyte (μg/g dry)	Baseline Tissue	Baseline Sediment	Sediment 1	Sediment 2	Tissue 1	Tissue 2	Tissue 3
Arsenic	5.57 ●	1.65 ●	0.73	1.09	7.47	7.6	
Cadmium	0.70 ●	0.00 ●	0.00	0.00	1.7	1.72	
Copper	6.32 ●	3.88 ●	1.66	2.82	26.2	108	
Lead	0.34 ●	11.70 ●	6.41	10.20	3.05	4.24	
Methyl Mercury	0.03 ●	0.00 ●	0.00	0.00			
Mercury	0.04 ●	0.02 ●	0.01	0.01	0.0729	0.0768	
Silver	0.00 ●	0.22 ●	0.00	0.33	0.0234	0.0515	
Zinc	49.20 ●	24.20 ●	9.48	19.50	70.3	80.2	

Analyte (ng/g dry)	Baseline Tissue	Baseline Sediment	Sediment 1	Sediment 2	Tissue 1	Tissue 2	Tissue 3
Alpha-Chlordane	5.86 ●	0.00 ●	0.00	0.00	0.49	0.66	
Chlorpyrifos	0.00 ●	0.00 ●	0.00	0.00	0	0	
DDT	47.73 ●	0.30 ●	0.07	0.04	3.43	4.54	
Heptachlor	0.00 ●	0.00 ●	0.02	0.00	1.35	2.15	
Hexachlorobenzene	5.08 ●	0.03 ●	0.00	0.00	0.44	0.52	
Mirex	0.00 ●	0.00 ●	0.02	0.00	0	0	
Benzo[a]pyrene	487.29 ●	33.26 ●	6.71	6.91	5.9	8.7	
Benzo[e]pyrene	16.57 ●	21.72 ●	4.64	5.71	7.1	10.2	
PCB	1976.91 ●	359.00 ●	5.05	13.80	116.4	147.02	

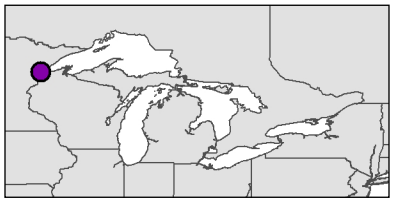
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

U.S. Areas of Concern




Canada
St. Lawrence River
Eighteenmile Creek
Oswego River/Harbor
Rochester Embayment
Niagara River
Buffalo River
St. Clair River
Presque Isle
Ashtabula River
Black River
Cuyahoga River
0 75 150 300 450 600
Km

St. Louis River



Legend

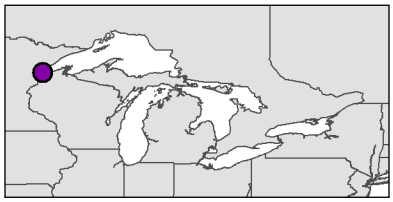
Low ● Medium ● High ● Outlier ★

Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010		Tissue - 2011
Arsenic	3.3	4.5	5.9	6.7	
Cadmium	1.21	0.29	0.55	0.52	
Copper	14	21	30	34	
Lead	1.7	19	27	32	
Methyl Mercury	0.08	0.000	0.000	0.000	
Mercury	0.12	0.090	0.176	0.210	
Zinc	120	87	141	165	

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010		Tissue - 2011
Alpha-Chlordane	8.2	0.05	0.25	0.36	
Chlorpyrifos	0.00	0.05	0.51	0.29	
DDT	130	0.8	3.4	4.7	
Heptachlor	0	0.12	0.10	0.06	
Hexachlorobenzene	4	0.09	0.08	0.14	
Mirex	1.4	0.045	0.038	0.024	
Benzo[a]pyrene	1141	208	741	435	
Benzo[e]pyrene	1276	152	446	287	
PCB	894	21	19	29	

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Minnesota Point



Legend

Low Medium High Outlier

Arsenic	3.9	
Cadmium	5.88	
Copper	15	
Lead	0.3	
Methyl Mercury	0.02	
Mercury	0.05	
Zinc	97	

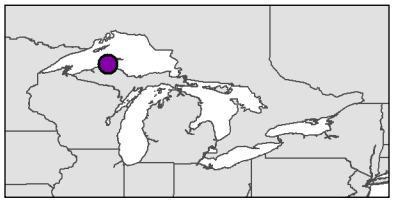
Alpha-Chlordane	5.9	
Chlorpyrifos	12	
DDT	33	
Heptachlor	0	
Hexachlorobenzene	11	
Mirex	0.0	
Benzo[a]pyrene	185	
Benzo[e]pyrene	57	
PCB	305	

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Torch Lake

Legend

Low Medium High Outlier

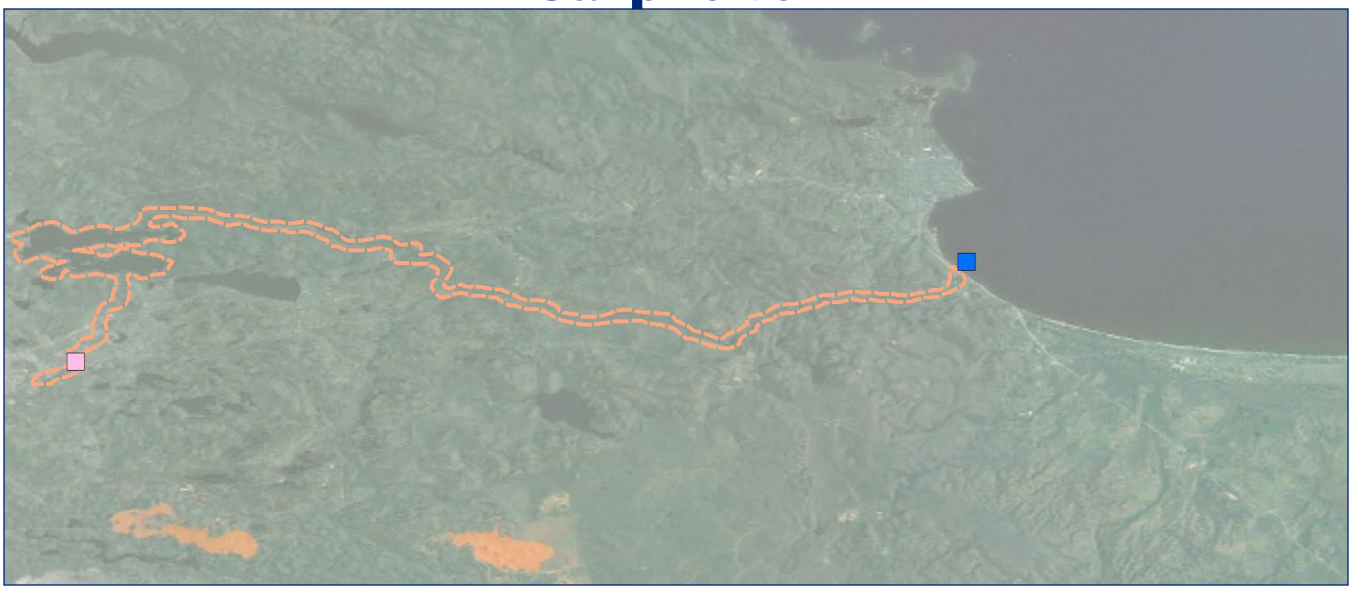


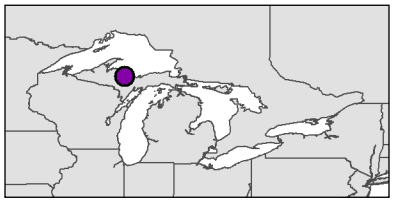
Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010		Tissue - 2011		
Arsenic		19.7	3.5	24.8			
Cadmium		0.79	0.21	0.91			
Copper		1330	337	1950			
Lead		66	15	133			
Methyl Mercury		0.000	0.000	0.000			
Mercury		0.294	0.075	0.476			
Zinc		205	52	232			

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010		Tissue - 2011		
Alpha-Chlordane		0.08	0.02	0.32			
Chlorpyrifos		0.00	0.03	0.11			
DDT		2.4	0.3	5.2			
Heptachlor		0.04	0.03	0.27			
Hexachlorobenzene		0.15	0.55	0.68			
Mirex		0.071	0.000	0.069			
Benzo[a]pyrene		42	7	173			
Benzo[e]pyrene		39	7	122			
PCB		25	3	43			

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Carp River





Legend

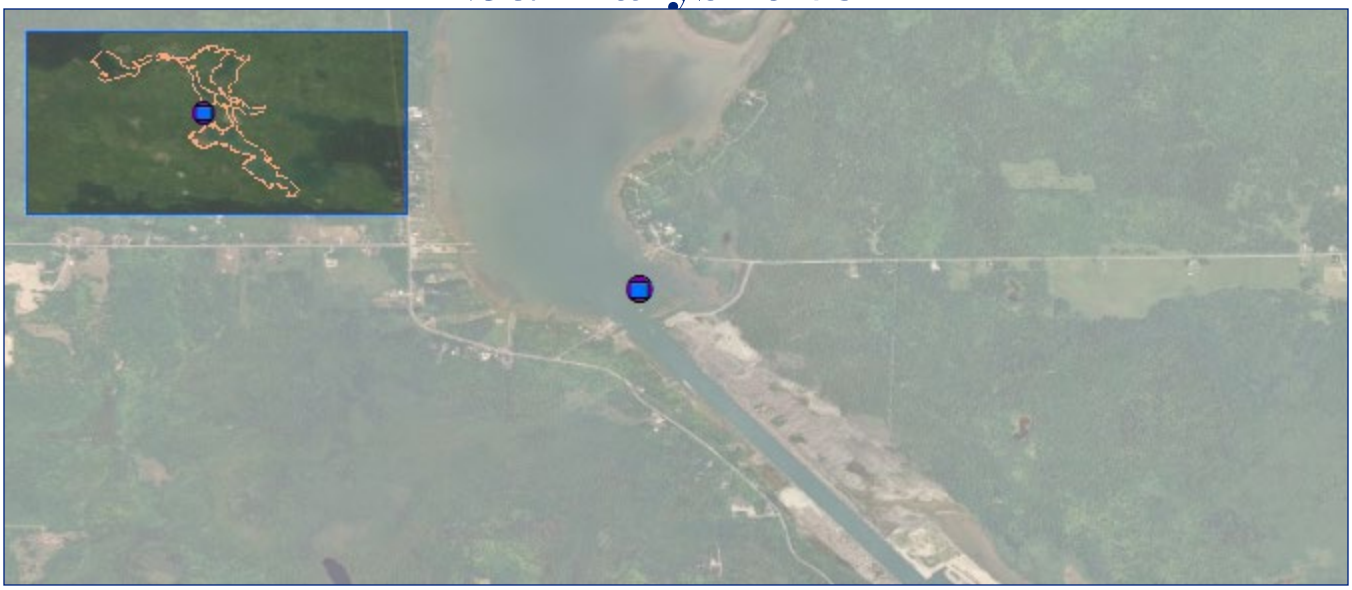
Low Medium High Outlier

Arsenic	6.8		12.4
Cadmium	0.29		0.00
Copper	17		10
Lead	21		11
Methyl Mercury	0.000		0.000
Mercury	0.002		0.049
Zinc	58		40

Alpha-Chlordane	0.00		0.00
Chlorpyrifos	0.00		0.00
DDT	0.0		0.2
Heptachlor	0.00		0.00
Hexachlorobenzene	0.00		0.04
Mirex	0.000		0.017
Benzo[a]pyrene	1		66
Benzo[e]pyrene	1		39
PCB	0		0

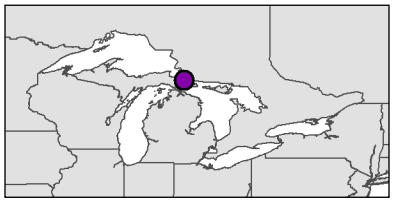
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

St. Marys River



Legend

Low Medium High Outlier

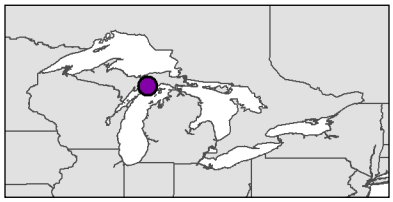


Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Arsenic				
Cadmium				
Copper				
Lead				
Methyl Mercury				
Mercury				
Zinc				

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Alpha-Chlordane		0.00		
Chlorpyrifos		0.00		
DDT		0.0		
Heptachlor		0.00		
Hexachlorobenzene		0.01		
Mirex		0.000		
Benzo[a]pyrene		29		
Benzo[e]pyrene		19		
PCB		1		

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Manistique River



Legend

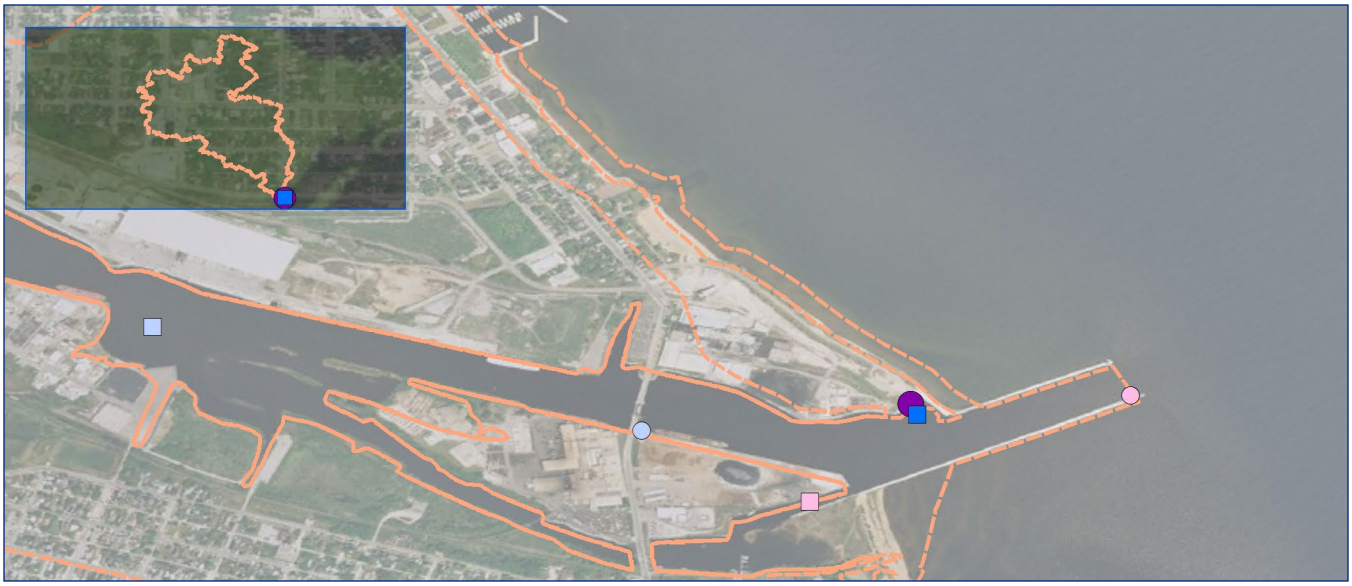
Low ● Medium ● High ● Outlier ★

Arsenic	5.6	●	1.7	■	0.7	1.1	7.5	7.6
Cadmium	0.70	●	0.00	■	0.00	0.00	1.70	1.72
Copper	6	●	4	■	2	3	26	108
Lead	0.3	●	12	■	6	10	3	4
Methyl Mercury	0.03	●	0.000	■	0.000	0.000		
Mercury	0.04	●	0.020	■	0.009	0.012	0.073	0.077
Zinc	49	●	24	■	9	20	70	80

Alpha-Chlordane	5.9	●	0.00	■	0.00	0.00	6.3	8.7
Chlorpyrifos	0	●	0.00	■	0.00	0.00	0	0
DDT	48	●	0.3	■	0.1	0.0	44	60
Heptachlor	0	●	0.00	■	0.02	0.00	17	28
Hexachlorobenzene	5	●	0.03	■	0.00	0.00	6	7
Mirex	0.0	●	0.000	■	0.015	0.000	0.0	0.0
Benzo[a]pyrene	487	●	33	■	7	7	76	114
Benzo[e]pyrene	17	●	22	■	5	6	91	134
PCB	1977	●	359	■	5	14	1492	1934

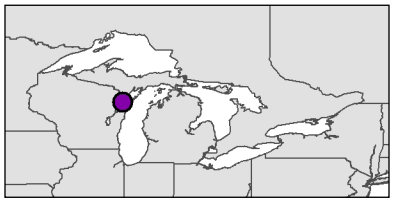
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Menominee River



Legend

Low Medium High Outlier

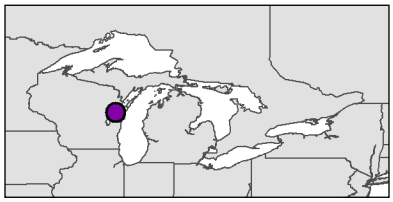


Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Sediment	Sediment - 2010		Tissue - 2011	
Arsenic	6.3	11.7	4.0	16.7	6.8	6.1
Cadmium	0.35	0.45	0.24	0.67	0.38	0.39
Copper	7	39	11	22	11	13
Lead	0.9	28	14	23	1	1
Methyl Mercury	0.08	0.001	0.001	0.002		
Mercury	0.15	0.180	0.087	0.251	0.088	0.103
Zinc	61	100	52	94	58	60

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Sediment	Sediment - 2010		Tissue - 2011	
Alpha-Chlordane	3.0	1.04	0.66	0.71	5.1	3.1
Chlorpyrifos	0	0.88	0.56	0.53	0	0
DDT	210	5.8	3.7	3.9	31	39
Heptachlor	0	0.00	0.02	0.05	0	0
Hexachlorobenzene	10	1.31	0.29	0.64	16	15
Mirex	3.4	0.724	0.468	0.211	0.0	0.0
Benzo[a]pyrene	1126	608	485	296	170	761
Benzo[e]pyrene	740	489	305	214	256	309
PCB	644	53	29	95	549	447

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Green Bay Fox River



Legend

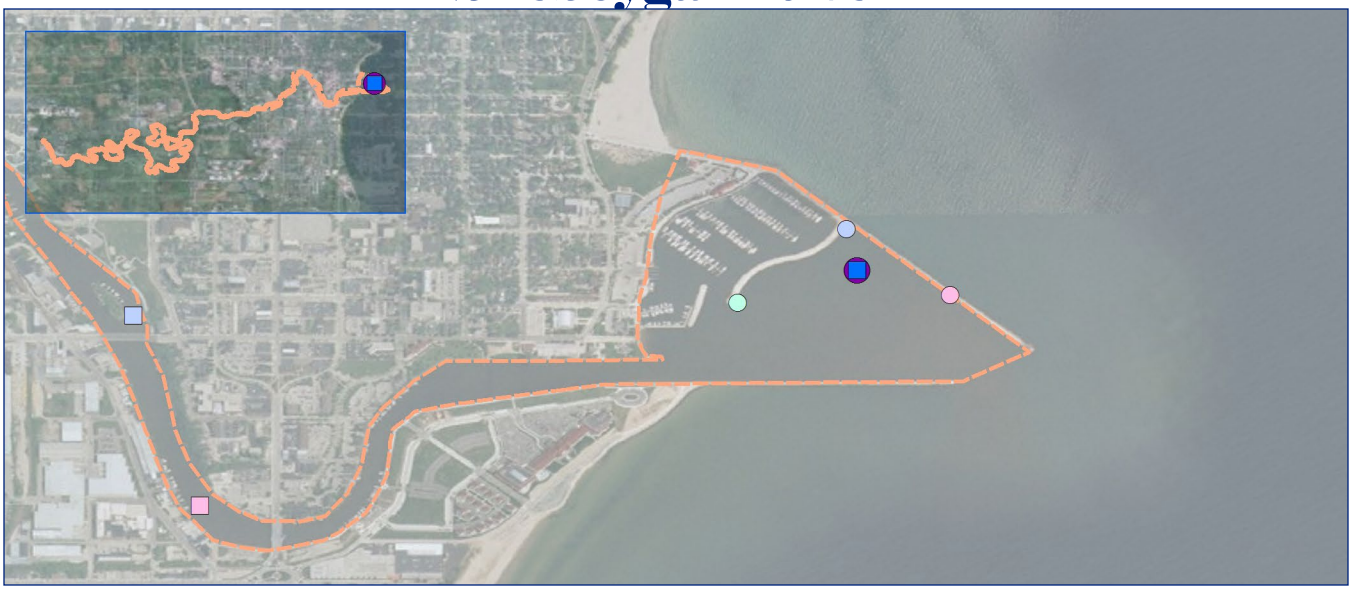
Low ● Medium ● High ● Outlier ★

Arsenic	3.7	●	2.2	■	0.0	2.5
Cadmium	0.28	●	0.64	■	0.19	1.06
Copper	13	●	34	■	14	62
Lead	1.3	●	46	■	18	67
Methyl Mercury	0.02	●	0.002	■	0.001	0.004
Mercury	0.06	●	0.764	★	0.219	1.050
Zinc	95	●	102	■	46	183

Alpha-Chlordane	3.7	●	0.00	■	0.00	1.12
Chlorpyrifos	0	●	0.00	■	0.00	0.00
DDT	170	●	1.8	■	6.5	2.3
Heptachlor	0	●	0.00	■	0.00	0.00
Hexachlorobenzene	4	●	0.77	■	0.00	0.00
Mirex	0.0	●	0.000	■	0.000	0.000
Benzo[a]pyrene	391	●	992	■	1090	1109
Benzo[e]pyrene	893	●	641	■	536	696
PCB	21439	●	1088	★	276	1507

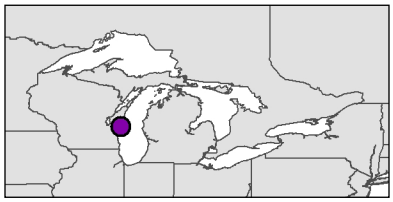
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Sheboygan River



Legend

Low Medium High Outlier

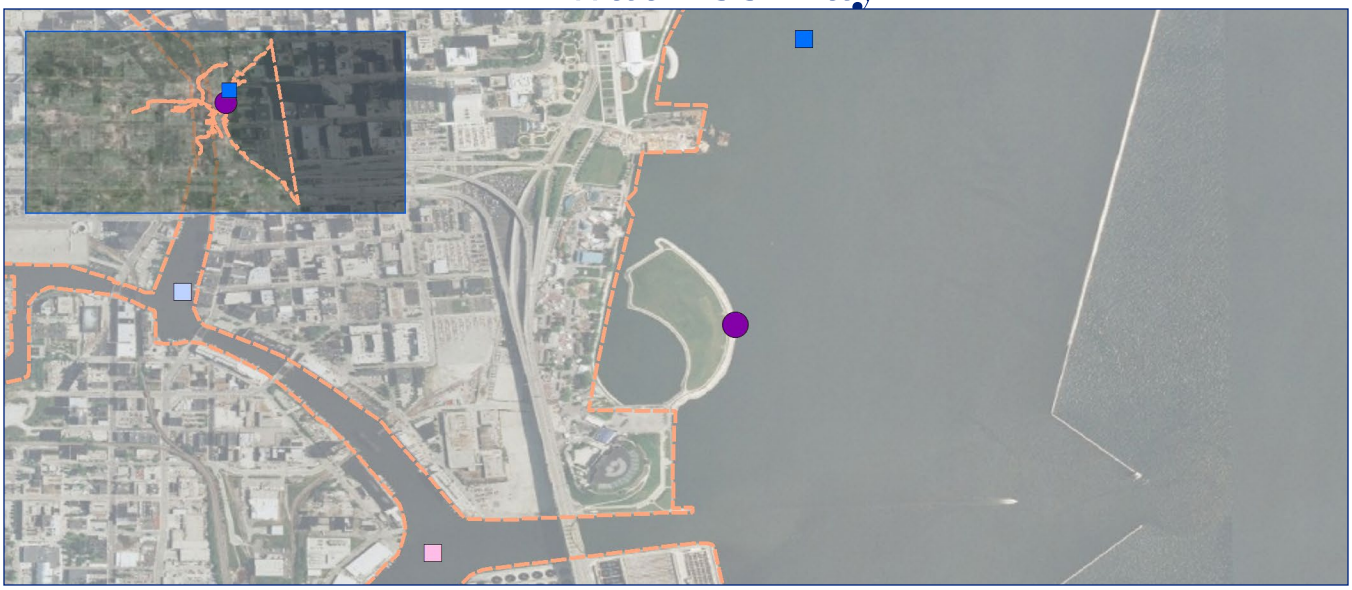


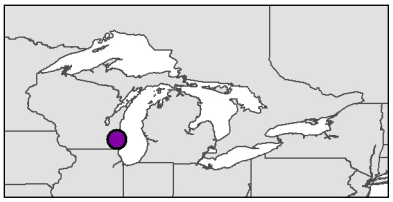
Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010		Tissue - 2011		
Arsenic	3.7	2.0	1.4	2.1	4.2	3.7	4.3
Cadmium	0.62	0.31	0.29	0.25	0.41	0.37	0.36
Copper	31	25	27	31	15	9	11
Lead	1.8	22	46	35	1	1	1
Methyl Mercury	0.06	0.002	0.001	0.001			
Mercury	0.08	0.062	0.057	0.153	0.051	0.059	0.053
Zinc	71	73	78	93	57	46	54

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010		Tissue - 2011		
Alpha-Chlordane	18.2	1.45	0.00	0.00	27.5	33.4	29.1
Chlorpyrifos	7	0.00	0.00	0.00	0	0	0
DDT	438	7.6	21.5	24.4	680	745	919
Heptachlor	0	0.00	0.00	0.00	0	39	0
Hexachlorobenzene	15	2.17	0.24	0.21	32	121	18
Mirex	0.0	0.000	0.000	0.000	0.0	0.0	0.0
Benzo[a]pyrene	419	99	384	413	919	217	1355
Benzo[e]pyrene	378	84	300	287	534	392	911
PCB	21969	397	786	786	30310	22273	38261

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Milwaukee Bay





Legend

Low ● Medium ● High ● Outlier ★

Arsenic	5.2	●	1.7	■	3.2	1.7
Cadmium	0.87	●	0.70	■	1.44	0.68
Copper	43	●	13	■	60	26
Lead	3.8	●	21	■	77	112
Methyl Mercury	0.02	●	0.000	■	0.001	0.000
Mercury	0.03	●	0.068	■	0.174	0.094
Zinc	81	●	90	■	278	146

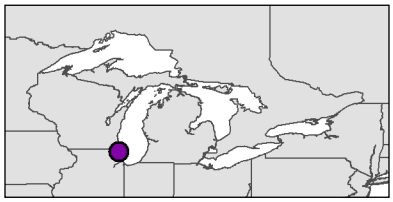
Alpha-Chlordane	46.8	●	0.47	■	3.55	1.62
Chlorpyrifos	13	●	0.00	■	0.00	0.00
DDT	1018	●	9.6	■	78.0	44.6
Heptachlor	6	●	0.00	■	6.08	0.00
Hexachlorobenzene	213	●	7.17	■	0.557	0.319
Mirex	0.0	●	0.000	■	0.000	0.000
Benzo[a]pyrene	1620	●	965	■	961	1021
Benzo[e]pyrene	3943	★	597	■	743	607
PCB	14752	●	152	■	661	602

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Waukegan Harbor

Legend

Low Medium High Outlier

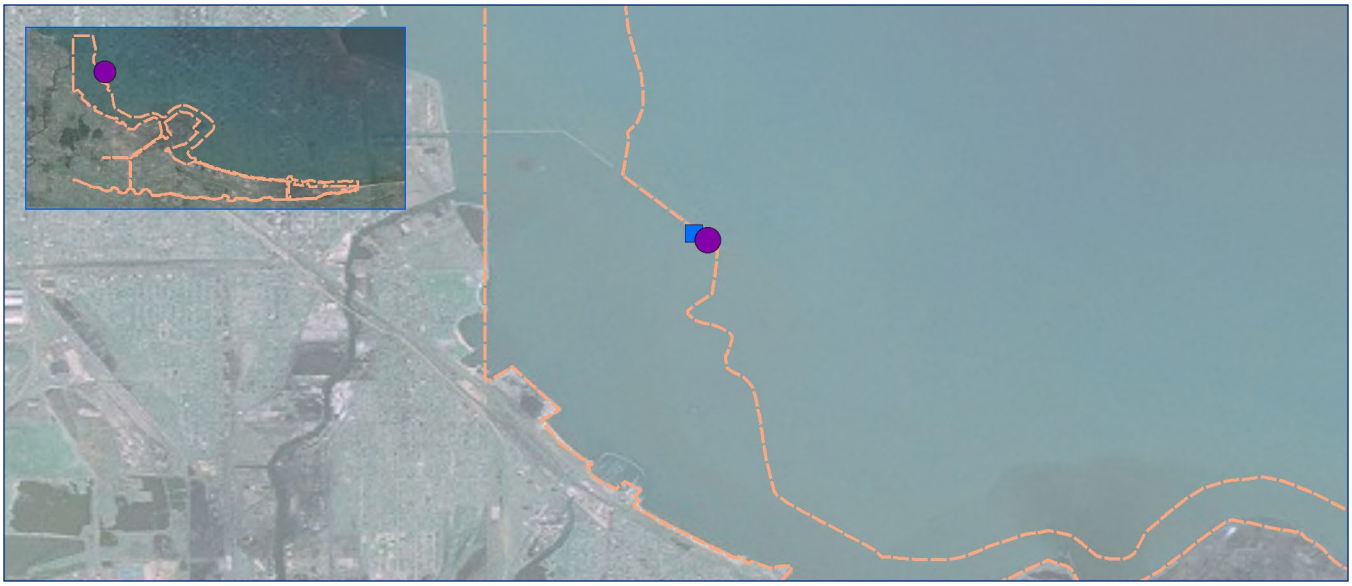


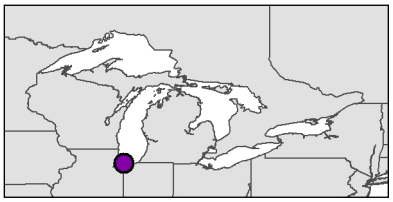
Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011		
Arsenic	6.9	10.0		7.6	2.6	2.5
Cadmium	2.01	3.88		2.35	0.52	0.49
Copper	52	85		24	19	51
Lead	4.4	54		2	1	1
Methyl Mercury	0.01	0.003				
Mercury	0.04	0.141		0.033	0.036	0.034
Zinc	80	165		68	51	57

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011		
Alpha-Chlordane	16.2	0.00		18.6	23.6	24.4
Chlorpyrifos	29	0.00		0	0	0
DDT	481	0.0		515	395	697
Heptachlor	75	0.00		0	0	
Hexachlorobenzene	6	1.45		9	13	9
Mirex	2.1	0.000		1.7	1.0	1.2
Benzo[a]pyrene	940	674		1614	975	1209
Benzo[e]pyrene	899	565		1007	1143	1506
PCB	3924	8993		9247	6154	5315

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Calumet Breakwater





Legend

Low ● Medium ● High ● Outlier ★

Arsenic	7.3	●	5.5	■
Cadmium	3.08	●	0.45	■
Copper	28	●	28	■
Lead	2.2	●	35	■
Methyl Mercury	0.01	●	0.001	■
Mercury	0.04	●	0.069	■
Zinc	67	●	106	■

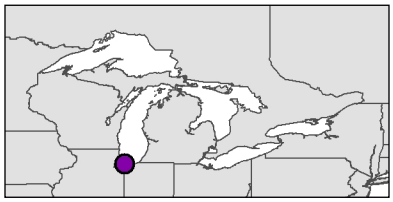
Alpha-Chlordane	9.2	●	0.57	■
Chlorpyrifos	10	●	0.58	■
DDT	144	●	19.8	■
Heptachlor	0	●	0.64	■
Hexachlorobenzene	4	●	0.81	■
Mirex	4.0	●	0.000	■
Benzo[a]pyrene	1580	●	308	■
Benzo[e]pyrene	853	●	214	■
PCB	1167	●	66	■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Hammond Marina

Legend

Low Medium High Outlier

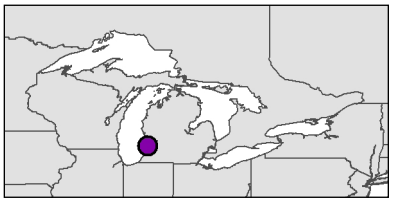


Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue		Baseline - 2009/10** Sediment		Sediment - 2010		Tissue - 2011		
Arsenic	5.4	Low	3.2	Low					
Cadmium	1.81	Medium	0.00	Low					
Copper	22	Low	6	Low					
Lead	1.7	Low	12	Low					
Methyl Mercury	0.01	Low	0.000	Low					
Mercury	0.02	Low	0.012	Low					
Zinc	57	Low	59	Low					

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue		Baseline - 2009/10** Sediment		Sediment - 2010		Tissue - 2011		
Alpha-Chlordane	0.0	Low	0.00	Low					
Chlorpyrifos	15	Medium	0.00	Low					
DDT	109	Low	2.2	Low					
Heptachlor	0	Low	0.00	Low					
Hexachlorobenzene	5	Low	0.00	Low					
Mirex	2.4	Low	0.000	Low					
Benzo[a]pyrene	779	Medium	16	Low					
Benzo[e]pyrene	805	High	15	Low					
PCB	1270	Low	8	Low					

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Kalamazoo River



Legend

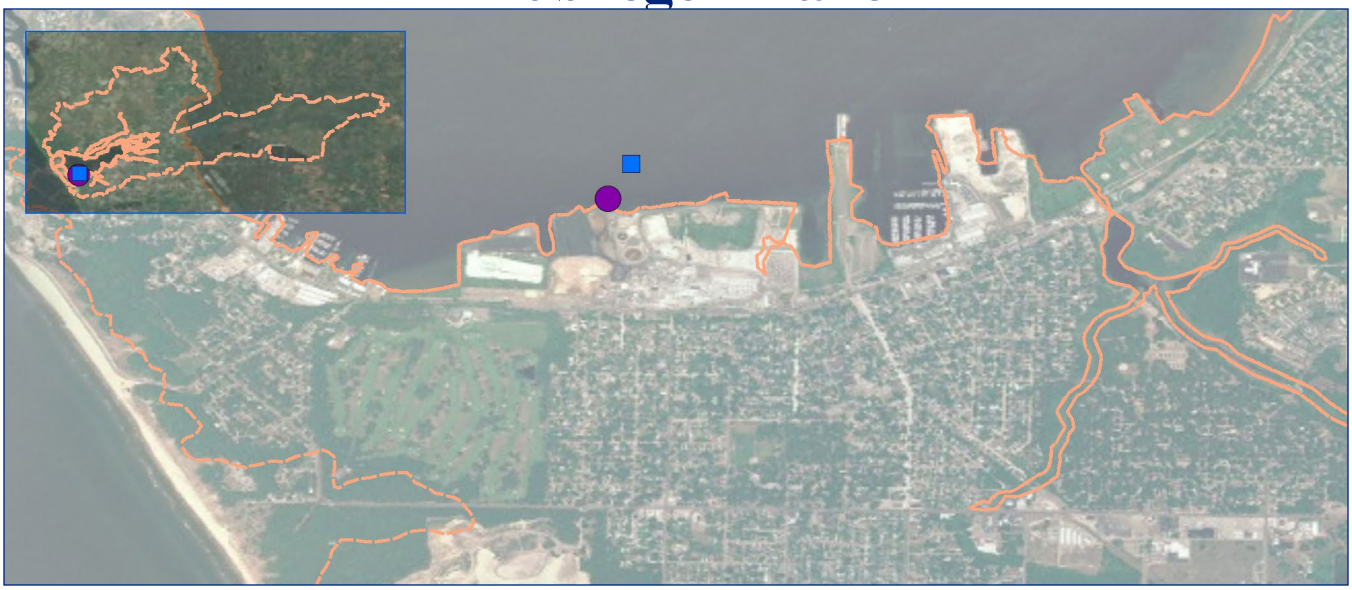
Low ● Medium ● High ● Outlier ★

Arsenic	3.7	■	5.3
Cadmium	0.28	■	0.34
Copper	10	■	11
Lead	21	■	27
Methyl Mercury	0.000	■	0.001
Mercury	0.097	■	0.191
Zinc	46	■	54

Alpha-Chlordane	0.25	■	0.42
Chlorpyrifos	0.29	■	0.11
DDT	4.9	■	9.7
Heptachlor	0.02	■	0.09
Hexachlorobenzene	0.13	■	0.062
Mirex	0.000	■	0.000
Benzo[a]pyrene	32	■	28
Benzo[e]pyrene	23	■	24
PCB	80	■	173

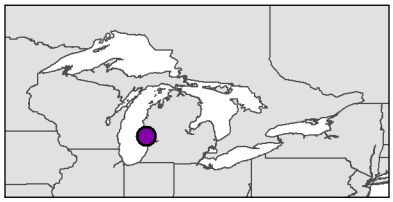
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Muskegon Lake



Legend

Low Medium High Outlier



Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Arsenic	11.4	7.8		
Cadmium	0.57	2.22		
Copper	11	61		
Lead	1.5	83		
Methyl Mercury	0.02	0.001		
Mercury	0.05	0.227		
Zinc	71	201		

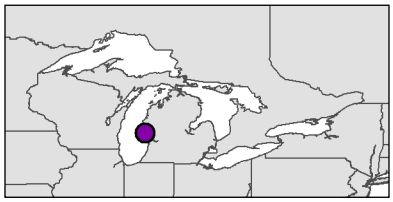
Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Alpha-Chlordane	17.1	1.39		
Chlorpyrifos	15	0.73		
DDT	110	37.3		
Heptachlor	0	1.19		
Hexachlorobenzene	14	0.72		
Mirex	3.8	0.026		
Benzo[a]pyrene	753	371		
Benzo[e]pyrene	475	306		
PCB	773	110		

*Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).

White Lake

Legend

Low ● Medium ● High ● Outlier ★



Arsenic	5.5	●	3.4	■	2.1
Cadmium	0.76	●	0.49	■	0.00
Copper	31	●	15	■	2
Lead	1.2	●	18	■	11
Methyl Mercury	0.05	●	0.003	■	0.000
Mercury	0.07	●	0.091	■	0.015
Zinc	68	●	64	■	36

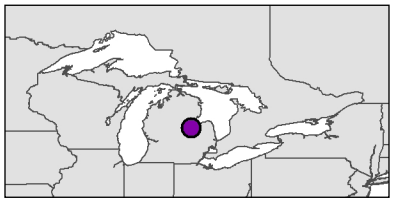
Alpha-Chlordane	7.5	●	0.12	■	0.03
Chlorpyrifos	9	●	0.27	■	0.05
DDT	89	●	6.8	■	0.2
Heptachlor	0	●	0.05	■	0.00
Hexachlorobenzene	8	●	0.12	■	0.127
Mirex	55.0	●	0.032	■	0.017
Benzo[a]pyrene	119	●	46	■	1
Benzo[e]pyrene	107	●	38	■	1
PCB	677	●	4	■	3

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Saginaw River

Legend

Low Medium High Outlier

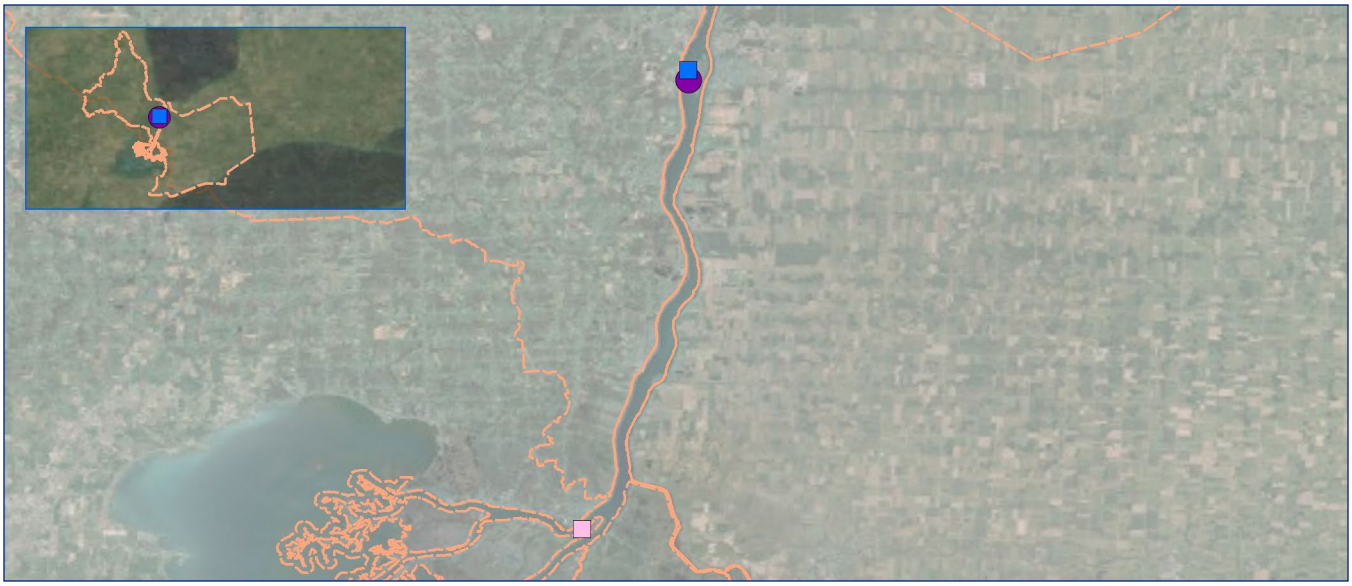


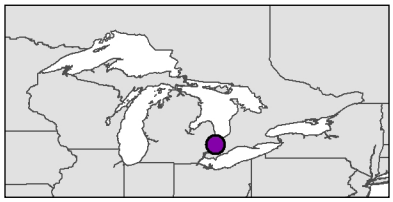
Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Arsenic	7.3	5.5	6.5	
Cadmium	0.50	0.58	0.66	
Copper	24	30	31	
Lead	1.7	27	29	
Methyl Mercury	0.02	0.001	0.001	
Mercury	0.04	0.095	0.094	
Zinc	80	130	144	

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Alpha-Chlordane	16.7	0.05	0.18	
Chlorpyrifos	11	0.05	0.31	
DDT	238	5.3	11.4	
Heptachlor	0	0.26	0.30	
Hexachlorobenzene	8	3.86	6.394	
Mirex	0.0	0.024	0.031	
Benzo[a]pyrene	552	162	238	
Benzo[e]pyrene	462	128	205	
PCB	3035	98	90	

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

St. Clair River





Legend

Low Medium High Outlier

Arsenic	5.4		2.3		3.5
Cadmium	3.55		0.00		0.49
Copper	80		5		21
Lead	3.1		9		15
Methyl Mercury	0.02		0.001		0.002
Mercury	0.06		0.012		0.138
Zinc	135		28		62

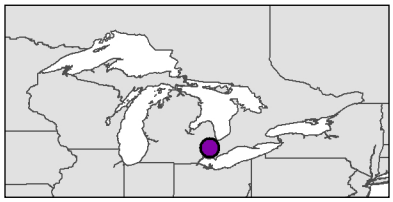
Alpha-Chlordane	8.0		0.00		0.02
Chlorpyrifos	0		0.06		0.12
DDT	24		0.3		1.7
Heptachlor	0		0.00		0.10
Hexachlorobenzene	2		0.57		10.857
Mirex	1.2		0.000		0.094
Benzo[a]pyrene	0		6		33
Benzo[e]pyrene	0		5		25
PCB	173		2		24

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Clinton River

Legend

Low ● Medium ● High ● Outlier ★

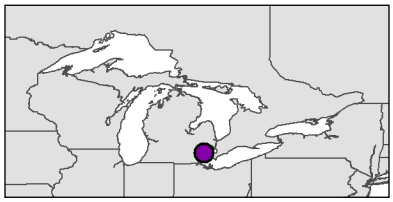


Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Arsenic	5.3	7.9	7.2	
Cadmium	1.05	2.78	2.54	
Copper	30	85	75	
Lead	1.9	82	75	
Methyl Mercury	0.04	0.001	0.001	
Mercury	0.07	0.204	0.182	
Zinc	214	380	330	

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Alpha-Chlordane	43.8	4.66	0.46	
Chlorpyrifos	22	0.61	0.55	
DDT	474	68.1	66.9	
Heptachlor	0	1.07	1.54	
Hexachlorobenzene	7	1.77	1.257	
Mirex	1.5	0.552	0.422	
Benzo[a]pyrene	169	3569	2594	
Benzo[e]pyrene	1038	3369	1988	
PCB	2636	367	378	

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Rouge River



Legend

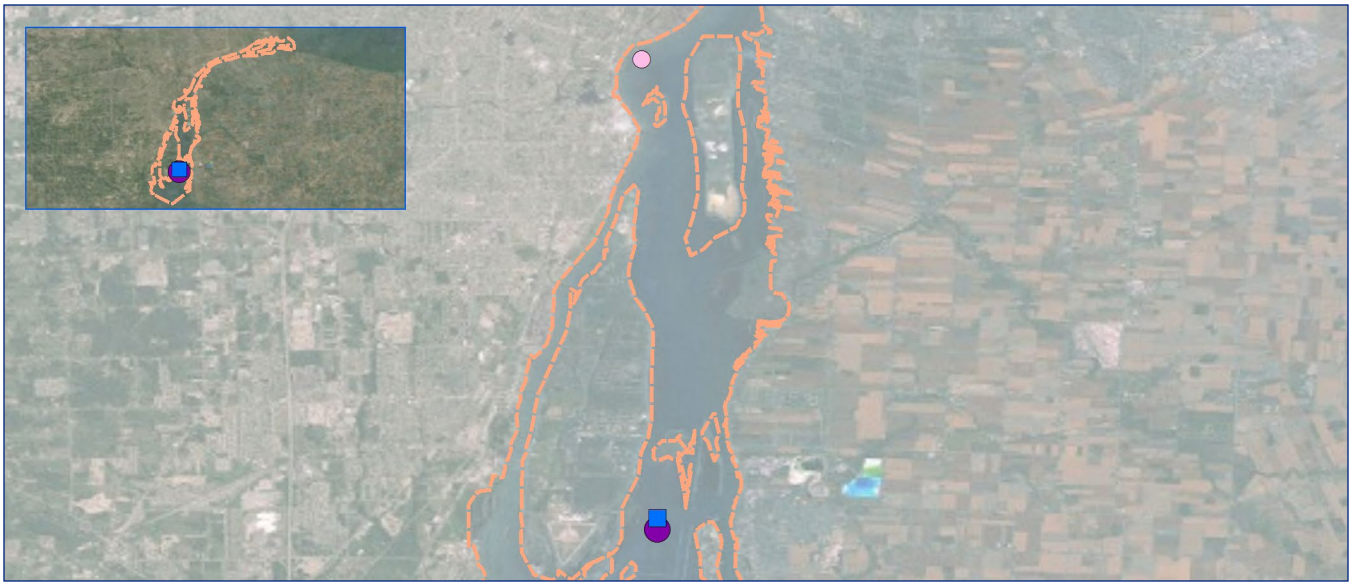
Low ● Medium ● High ● Outlier ★

Arsenic	4.0	■
Cadmium	0.86	■
Copper	94	■
Lead	54	■
Methyl Mercury	0.001	■
Mercury	0.195	■
Zinc	180	■

Alpha-Chlordane	13.10	★
Chlorpyrifos	0.00	■
DDT	58.6	★
Heptachlor	9.96	■
Hexachlorobenzene	0.27	■
Mirex	0.062	■
Benzo[a]pyrene	16454	★
Benzo[e]pyrene	6715	★
PCB	372	■

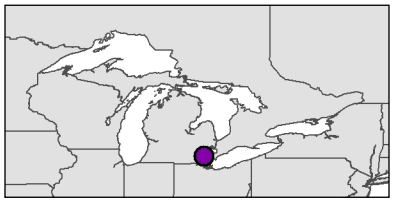
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Detroit River



Legend

Low Medium High Outlier



Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Arsenic	3.6	6.4		3.7
Cadmium	0.83	0.80		0.87
Copper	35	37		60
Lead	1.7	29		4
Methyl Mercury	0.03	0.002		
Mercury	0.05	0.323		0.046
Zinc	46	114		86

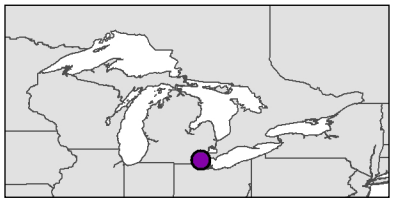
Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Alpha-Chlordane	7.4	0.67		0.0
Chlorpyrifos	9	0.00		0
DDT	73	9.2		454
Heptachlor	0	0.00		0
Hexachlorobenzene	12	4.08		16
Mirex	0.0	0.000		0.0
Benzo[a]pyrene	246	401		1852
Benzo[e]pyrene	441	288		2602
PCB	1652	68		5126

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

River Raisin

Legend

Low | Medium | High | Outlier



Arsenic	3.8		6.6	
Cadmium	1.97		0.60	
Copper	16		26	
Lead	2.6		29	
Methyl Mercury	0.01		0.002	
Mercury	0.04		0.077	
Zinc	54		94	

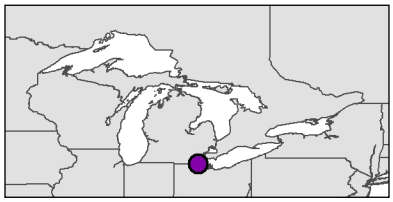
Alpha-Chlordane	33.5		0.97	
Chlorpyrifos	32		0.00	
DDT	225		21.2	
Heptachlor	0		0.00	
Hexachlorobenzene	16		0.38	
Mirex	1.5		0.000	
Benzo[a]pyrene	288		1210	
Benzo[e]pyrene	578		616	
PCB	4562		223	

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Maumee River

Legend

Low Medium High Outlier

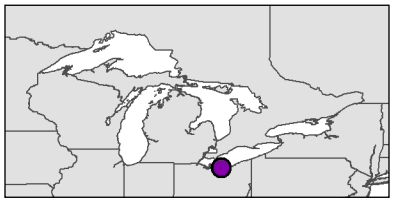


Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Sediment	Sediment - 2010	Tissue - 2011
Arsenic	3.6	6.6		
Cadmium	0.64	0.53		
Copper	14	24		
Lead	1.7	19		
Methyl Mercury	0.02	0.001		
Mercury	0.03	0.058		
Zinc	53	83		

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Sediment	Sediment - 2010	Tissue - 2011
Alpha-Chlordane	48.2	0.69		
Chlorpyrifos	249	0.53		
DDT	216	7.9		
Heptachlor	0	0.21		
Hexachlorobenzene	7	0.19		
Mirex	1.6	0.000		
Benzo[a]pyrene	543	190		
Benzo[e]pyrene	1095	153		
PCB	2726	101		

*Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).

Black River



Legend

Low | Medium | High | Outlier

Arsenic	4.4		10.5		5.0	4.8	5.1
Cadmium	2.15		1.30		2.43	2.98	2.57
Copper	15		31		18	48	17
Lead	2.9		27		2	3	2
Methyl Mercury	0.02		0.001				
Mercury	0.03		0.058		0.051	0.055	0.050
Zinc	56		144		64	70	54

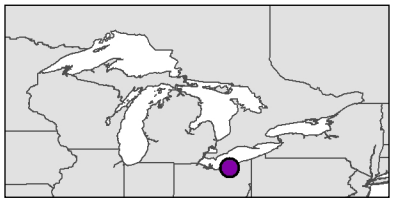
Alpha-Chlordane	121.5		1.21		93.8	61.5	74.1
Chlorpyrifos	14		0.39		0	0	0
DDT	185		8.2		171	213	244
Heptachlor	0		0.07		0	0	275
Hexachlorobenzene	10		3.77		0	0	0
Mirex	2.0		0.000		0.0	0.0	0.0
Benzo[a]pyrene	1308		219		300	322	174
Benzo[e]pyrene	1196		167		711	581	428
PCB	1624		62		1327	1511	1343

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Cuyahoga River

Legend

Low Medium High Outlier

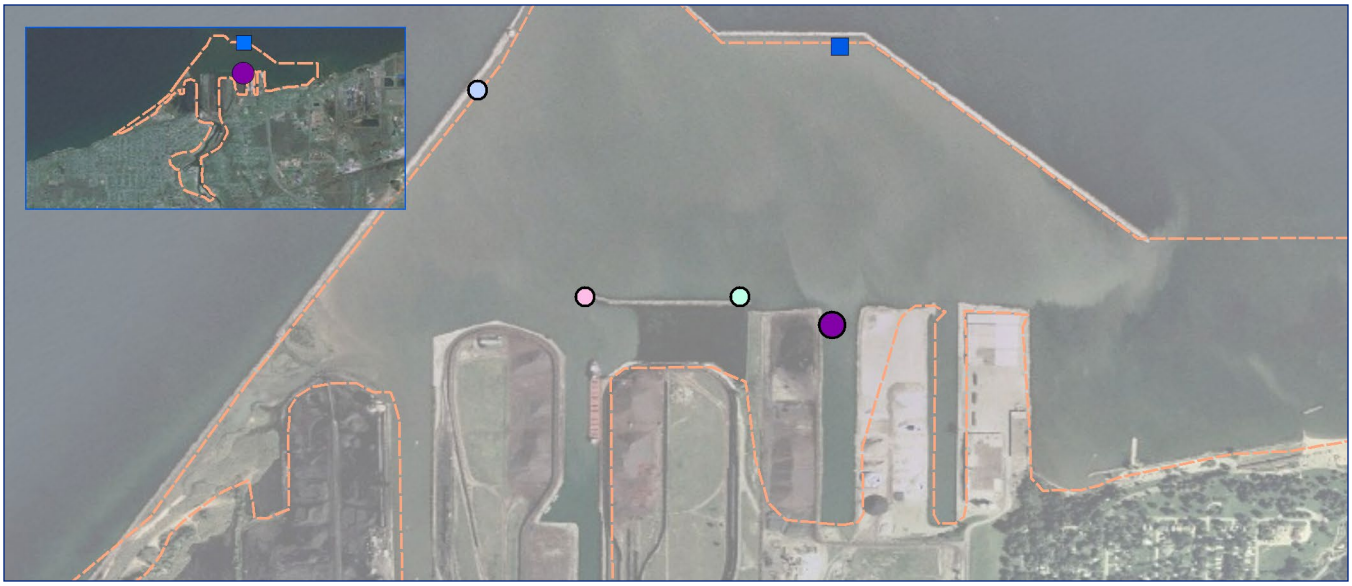


Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011		
Arsenic	4.3	17.1		5.7	5.8	5.2
Cadmium	0.95	0.93		1.60	1.55	1.31
Copper	50	43		20	54	38
Lead	4.4	41		3	5	4
Methyl Mercury	0.02	0.001				
Mercury	0.03	0.095		0.044	0.048	0.050
Zinc	76	203		69	90	79

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011		
Alpha-Chlordane	177.3	3.14		195.9	225.0	218.3
Chlorpyrifos	23	0.00		0	0	0
DDT	344	13.9		516	596	602
Heptachlor	0	0.00		0	0	0
Hexachlorobenzene	10	1.51		0	0	0
Mirex	3.5	0.000		0.0	0.0	0.0
Benzo[a]pyrene	756	454		1080	1245	540
Benzo[e]pyrene	2087	418		2980	3286	1660
PCB	3557	163		3903	4664	4161

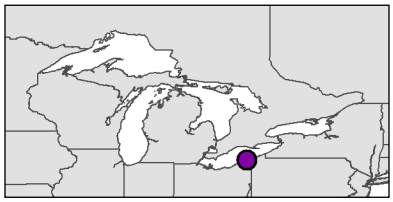
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Ashtabula River



Legend

Low ● Medium ● High ● Outlier ★

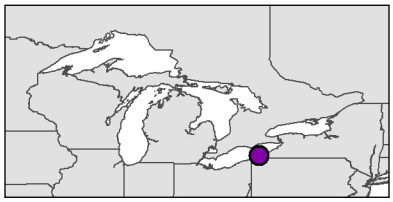


Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011		
Arsenic	7.9	14.2		5.1	6.6	6.3
Cadmium	2.34	0.59		2.74	2.71	1.77
Copper	124	30		14	15	15
Lead	5.4	25		1	1	2
Methyl Mercury	0.02	0.001				
Mercury	0.04	0.055		0.038	0.045	0.045
Zinc	97	117		50	60	59

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011		
Alpha-Chlordane	19.2	3.83		9.2	23.4	10.7
Chlorpyrifos	6	0.00		0	0	0
DDT	46	7.1		62	99	50
Heptachlor	0	0.00		0	0	0
Hexachlorobenzene	131	4.99		58	137	130
Mirex	0.0	0.000		0.0	8.3	0.0
Benzo[a]pyrene	403	361		94	145	323
Benzo[e]pyrene	627	250		208	360	640
PCB	1289	102		1067	1979	1292

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Presque Isle Bay



Legend

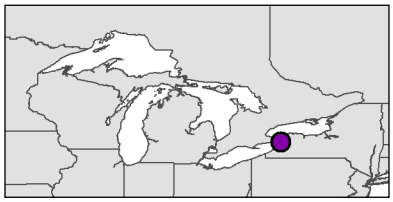
Low Medium High Outlier

Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Arsenic	6.3	7.4		
Cadmium	2.38	1.47		
Copper	41	30		
Lead	10.1	47		
Methyl Mercury	0.02	0.001		
Mercury	0.06	0.147		
Zinc	82	114		

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Alpha-Chlordane	84.7	2.96		
Chlorpyrifos	4	0.00		
DDT	224	7.2		
Heptachlor	0	0.00		
Hexachlorobenzene	238	8.56		
Mirex	22.6	0.000		
Benzo[a]pyrene	38041	2380		
Benzo[e]pyrene	23196	1300		
PCB	4138	182		

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Buffalo River



Legend

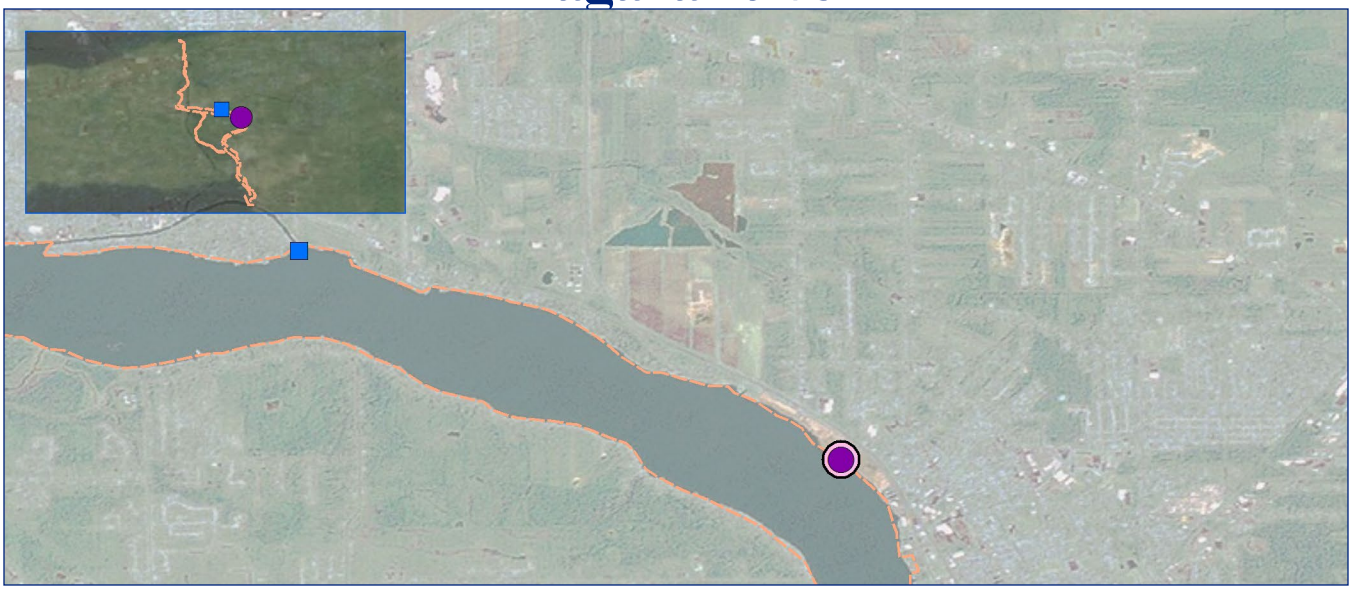
Low ● Medium ● High ● Outlier ★

Arsenic	4.4	●	13.1	■
Cadmium	0.78	●	0.50	■
Copper	43	●	41	■
Lead	5.3	●	32	■
Methyl Mercury	0.08	●	0.002	■
Mercury	0.11	●	0.076	■
Zinc	82	●	139	■

Alpha-Chlordane	24.4	●	1.22	■
Chlorpyrifos	10	●	0.39	■
DDT	249	●	7.8	■
Heptachlor	0	●	0.00	■
Hexachlorobenzene	17	●	0.69	■
Mirex	4.5	●	0.000	■
Benzo[a]pyrene	879	●	201	■
Benzo[e]pyrene	1313	●	179	■
PCB	1789	●	53	■

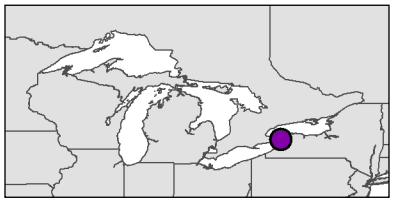
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Niagara River



Legend

Low Medium High Outlier

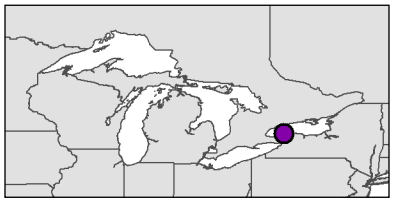


Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Sediment	Sediment - 2010	Tissue - 2011
Arsenic	3.6	2.0		7.1
Cadmium	1.23	0.21		1.23
Copper	36	6		53
Lead	2.8	10		4
Methyl Mercury	0.02	0.001		
Mercury	0.04	0.034		0.067
Zinc	51	57		89

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Sediment	Sediment - 2010	Tissue - 2011
Alpha-Chlordane	12.9	0.16		9.3
Chlorpyrifos	5	0.00		0
DDT	84	1.0		101
Heptachlor	0	0.00		0
Hexachlorobenzene	25	0.58		0
Mirex	6.3	0.000		0.0
Benzo[a]pyrene	1067	26		2443
Benzo[e]pyrene	1416	28		4029
PCB	4715	25		5064

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Eighteenmile Creek



Legend

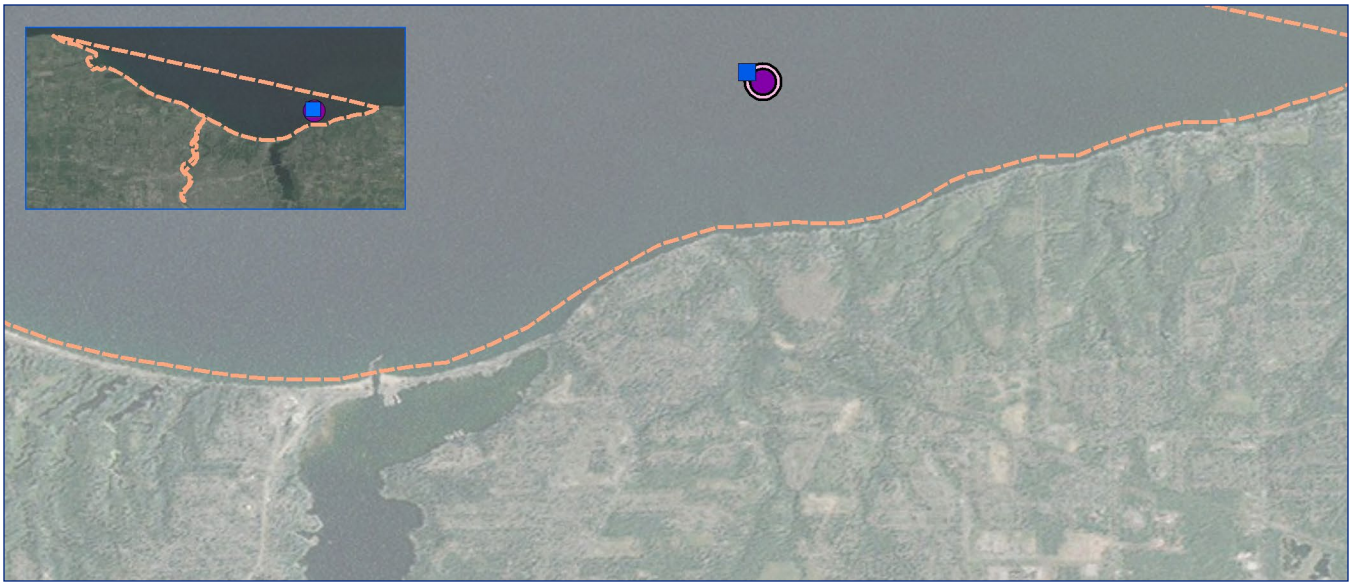
Low ● Medium ● High ● Outlier ★

Arsenic	2.9	●	4.0	■
Cadmium	0.70	●	0.48	■
Copper	56	●	63	■
Lead	9.3	●	47	■
Methyl Mercury	0.05	●	0.002	■
Mercury	0.08	●	0.127	■
Zinc	96	●	182	■

Alpha-Chlordane	37.7	●	0.77	■
Chlorpyrifos	15	●	0.36	■
DDT	1896	●	21.1	■
Heptachlor	0	●	0.00	■
Hexachlorobenzene	22	●	0.60	■
Mirex	52.0	●	0.310	■
Benzo[a]pyrene	344	●	170	■
Benzo[e]pyrene	791	●	135	■
PCB	23964	●	170	■

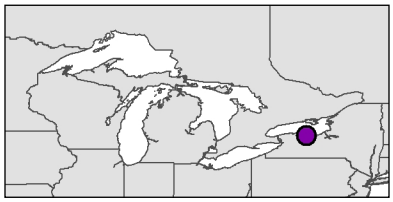
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Rochester



Legend

Low Medium High Outlier

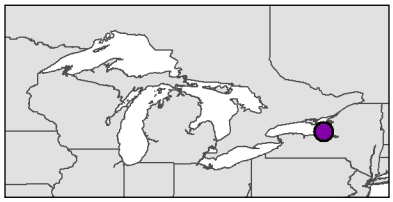


Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Arsenic	6.4	8.9		6.5
Cadmium	2.14	0.55		2.10
Copper	11	28		26
Lead	2.0	24		1
Methyl Mercury	0.02	0.001		
Mercury	0.04	0.136		0.033
Zinc	58	111		66

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue	Baseline - 2009/10** Sediment	Sediment - 2010	Tissue - 2011
Alpha-Chlordane	10.9	0.64		10.0
Chlorpyrifos	8	0.30		0
DDT	119	6.9		216
Heptachlor	0	0.06		0
Hexachlorobenzene	16	3.23		0
Mirex	42.8	0.000		0.0
Benzo[a]pyrene	173	147		197
Benzo[e]pyrene	395	113		332
PCB	681	32		434

*Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).

Oswego River



Legend

Low ● Medium ● High ● Outlier ★

Arsenic	3.6	●	1.7	■
Cadmium	0.65	●	0.16	■
Copper	23	●	9	■
Lead	0.9	●	15	■
Methyl Mercury	0.04	●	0.001	■
Mercury	0.06	●	0.065	■
Zinc	57	●	36	■

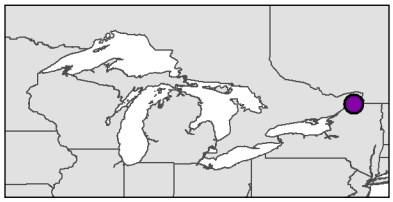
Alpha-Chlordane	5.2	●	0.33	■
Chlorpyrifos	4	●	0.08	■
DDT	64	●	2.9	■
Heptachlor	0	●	0.00	■
Hexachlorobenzene	21	●	0.38	■
Mirex	16.3	●	1.310	■
Benzo[a]pyrene	106	●	213	■
Benzo[e]pyrene	380	●	140	■
PCB	667	●	17	■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

St. Lawrence River

Legend

Low Medium High Outlier

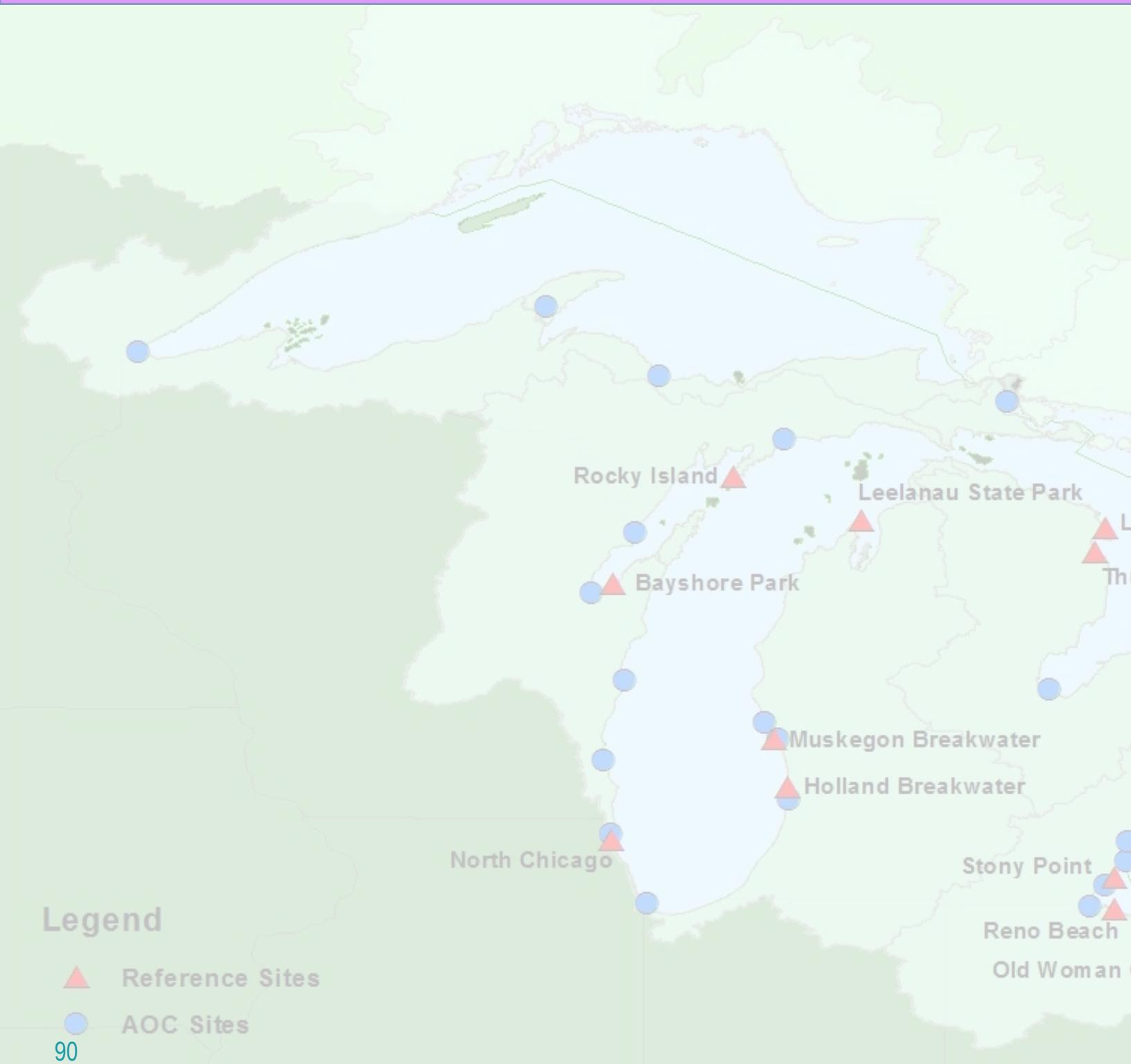


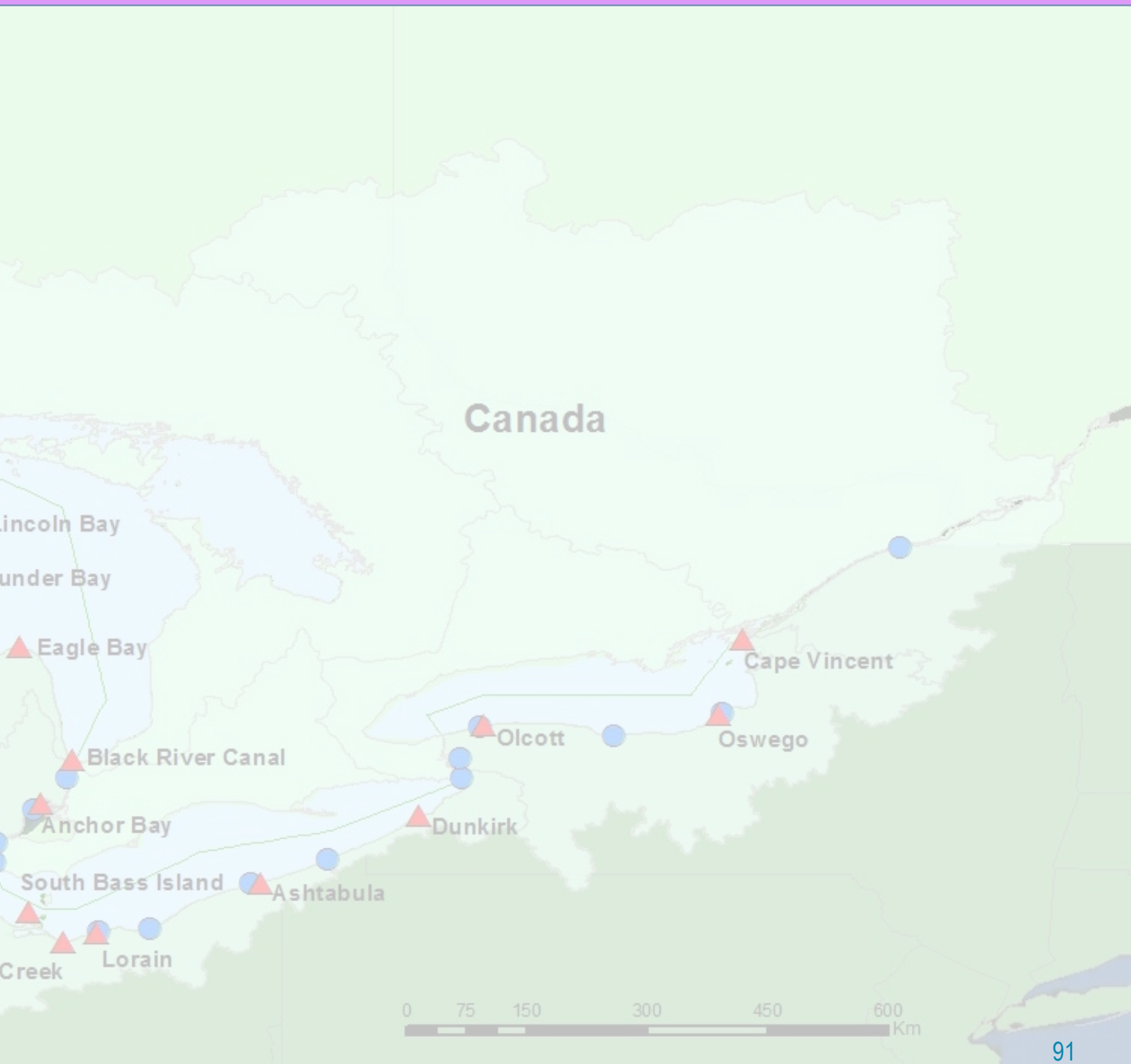
Metals (µg/g dry wt.)	Baseline - 2009/10** Tissue		Baseline - 2009/10** Sediment		Sediment - 2010		Tissue - 2011		
Arsenic	4.7		22.7						
Cadmium	1.06		0.16						
Copper	12		19						
Lead	1.5		16						
Methyl Mercury	0.02		0.000						
Mercury	0.04		0.020						
Zinc	50		91						

Organics (ng/g dry wt.)*	Baseline - 2009/10** Tissue		Baseline - 2009/10** Sediment		Sediment - 2010		Tissue - 2011		
Alpha-Chlordane	6.0		0.04						
Chlorpyrifos	14		0.00						
DDT	40		0.5						
Heptachlor	0		0.02						
Hexachlorobenzene	4		0.17						
Mirex	22.7		0.000						
Benzo[a]pyrene	386		12						
Benzo[e]pyrene	621		12						
PCB	399		5						

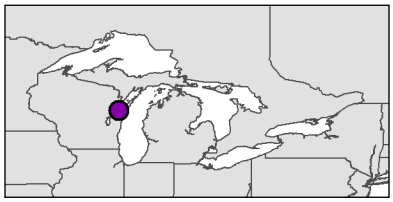
***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Reference sites




Canada
incoln Bay
under Bay
Eagle Bay
Cape Vincent
Olcott
Oswego
Black River Canal
Anchor Bay
Dunkirk
South Bass Island
Ashtabula
Lorain
Creek
0 75 150 300 450 600
Km

Bayshore Park



Legend

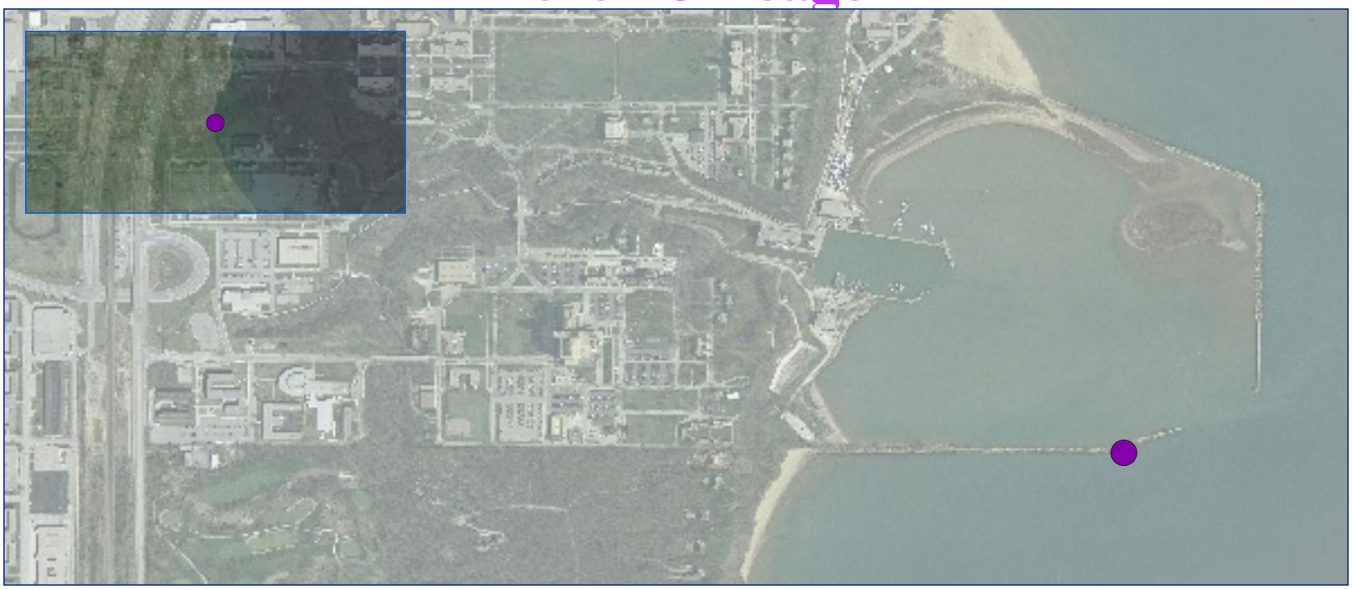
Low ● Medium ● High ● Outlier ★

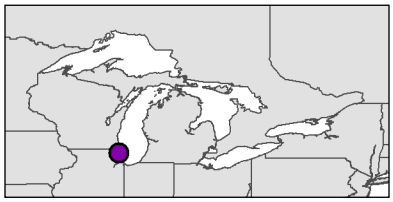
Metals (µg/g dry wt.)	Baseline** Tissue ●		Sediment ■	
Arsenic	3.7	●	1.6	■
Cadmium	0.35	●	0.39	■
Copper	206	●	13	■
Lead	7.0	●	21	■
Methyl Mercury	0.06	●	0.001	■
Mercury	0.08	●	0.261	■
Zinc	200	★	53	■

Organics (ng/g dry wt.)*	Baseline** Tissue ●		Sediment ■	
Alpha-Chlordane	3.3	●	0.28	■
Chlorpyrifos	2	●	0.65	■
DDT	109	●	1.3	■
Heptachlor	53	●	0.04	■
Hexachlorobenzene	18	●	0.26	■
Mirex	0.9	●	0.000	■
Benzo[a]pyrene	241	●	189	■
Benzo[e]pyrene	151	●	115	■
PCB	4741	●	100	■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

North Chicago





Legend

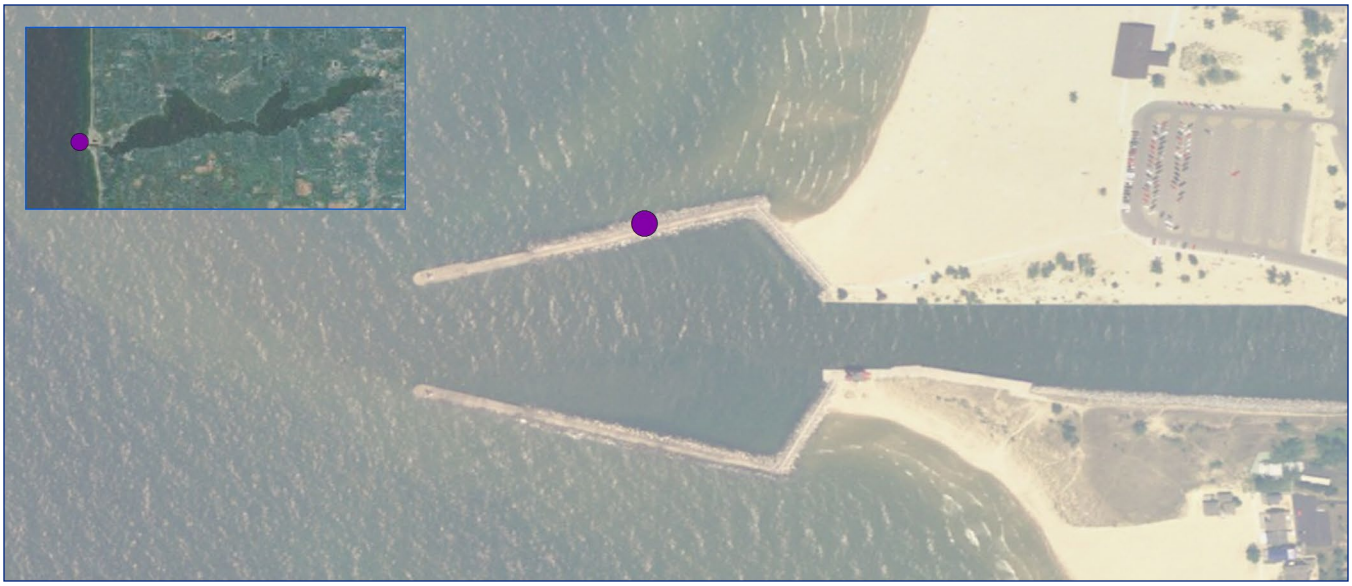
Low ● Medium ● High ● Outlier ★

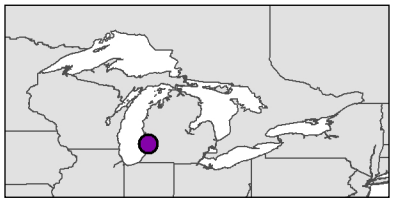
Metals (μg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	6.2	●
Cadmium	3.01	●
Copper	28	●
Lead	8.5	●
Methyl Mercury	0.01	●
Mercury	0.03	●
Zinc	74	●

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	26.0	●
Chlorpyrifos	22	●
DDT	788	●
Heptachlor	0	●
Hexachlorobenzene	6	●
Mirex	4.1	●
Benzo[a]pyrene	794	●
Benzo[e]pyrene	562	●
PCB	1851	●

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Holland Breakwater





Legend

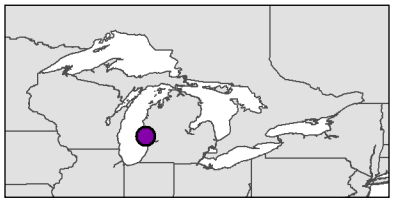
Low ● Medium ● High ● Outlier ★

Metals (μg/g dry wt.)	Baseline** Tissue ●	Sediment ■
Arsenic	5.0	●
Cadmium	1.92	●
Copper	28	●
Lead	1.2	●
Methyl Mercury	0.03	●
Mercury	0.05	●
Zinc	75	●

Organics (ng/g dry wt.)*	Baseline** Tissue ●	Sediment ■
Alpha-Chlordane	19.3	●
Chlorpyrifos	10	●
DDT	211	●
Heptachlor	0	●
Hexachlorobenzene	9	●
Mirex	0.0	●
Benzo[a]pyrene	187	●
Benzo[e]pyrene	142	●
PCB	1192	●

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Muskegon



Legend

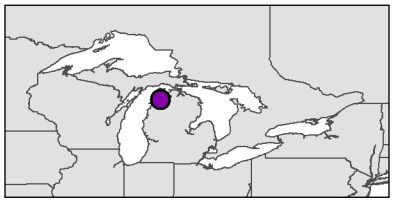
Low ● Medium ● High ● Outlier ★

Metals (μg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	4.3	●
Cadmium	1.39	●
Copper	13	●
Lead	1.2	●
Methyl Mercury	0.02	●
Mercury	0.04	●
Zinc	53	●

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	18.9	●
Chlorpyrifos	14	●
DDT	145	●
Heptachlor	0	●
Hexachlorobenzene	6	●
Mirex	3.5	●
Benzo[a]pyrene	275	●
Benzo[e]pyrene	114	●
PCB	665	●

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Leelanau State Park



Legend

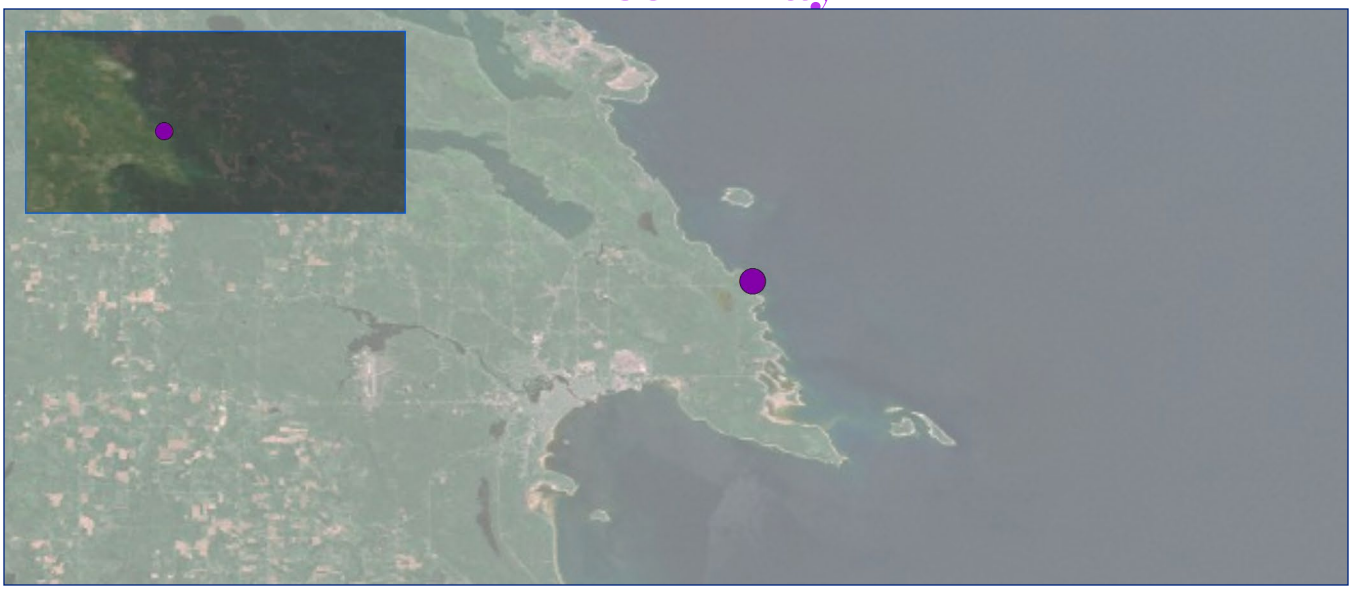
Low ● Medium ● High ● Outlier ★

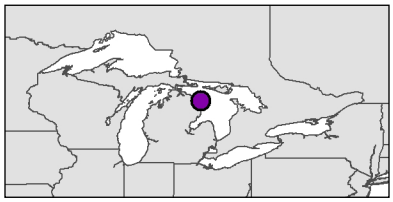
Metals (µg/g dry wt.)	Baseline** Tissue ●	Sediment ■
Arsenic	9.9	●
Cadmium	4.24	●
Copper	44	●
Lead	1.6	●
Methyl Mercury	0.02	●
Mercury	0.05	●
Zinc	69	●

Organics (ng/g dry wt.)*	Baseline** Tissue ●	Sediment ■
Alpha-Chlordane	5.3	●
Chlorpyrifos	6	●
DDT	15	●
Heptachlor	0	●
Hexachlorobenzene	0	●
Mirex	0.6	●
Benzo[a]pyrene	0	●
Benzo[e]pyrene	33	●
PCB	103	●

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Lincoln Bay





Legend

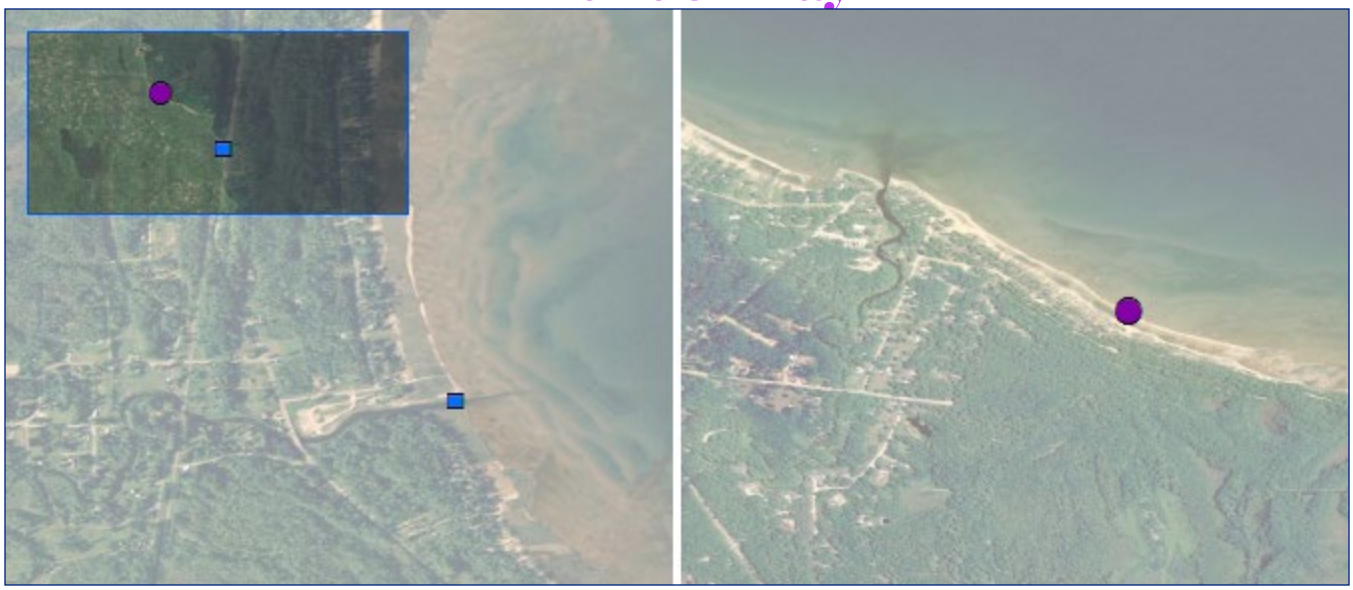
Low ● Medium ● High ● Outlier ★

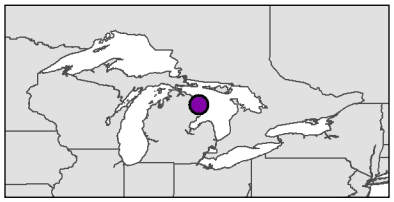
Metals (μg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	9.5	●
Cadmium	6.93	●
Copper	19	●
Lead	0.4	●
Methyl Mercury	0.03	●
Mercury	0.09	●
Zinc	68	●

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	3.4	●
Chlorpyrifos	0	●
DDT	14	●
Heptachlor	0	●
Hexachlorobenzene	3	●
Mirex	0.9	●
Benzo[a]pyrene	0	●
Benzo[e]pyrene	0	●
PCB	75	●

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Thunder Bay





Legend

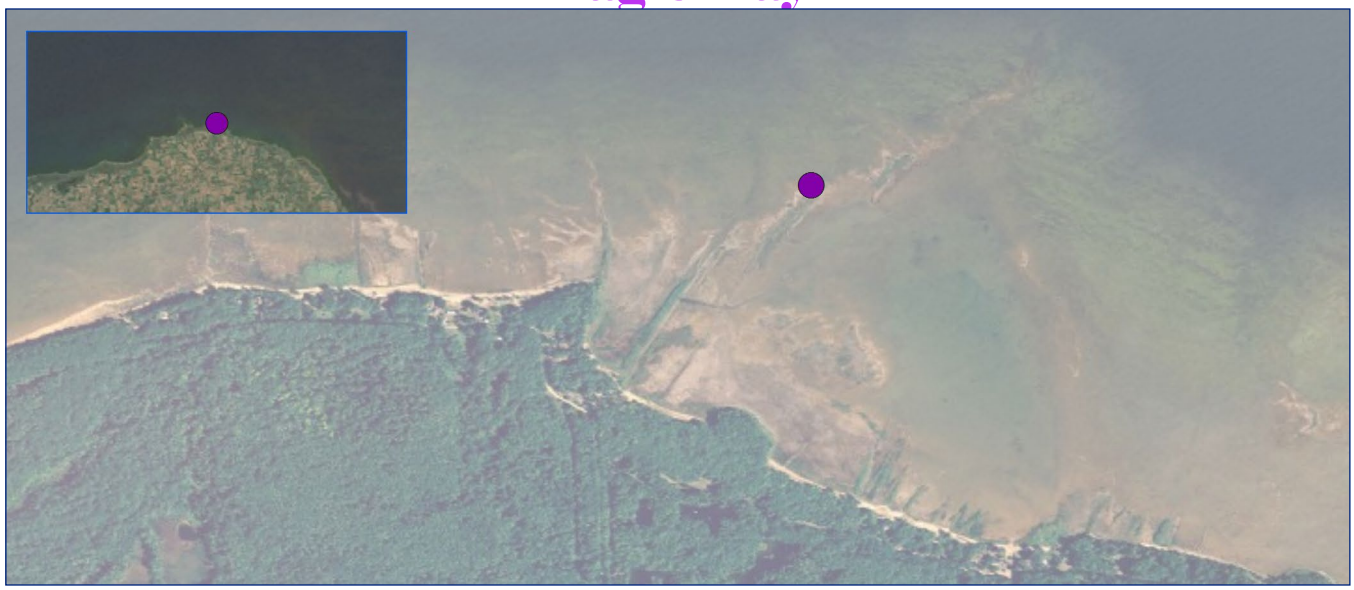
Low ● Medium ● High ● Outlier ★

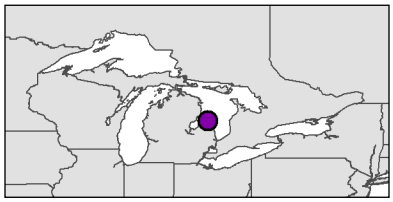
Metals (μg/g dry wt.)	Tissue ●		Baseline** Sediment ■	
Arsenic	5.4	●	1.3	■
Cadmium	8.44	●	0.24	■
Copper	125	●	9	■
Lead	4.9	●	10	■
Methyl Mercury	0.02	●	0.002	■
Mercury	0.07	●	0.040	■
Zinc	139	●	34	■

Organics (ng/g dry wt.)*	Tissue ●		Baseline** Sediment ■	
Alpha-Chlordane	9.5	●	0.07	■
Chlorpyrifos	3	●	0.00	■
DDT	30	●	0.6	■
Heptachlor	0	●	0.00	■
Hexachlorobenzene	5	●	0.098	■
Mirex	0.0	●	0.011	■
Benzo[a]pyrene	0	●	85	■
Benzo[e]pyrene	0	●	46	■
PCB	75	●	2	■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Eagle Bay





Legend

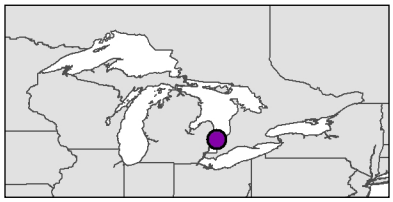
Low ● Medium ● High ● Outlier ★

Metals (μg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	6.7	●
Cadmium	3.94	●
Copper	51	●
Lead	0.9	●
Methyl Mercury	0.02	●
Mercury	0.06	●
Zinc	109	●

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	8.3	●
Chlorpyrifos	12	●
DDT	38	●
Heptachlor	8	●
Hexachlorobenzene	4	●
Mirex	0.0	●
Benzo[a]pyrene	625	●
Benzo[e]pyrene	54	●
PCB	245	●

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Black River Canal



Legend

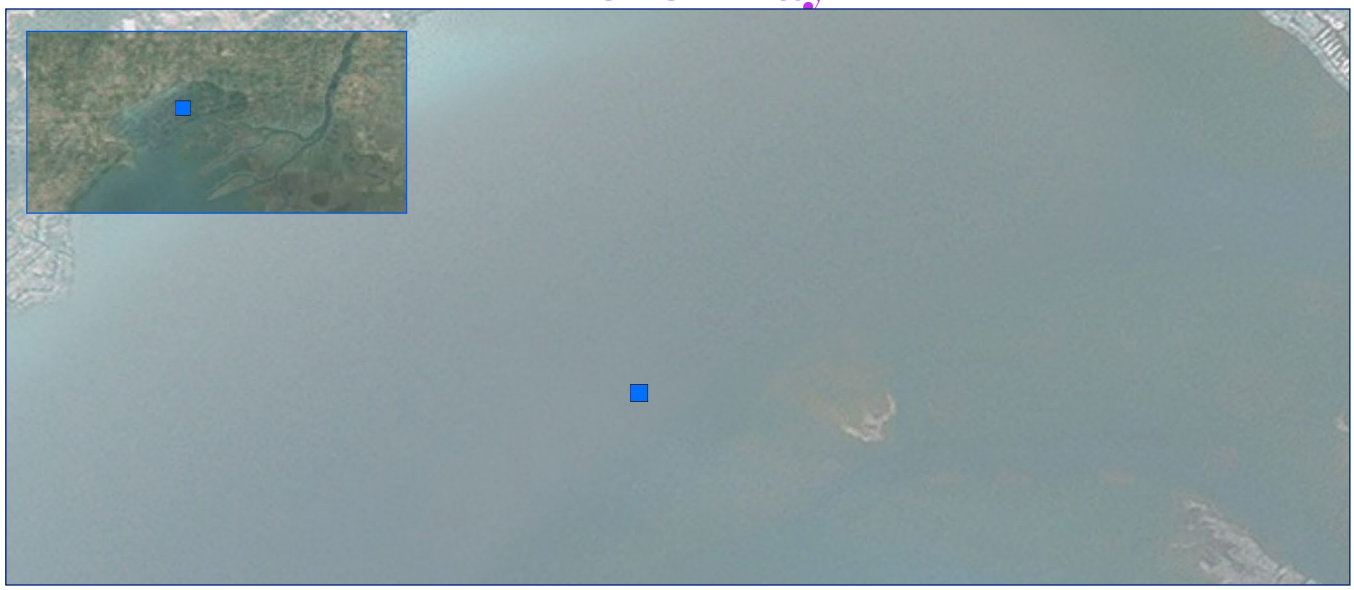
Low ● Medium ● High ● Outlier ★

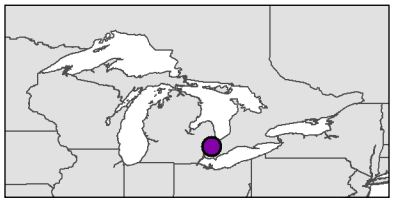
Metals (μg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	8.1	●
Cadmium	5.57	●
Copper	38	●
Lead	1.5	●
Methyl Mercury	0.02	●
Mercury	0.08	●
Zinc	102	●

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	8.7	●
Chlorpyrifos	22	●
DDT	48	●
Heptachlor	0	●
Hexachlorobenzene	2	●
Mirex	1.3	●
Benzo[a]pyrene	0	●
Benzo[e]pyrene	0	●
PCB	161	●

*Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).

Anchor Bay





Legend

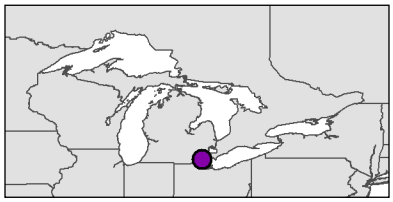
Low Medium High Outlier

Metals (μg/g dry wt.)	Tissue	Baseline** Sediment
Arsenic		3.3
Cadmium		0.68
Copper		17
Lead		12
Methyl Mercury		0.001
Mercury		0.072
Zinc		62

Organics (ng/g dry wt.)*	Tissue	Baseline** Sediment
Alpha-Chlordane		0.02
Chlorpyrifos		0.00
DDT		0.8
Heptachlor		0.04
Hexachlorobenzene		4.069
Mirex		0.000
Benzo[a]pyrene		25
Benzo[e]pyrene		18
PCB		10

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Stony Point



Legend

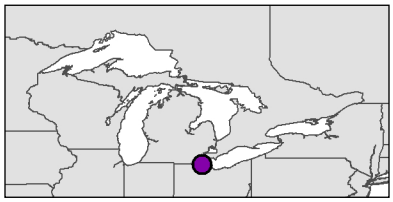
Low ● Medium ● High ● Outlier ★

Metals (μg/g dry wt.)	Tissue ●		Baseline** Sediment ■	
Arsenic	3.9	●	4.1	■
Cadmium	2.11	●	0.98	■
Copper	69	●	23	■
Lead	5.3	●	26	■
Methyl Mercury	0.04	●	0.001	■
Mercury	0.09	●	0.306	■
Zinc	90	●	100	■

Organics (ng/g dry wt.)*	Tissue ●		Baseline** Sediment ■	
Alpha-Chlordane	37.1	●	0.54	■
Chlorpyrifos	18	●	0.00	■
DDT	408	●	9.8	■
Heptachlor	0	●	1.49	■
Hexachlorobenzene	20	●	1.08	■
Mirex	3.5	●	0.000	■
Benzo[a]pyrene	577	●	174	■
Benzo[e]pyrene	1293	●	139	■
PCB	7334	●	95	■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Reno Beach



Legend

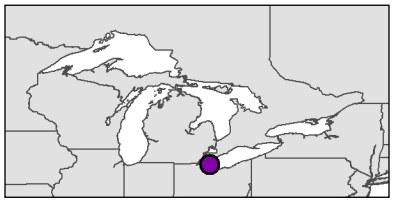
Low ● Medium ● High ● Outlier ★

Metals (μg/g dry wt.)	Tissue ●		Baseline** Sediment ■	
Arsenic	5.0	●	9.0	■
Cadmium	1.79	●	0.55	■
Copper	109	●	16	■
Lead	4.0	●	15	■
Methyl Mercury	0.02	●	0.001	■
Mercury	0.03	●	0.057	■
Zinc	92	●	53	■

Organics (ng/g dry wt.)*	Tissue ●		Baseline** Sediment ■	
Alpha-Chlordane	10.1	●	0.50	■
Chlorpyrifos	17	●	0.42	■
DDT	43	●	7.6	■
Heptachlor	0	●	0.16	■
Hexachlorobenzene	15	●	0.64	■
Mirex	0.0	●	0.000	■
Benzo[a]pyrene	156	●	35	■
Benzo[e]pyrene	335	●	47	■
PCB	749	●	51	■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Peach Orchard Pt.



Legend

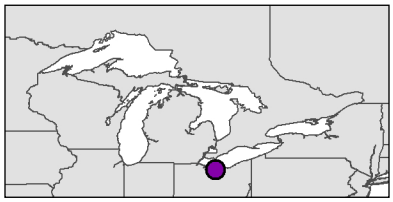
Low ● Medium ● High ● Outlier ★

Metals (µg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	5.1 ●	6.5 ■
Cadmium	2.61 ●	0.96 ■
Copper	12 ●	30 ■
Lead	2.7 ●	35 ■
Methyl Mercury	0.01 ●	0.001 ■
Mercury	0.04 ●	0.179 ■
Zinc	54 ●	133 ■

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	15.0 ●	0.73 ■
Chlorpyrifos	20 ●	0.24 ■
DDT	109 ●	8.9 ■
Heptachlor	0 ●	0.53 ■
Hexachlorobenzene	9 ●	0.84 ■
Mirex	1.9 ●	0.000 ■
Benzo[a]pyrene	130 ●	82 ■
Benzo[e]pyrene	391 ●	95 ■
PCB	2857 ●	90 ■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Old Woman Creek



Legend

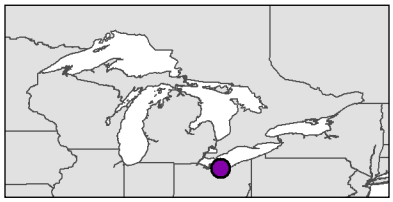
Low ● Medium ● High ● Outlier ★

Metals (μg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	4.2 ●	11.8 ■
Cadmium	2.11 ●	0.86 ■
Copper	12 ●	31 ■
Lead	1.2 ●	26 ■
Methyl Mercury	0.01 ●	0.001 ■
Mercury	0.03 ●	0.075 ■
Zinc	56 ●	91 ■

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	14.9 ●	0.79 ■
Chlorpyrifos	16 ●	0.82 ■
DDT	50 ●	23.9 ■
Heptachlor	0 ●	0.06 ■
Hexachlorobenzene	5 ●	0.34 ■
Mirex	0.0 ●	0.020 ■
Benzo[a]pyrene	40 ●	234 ■
Benzo[e]pyrene	77 ●	164 ■
PCB	373 ●	30 ■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Lorain



Legend

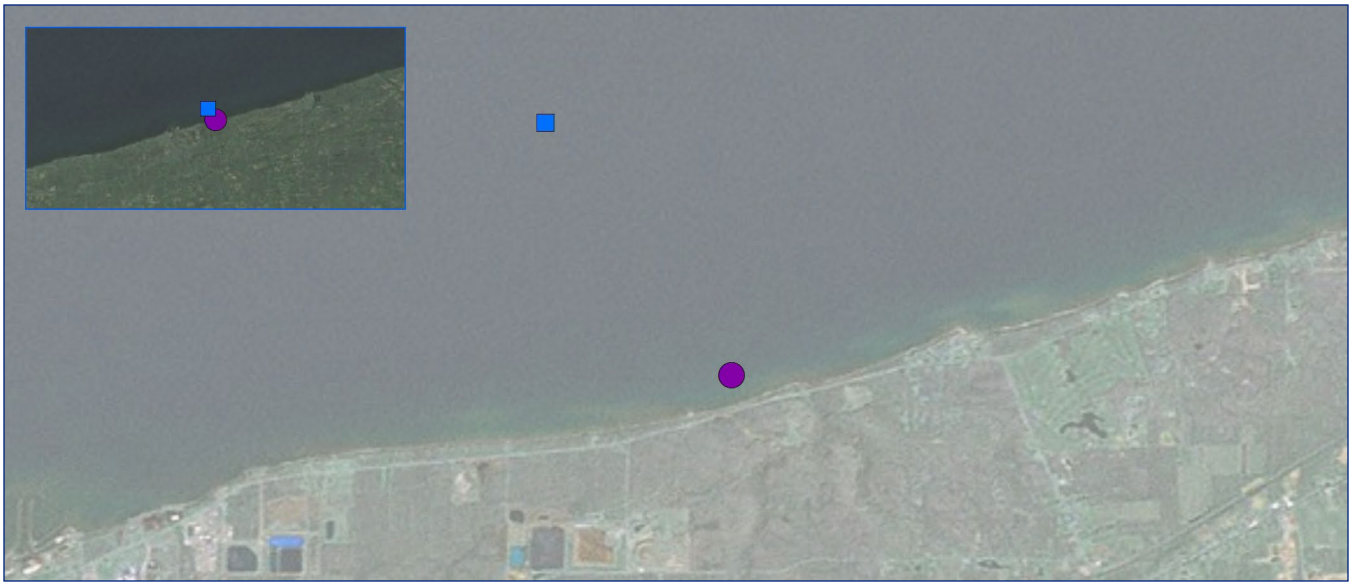
Low ● Medium ● High ● Outlier ★

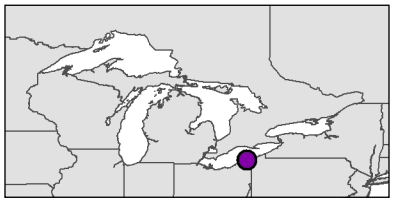
Metals (µg/g dry wt.)	Baseline** Tissue ●	Sediment ■
Arsenic	3.9	●
Cadmium	2.66	●
Copper	10	●
Lead	1.6	●
Methyl Mercury	0.02	●
Mercury	0.03	●
Zinc	47	●

Organics (ng/g dry wt.)*	Baseline** Tissue ●	Sediment ■
Alpha-Chlordane	23.2	●
Chlorpyrifos	11	●
DDT	58	●
Heptachlor	0	●
Hexachlorobenzene	6	●
Mirex	0.9	●
Benzo[a]pyrene	96	●
Benzo[e]pyrene	320	●
PCB	604	●

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Ashtabula





Legend

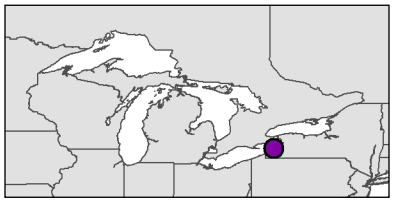
Low ● Medium ● High ● Outlier ★

Metals (μg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	6.1 ●	10.6 ■
Cadmium	3.52 ●	0.54 ■
Copper	10 ●	22 ■
Lead	1.4 ●	23 ■
Methyl Mercury	0.01 ●	0.000 ■
Mercury	0.03 ●	0.058 ■
Zinc	58 ●	106 ■

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	15.1 ●	0.72 ■
Chlorpyrifos	4 ●	0.05 ■
DDT	49 ●	9.0 ■
Heptachlor	0 ●	0.18 ■
Hexachlorobenzene	21 ●	1.46 ■
Mirex	2.6 ●	0.000 ■
Benzo[a]pyrene	63 ●	128 ■
Benzo[e]pyrene	135 ●	118 ■
PCB	1120 ●	109 ■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Dunkirk



Legend

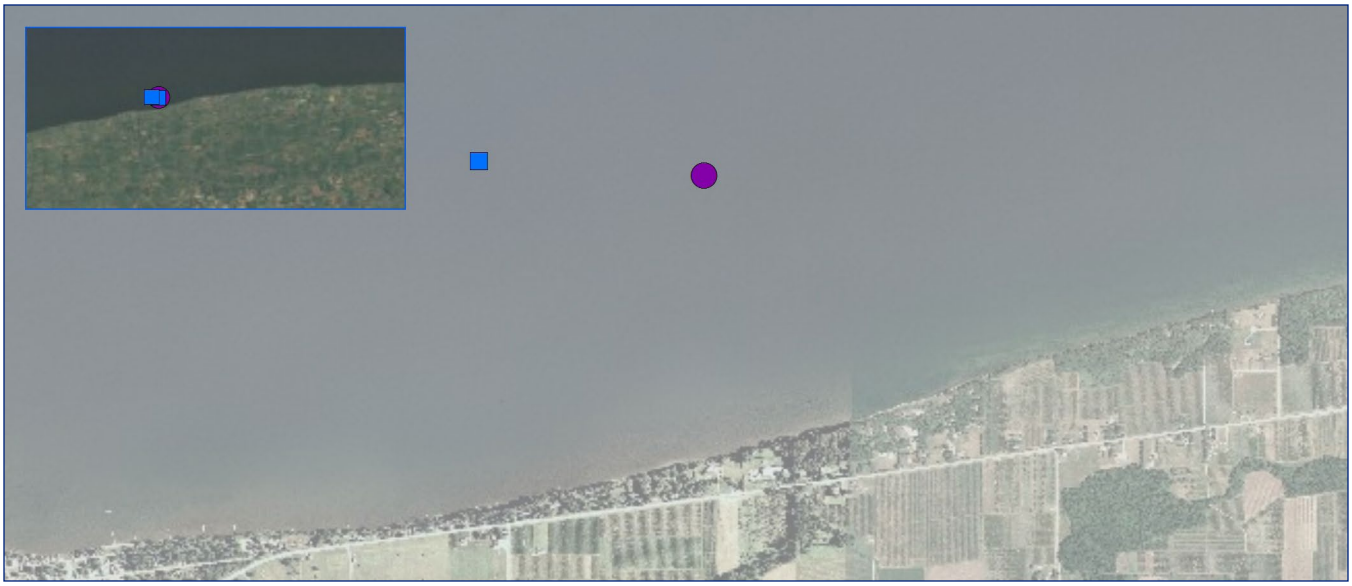
Low ● Medium ● High ● Outlier ★

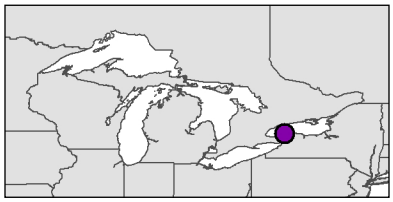
Metals (µg/g dry wt.)	Baseline** Tissue ●	Sediment ■
Arsenic	6.6 ●	12.3 ■
Cadmium	3.99 ●	0.36 ■
Copper	11 ●	15 ■
Lead	2.0 ●	22 ■
Methyl Mercury	0.01 ●	0.000 ■
Mercury	0.03 ●	0.033 ■
Zinc	56 ●	109 ■

Organics (ng/g dry wt.)*	Baseline** Tissue ●	Sediment ■
Alpha-Chlordane	7.5 ●	0.53 ■
Chlorpyrifos	4 ●	0.07 ■
DDT	53 ●	8.2 ■
Heptachlor	0 ●	0.00 ■
Hexachlorobenzene	10 ●	1.26 ■
Mirex	0.0 ●	0.000 ■
Benzo[a]pyrene	139 ●	57 ■
Benzo[e]pyrene	219 ●	65 ■
PCB	599 ●	31 ■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Olcott





Legend

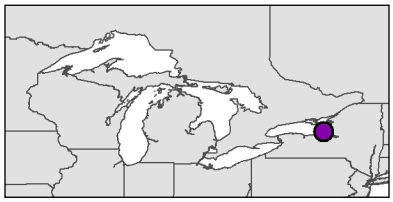
Low ● Medium ● High ● Outlier ★

Metals (µg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	6.2 ●	10.6 ■
Cadmium	3.59 ●	0.54 ■
Copper	9 ●	28 ■
Lead	0.9 ●	25 ■
Methyl Mercury	0.02 ●	0.002 ■
Mercury	0.04 ●	0.176 ■
Zinc	57 ●	122 ■

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	9.9 ●	0.81 ■
Chlorpyrifos	8 ●	0.10 ■
DDT	117 ●	7.7 ■
Heptachlor	0 ●	0.00 ■
Hexachlorobenzene	17 ●	6.1 ■
Mirex	47.4 ●	0.400 ■
Benzo[a]pyrene	77 ●	149 ■
Benzo[e]pyrene	207 ●	129 ■
PCB	866 ●	99 ■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

Oswego



Legend

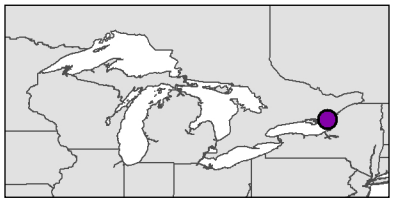
Low ● Medium ● High ● Outlier ★

Metals (µg/g dry wt.)	Baseline** Tissue ●	Sediment ■
Arsenic	3.5	●
Cadmium	1.08	●
Copper	12	●
Lead	0.5	●
Methyl Mercury	0.01	●
Mercury	0.03	●
Zinc	34	●

Organics (ng/g dry wt.)*	Baseline** Tissue ●	Sediment ■
Alpha-Chlordane	9.7	●
Chlorpyrifos	5	●
DDT	62	●
Heptachlor	0	●
Hexachlorobenzene	9	●
Mirex	18.7	●
Benzo[a]pyrene	100	●
Benzo[e]pyrene	61	●
PCB	281	●

*Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).

Cape Vincent



Legend

Low ● Medium ● High ● Outlier ★

Metals (μg/g dry wt.)	Tissue ●	Baseline** Sediment ■
Arsenic	7.5 ●	4.1 ■
Cadmium	1.90 ●	1.00 ■
Copper	10 ●	31 ■
Lead	0.73 ●	22 ■
Methyl Mercury	0.01 ●	0.002 ■
Mercury	0.04 ●	0.105 ■
Zinc	54 ●	95 ■

Organics (ng/g dry wt.)*	Tissue ●	Baseline** Sediment ■
Alpha-Chlordane	8.5 ●	0.58 ■
Chlorpyrifos	14 ●	0.27 ■
DDT	29 ●	3.0 ■
Heptachlor	0 ●	0.00 ■
Hexachlorobenzene	6 ●	1.01 ■
Mirex	37.4 ●	1.060 ■
Benzo[a]pyrene	34 ●	51 ■
Benzo[e]pyrene	288 ●	45 ■
PCB	293 ●	18 ■

***Tissue data is lipid normalized. **Core basin-wide measurements (AOC and reference sites).**

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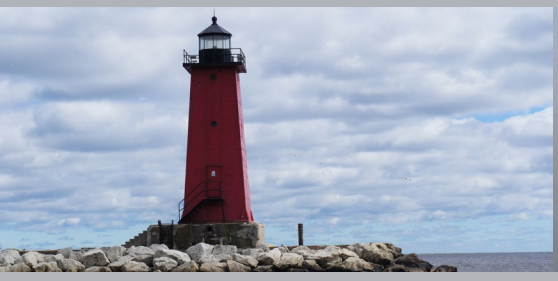

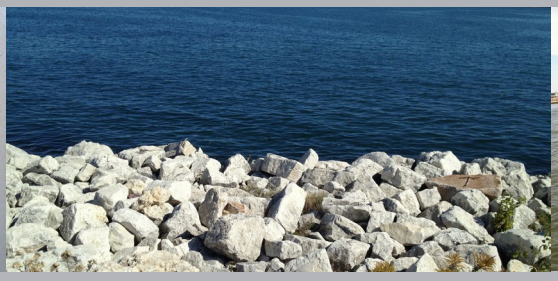
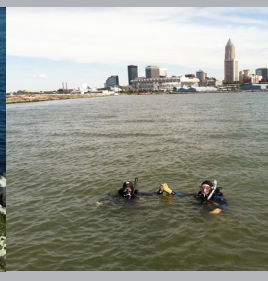

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