Northeast Ohio Regional Sewer District

2018 Cuyahoga River and Nearshore Lake Erie Fish Tissue Study

Northeast Ohio Regional Sewer District
Water Quality and Industrial Surveillance
Environmental Assessment Division

Ohio Environmental Protection Agency

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Executive Summary

In 2018, a study was conducted to determine current concentrations of PCBs, pesticides, mercury, and selenium in fish tissue samples from the Cuyahoga River and nearshore Lake Erie. Fish were collected from sites on the Cuyahoga River (one reference, four AOC), Lake Erie (two reference, three AOC), and the Chagrin River (one reference) using electrofishing methods. Composite fillet samples were collected to represent potential health impacts to humans who consume contaminated fish. Whole-body samples were collected to represent potential impacts to piscivorous wildlife and to apply certain standards that are applicable to whole-body samples. The results were compared to previous studies conducted in 1989-1992, 2005, and 2008 to evaluate temporal and spatial changes in fish contaminant levels. The results were also compared to applicable federal and state standards to evaluate potential ecological or human health risks.

Generally, total and lipid-normalized PCB fish tissue concentrations were greater in AOC locations than the selected reference sites, with most comparisons demonstrating a significant difference ($p<0.05$). Fish fillet PCB concentrations in 2018 were generally less than those from the 2008 study, with the river reference locations remaining low. Fish collected in 2018 at the AOC locations displayed a decline in PCB concentrations from the 2005 study, with some locations having the lowest PCB concentrations measured during this study. Risk assessments utilizing both the noncancer hazard index and the cancer potency factor indicated the potential for adverse health effects from eating fish contaminated with PCBs from the Lake Erie AOC, Lake Erie reference, and Cuyahoga River AOC locations for cancer only. The river reference locations did not demonstrate the potential for adverse health effects for the first time during this study. With a sufficient data set, fish concentrations would result in consumption advisories more stringent than Ohio statewide advice, but advisories were not more stringent than those currently in place for the lower Cuyahoga River and Lake Erie. Organochlorine pesticides were also detected in many of the composite fillet samples. However, when assessed using available reference doses and cancer potency factors for chlordane and DDT and its metabolites, lifetime exposure at the measured fish tissue concentrations falls within accepted risk guidelines.

The results obtained from the study indicate that mercury contamination may be widespread, and not just associated with fish inside the AOC. Composite fillet and whole-body fish tissue concentrations of mercury in samples collected from reference sites were generally equal to or greater than those found at AOC locations. Concentrations of mercury in fish tissue were higher upstream of the Cuyahoga AOC than those found in similar species collected in the shipping channel (RM 0.92), suggesting the numerous municipal wastewater dischargers are not having an adverse impact on mercury bioaccumulation in fish. Selenium concentrations at four Cuyahoga River locations displayed slightly higher concentrations in the lower river than the upper river. However, all concentrations were well below recommended consumption advisories.

All Cuyahoga River HUC-12 watersheds and Lake Erie locations met applicable DDT, mercury, and chlordane human health WQS where collected, but the Chagrin River location is the only location which met all applicable human health fish tissue WQS. All Cuyahoga River locations, as well as all Lake Erie locations, had fish tissue concentrations that exceeded the PCB human health WQS criteria. Fish DELTs are now meeting BUI #4 requirements during most sampling events as frequencies of DELTs in fish have drastically improved over the last 35 years.

However, multiple locations sampled in 2018 and 2019 exceeded the BUI #4 delisting criteria.

Introduction

The lower 46.5 miles of the Cuyahoga River and the Lake Erie shoreline west of Cleveland to Euclid Creek have been designated as one of 42 Great Lakes Areas of Concern (AOC) by the International Joint Commission (IJC). AOCs are defined by the U.S.-Canada Great Lakes Water Quality Agreement (Annex 2 of the 1987 Protocol) as "*geographic areas that fail to meet the general or specific objectives of the agreement where such failure has caused or is likely to cause impairment of beneficial use...*" The beneficial use impairment (BUI) number 1 for the Cuyahoga River AOC lists restrictions on fish consumption. Ohio EPA released an updated delisting guidance and restoration targets for Ohio AOCs in 2017 (Ohio EPA, 2017a). Following the release of the delisting guidance, BUI number 1 was delisted in January of 2019 as *the removal criteria of there not being more stringent consumption advisories in the Cuyahoga River AOC sites than one meal per month (upstream of lake affected waters) or current Lake Erie advisories (for lake affected waters) were met* (Cuyahoga River Area of Concern). The general Ohio sport fish advice is listed in Table 1, with current Ohio Sport Fish Consumption Advisory for the Cuyahoga River and Lake Erie listed in Table 2.

The Cuyahoga River receives effluent from industrial and municipal discharges in addition to overflows from storm and combined sewers. Two of the largest municipal wastewater treatment plant (WWTP) dischargers are the Northeast Ohio Regional Sewer District's (NEORSD) Southerly Wastewater Treatment Center (WWTC) at 175 million gallons per day (MGD) design flow at river mile (RM) 10.57 and the City of Akron Water Reclamation Facility (WRF) at 90 MGD flow at RM 37.45. The river also receives pollutants from nonpoint sources such as agricultural, suburban and urban runoff, sediments from erosion, and atmospheric deposition. Fish and other organisms that are living in the river and nearshore Lake Erie can be exposed to contaminants found in discharges, overflows, runoff, and sediments, which may accumulate in their bodies. This can potentially cause health-related problems for humans and wildlife that eat the fish and are thus exposed to these contaminants.

Table 1. General Ohio Sport Fish Consumption Advice (Ohio Department of Health et al., 2019)

Meal Frequency	Fish Species
Two meals/week*	Yellow perch Sunfish (e.g., bluegill, green, longear, redear)
One meal/week	All fish not specified in this table
One meal/month	Flathead catfish 23" and over Northern pike 23" and over Steelhead trout from Lake Erie and its tributaries

* Consumption of these species should be limited to one meal/week from: Ashtabula River, Cuyahoga River, Mahoning River, Nesmith Lake, Ohio Canal, Ohio River and West Branch Reservoir; and as otherwise indicated in the Limit Your Meals from These Waters section of this advisory. Always refer to the full Advisory Table to determine if there is a more or less restrictive advisory on fish from a certain body of water.

Table 2. 2019 Ohio Sport Fish Consumption Advisory for the Cuyahoga River. (Ohio Department of Health et al., 2019)

Body of Water	Area Under Advisory	Species	Meal Frequency	Contaminant
Cuyahoga River	State Route 87, Russell Park, to Ohio Edison Dam Pool (Geauga, Portage, Summit Counties)	Rock Bass	Two/week	Mercury
		Black Crappie, Smallmouth Bass	One/month	Mercury
	Ohio Edison Dam Pool to mouth (Lake Erie) (Cuyahoga, Summit Counties)	Rock Bass	Two/week	Mercury
		Brown Bullhead, Channel Catfish, Common Carp, Smallmouth Buffalo	One/month	PCBs
		White Sucker 16" and over, Smallmouth Bass 15" and over	One/month	Mercury
		Freshwater Drum	One/month	Mercury, PCBs
Lake Erie	All waters (Ashtabula, Cuyahoga, Erie, Lake, Lorain, Lucas, Ottawa, Sandusky Counties)	Common Carp 27" and over	One/two months	PCBs
		Smallmouth Bass	One/month	PCBs, Mercury
		Channel Catfish, Common Carp 27" and under, Freshwater Drum, Lake Trout, Steelhead Trout, White Bass, Whitefish 21" and over, White Perch	One/month	PCBs
		Brown Bullhead	One/month	Mercury
		Bluegill Sunfish	Unrestricted	--

In support of Cuyahoga River Remedial Action Plan, three previous studies were completed by the NEORSD, the City of Akron, the Cuyahoga County Board of Health, the Cuyahoga Valley National Park, the Ohio Department of Health, the Ohio Department of Natural Resources (ODNR), the Ohio Environmental Protection Agency (EPA), and the United States Fish and Wildlife Service. In these studies, as in the current study, fish tissue samples from within the Cuyahoga River AOC and at reference locations were collected to determine the types and concentrations of compounds that had accumulated in the edible portions of those fish. The previous collections were made from 1989-1992, 2005, and in 2008 at six Cuyahoga River sites from RM 63.3 to RM 10.0 and at one Chagrin River site at RM 5.54. Collections were also made at five Lake Erie nearshore sites between Lakewood and Eastlake. In 2005, a site was added in the Cuyahoga River shipping channel near RM 1.2[a].

During the summer and fall of 2018, fish were collected from eleven sites on the Cuyahoga River, the Chagrin River, and nearshore Lake Erie. These sites were selected because they included heavily fished areas, areas of known pollution sources, and reference locations. For the most part, sample locations duplicated the sites used in the previous studies. These locations are detailed in Table 3 and shown in Figure 1. The Cuyahoga River sites from RM 45.10 to the mouth (RM 0.00) and the Lake Erie sites within the Cleveland Harbor and off Wildwood Park are located within the AOC. The Cuyahoga River site at RM 64.3, the Chagrin River at RM 5.54, and the

[a] Considered equivalent to RM 0.92 in the 2018 study.

Lake Erie sites off Lakewood and Eastlake are located outside the AOC and were used as reference locations.

Table 3. Sampling Locations

Location	Lat	Long	River Mile	Description	Quadrangle	Purpose
*Cuyahoga River at Shalersville (FTCS-01)	41.2449	-81.2862	64.30	Upstream from State Route 303	Kent	Reference
*Cuyahoga River Upstream of Akron (FTCS-02)	41.1195	-81.4912	45.10	Ohio Edison Dam Pool	Akron East	AOC
*Cuyahoga River Upstream of Akron WRF (FTCS-03)	41.1250	-81.5310	41.70	Upstream of Portage Path and Downstream of the Little Cuyahoga River	Peninsula	AOC
*Cuyahoga River at Southwest Interceptor (FTCS-06)	41.4291	-81.6694	9.78	Downstream of Southerly WWTC	Cleveland South	Impact of SWWTC/ AOC
*Cuyahoga River Navigation Channel (FTCS-07)	41.4930	-81.7040	0.92	Irishtown Bend	Cleveland South	AOC
Lake Erie West Harbor (FTCS-08)	41.4995	-81.7191	NA	Between Edgewater Marina and Cuyahoga River	Cleveland North/ Cleveland South	AOC
Lake Erie East Harbor (FTCS-09)	41.5410	-81.6393	NA	Between East 72nd Marina and East 55th Street	Cleveland North	AOC
Lake Erie off Eastlake (FTCS-10)	41.6758	-81.4403	NA	West of Chagrin River	Eastlake	Reference
Lake Erie off Wildwood (FTCS-11)	41.5860	-81.5675	NA	Between Wildwood Park Marina and Villa Angela Beach	East Cleveland	AOC
Lake Erie off Lakewood (FTCS-12)	41.4981	-81.8203	NA	Between Rocky River and Lakewood Park	Lakewood	Reference
Chagrin River at Daniels Park (FTCS-13)	41.6228	-81.4015	5.54	Upstream of the confluence with the East Branch	Eastlake	Reference

*Ohio EPA collected fish samples; NEORSD collected fish for all other sites

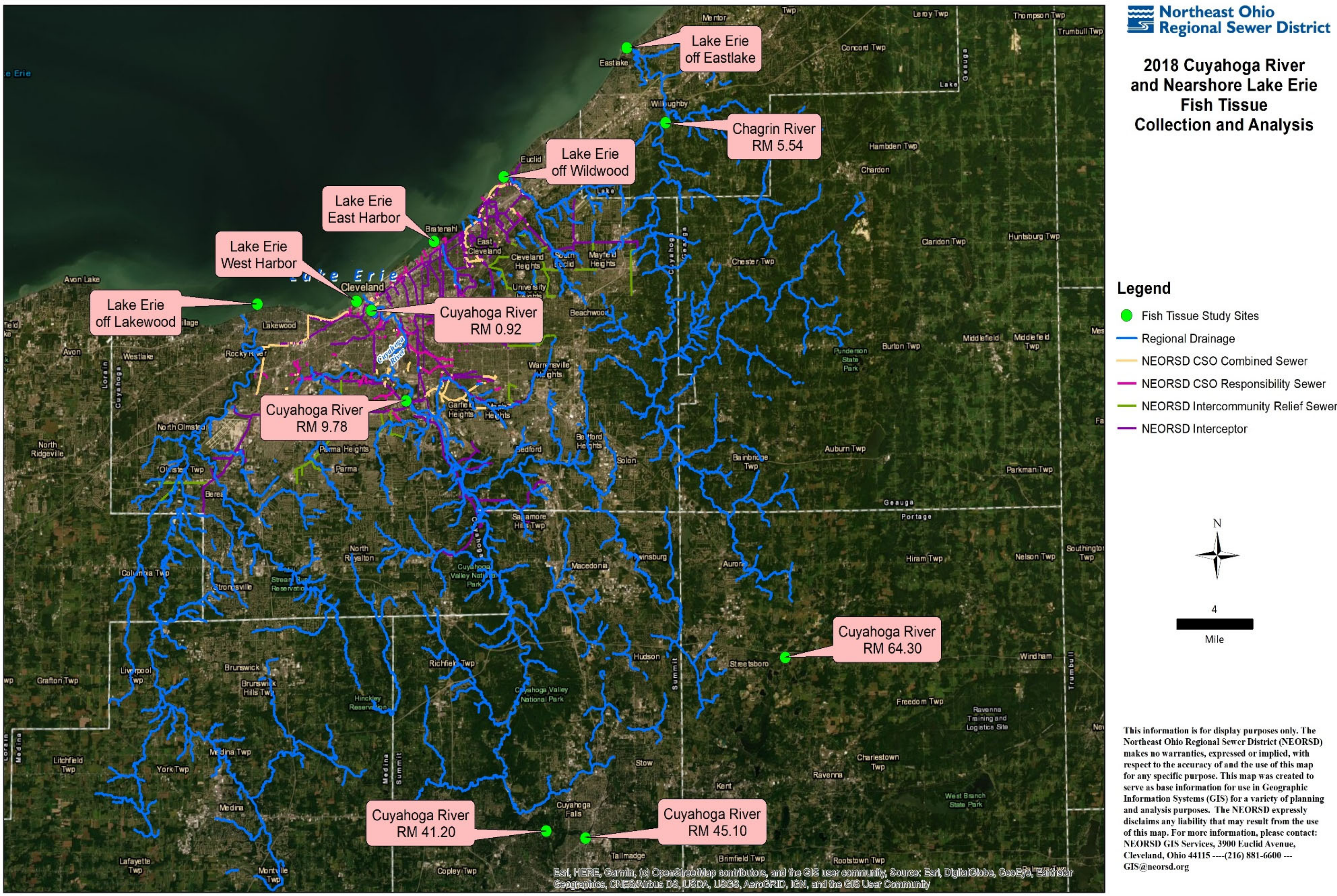

Figure 1. Cuyahoga River & Nearshore Lake Erie AOC Sampling Location Map

Two types of samples were collected during this study: composite fillet and whole-body. Fillet samples were composited of two to five of the same species and size class. Fish were considered to be of the same size class if the minimum and the maximum lengths of individual fish did not vary by more than 10%. Two bottom-feeding species and two sport species were collected at each site. Species making up the bottom feeding and sport fish categories are listed in Table 4 below. Sport fish were defined as those fish that are commonly sought by anglers. The bottom-dwellers represented worst-case risk through human consumption for certain pollutants since they are generally in closer proximity to contaminants, and the sport fish represent most likely human consumption. The whole-body samples generally consisted of 12 individuals of a sport species belonging to the same size class. These samples were collected at all sites with the exception of the Cuyahoga River at RM 41.20 (FTCS-03), where only fillet samples were collected.

Table 4: Fish Selection Order

River Sites		Lake Sites	
Bottom Feeders	Sport Fish	Bottom Feeders	Sport Fish
1. Common carp	1. Smallmouth bass	1. Common carp	1. Walleye, Sauger, Northern pike
2. White sucker	2. Largemouth bass	2. Channel catfish	2. Yellow perch
3. Brown bullhead catfish	3. Members of Sunfish family	3. Brown bullhead	3. Largemouth bass
4. Yellow Bullhead	4. Rock bass	4. Yellow bullhead	4. White bass
5. Channel catfish	5. White crappie	5. Golden redhorse	5. White perch
6. Golden redhorse	6. Black crappie		6. Freshwater drum
7. Northern hog sucker	7. Walleye		7. Smallmouth bass

All fish collections were made from June 20, 2018 through October 25, 2018, except fish from FTCS-03, which were collected the following year, on October 15, 2019. Collections were made by NEORSD and Ohio EPA personnel. The primary method of collection was with a boat-mounted electrofishing unit (Figure 2). The wading electrofishing method (Figure 3) was used at the Chagrin River RM 5.54 (FTCS-13) and Cuyahoga River RM 64.30 (FTCS-01) locations. Both methods followed standardized Ohio EPA methods as outlined in Biological Criteria for the

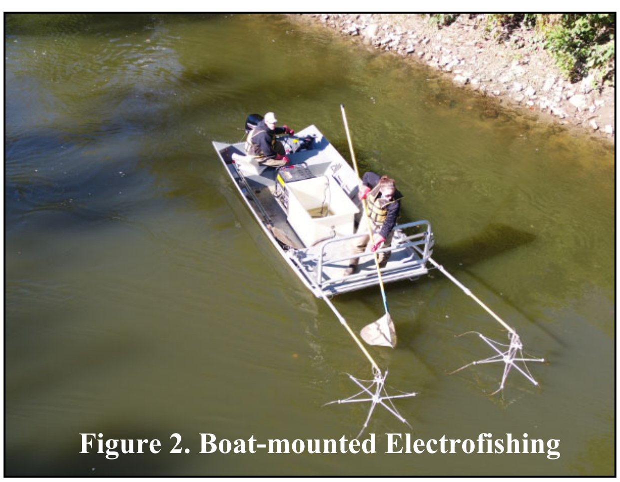

Figure 2. Boat-mounted Electrofishing

Figure 3. Wading Electrofishing

Protection of Aquatic Life Vol. III (Ohio EPA, 1987). All fish shocked at a site were collected and placed in a live-well for processing. Precautions were taken to keep all fish alive and release unharmed fish not used as a sample. All fish were kept in a live-well until they were selected as samples to prevent them from being shocked more than once. Care was taken to prevent the fish from coming into contact with oil, plastic, sediment, etc. that could contaminate the tissue samples. Selected fish were selected by species, weighed to the nearest gram, and a measurement to the nearest millimeter of the total length was recorded.

A sample information form, including the type of collection method, names of samplers, notes concerning any unusual event or discharges, along with individual records of each fish retained for analysis with information on species, weight, length, and notations of physical deformities, was completed for each location analyzed by the NEORSD.

The selected fish were sacrificed, then wrapped in aluminum foil and put into a plastic bag. Whole-body samples were put into a cooler filled with dry ice. The coolers were washed with hot water and 10% nitric acid and rinsed with de-ionized water prior to use. Samples to be filleted were placed into a cooler filled with wet ice. All samples were then transported to the NEORSD Environmental & Maintenance Services Center (EMSC) in Cuyahoga Heights or taken by Ohio EPA personnel for processing.

In order to determine the age of the fish, scales or otoliths (for ictalurids) were collected from each fish. Scales were collected from the left side of the fish between the lateral line and the dorsal insertion. The scales and/or otoliths were placed in plastic bags and labeled with the date, sample code, and species information. Scales were aged at NEORSD, while otoliths were sent to the Ohio Department of Natural Resources (ODNR) Division of Wildlife office in Akron for proper aging. Only fish collected and processed by NEORSD staff were assessed for fish age.

Fish used in the composite samples were filleted at the NEORSD EMSC in order to reduce possible contamination in the field. Fish were placed upon an aluminum foil-lined cutting board with the dull side towards the fish. The aluminum foil was rinsed with acetone before filleting and changed between each species, size class, and for each site. Fillets for each species were combined into one composite sample and submitted for analysis. Fish collected as whole-body samples were kept and analyzed as individuals rather than a composite sample.

Composite and whole-body samples were cut into chunks using a meat cleaver and then blended in a commercial-grade stainless steel blender or a Ninja professional countertop blender. Dry ice was added to the blender to ensure that the entire sample was frozen, and no moisture was visible. The resulting powdered tissue was placed in a 125mL plastic tube and labeled with date, sample code, and species for mercury analysis. Additionally, for the composite samples, a 16-oz glass jar was filled and labeled with date, sample code, and species for PCB, organochlorine pesticide, and percent lipids analysis by TestAmerica. The remaining sample was discarded. The blender and all tools used during blending were washed with soap and water and rinsed with acetone between each sample. All processed samples were placed in a freezer at -37°C for storage prior to analysis.

NEORSD Analytical Services analyzed fillet and whole-body samples for mercury using EPA Method 245.1 and whole-body samples for selenium using EPA Method 220.8. TestAmerica

(Pittsburgh, PA) was contracted to analyze fish fillet samples for percent lipids, PCBs using EPA method 8082A, and organochlorine pesticides using EPA method 8081BLL. Duplicate samples were collected to comprise 10% of the total number of field samples and followed the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (2018) QA/QC protocols. Copies of field sheets for each site are listed in Appendix A, quality assurance data and calculations are listed in Appendix B, and statistical analysis calculations are listed in Appendix C.

Results and Discussion

Overall results for each of the parameters analyzed are discussed below. Individual results for each sample are available upon request. The number of samples for some of the species analyzed were very limited. The results in these instances are presented here to provide a general overview of suspected conditions at a site, and it is possible that a more robust data set may result in a different set of conclusions.

When numbers of samples were sufficient, a statistical analysis was conducted in the R Studio environment to determine significant differences between groups. Generally, a Kruskal-Wallis rank sum test was conducted for groups of data. When the results from the Kruskal-Wallis test indicate at least one of the means was significantly different ($p<0.05$), individual pairs of means were then compared using the Wilcoxon Rank Sum Test. Tables showing the results from these analyses are presented in Appendix C.

PCBs

A total of 53 composite fillet samples were analyzed for PCB concentrations by the Ohio EPA and TestAmerica. Eighty-five percent of the samples displayed PCB concentrations above the laboratory detection limit. Detection limits varied depending on the laboratory. The Ohio EPA detection limit for PCBs was higher (~20 ug/L) than the one from TestAmerica (~1.0 ug/L), and detection limits also varied by year assessed (Table 5). Commercial mixtures of PCBs, known as Aroclors, detected in the samples included Aroclor 1242, Aroclor 1254, and Aroclor 1260, all of which were found in the 2008 study.

<table>
<tr><th colspan="5">Table 5. PCBs Detection Limit (ug/L) by year assessed</th></tr>
<tr><th>1989-1992</th><th>2005</th><th>2008</th><th colspan="2">2018</th></tr>
<tr><td rowspan="2">1.0</td><td rowspan="2">33</td><td rowspan="2">50.0</td><td>Ohio EPA</td><td>TestAmerica</td></tr>
<tr><td>20.0</td><td>1.0</td></tr>
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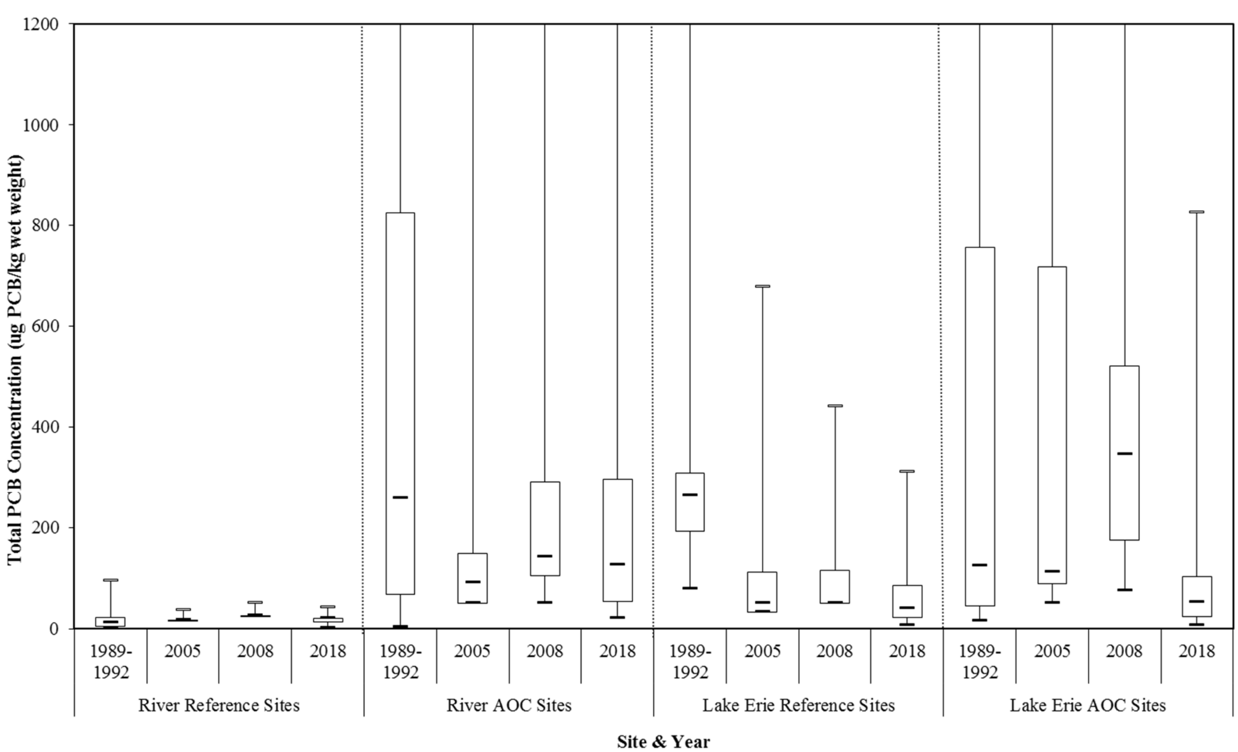
For all comparisons made using the PCB results, concentrations below the detection limit were assumed to be one-half the detection limit if that particular Aroclor was detected in another sample from that site or from a site of a similar type. All sites were assigned to one of the following groups: River Reference, River AOC, Lake Reference, and Lake AOC. Additionally, for the purpose of determining which Aroclors were present, the results from October 15, 2019, are included in the 2018 dataset, the results from the 2005 and 2008 studies are considered independent of each other, and the 1989-1992 study results were considered to be separate from the later studies.

Total PCBs

In 2018, the highest total PCB concentrations occurred in the Cuyahoga River portion of the AOC, with the lowest concentrations found in the river reference sites (Figure 4). All sites had at least one fish with total PCB concentrations greater than the reporting limit. A statistically significant difference was found between the results of the Cuyahoga River AOC sites and the river reference sites (Appendix C, Table 9). Although significantly higher than the river reference sites, the Cuyahoga River AOC median total PCB concentrations was slightly lower than those observed in the 2008 and the 1989-1992 studies but were slightly higher than those in 2005. The higher concentrations of PCBs in fish of the Cuyahoga River AOC may be due to the more urban landscape in the lower river reach and the persistence of these compounds in the environment.

No significant difference was calculated between the Lake Erie AOC sites and the Lake Erie reference sites (Appendix C, Table 9), indicating declining concentrations of total PCBs across the greater Cleveland Lakefront between 2008-2018. The 2018 Lake Erie AOC sites displayed significantly lower total PCB concentrations than the previous three studies (Appendix C, Table 5). The Lake Erie reference sites in 2018 also displayed significantly lower total PCB concentrations than the 1989-1992 and 2008 studies (Appendix C, Table 7). All groups have seen a decrease in total PCB concentrations since this study first started in 1989. Although the production-based discharge of PCBs was banned in 1977 and their manufacturing, processing, and distribution in commerce were banned in 1979, their tendency to remain in sediments and resistance to degradation allows them to still accumulate in fish tissue today.

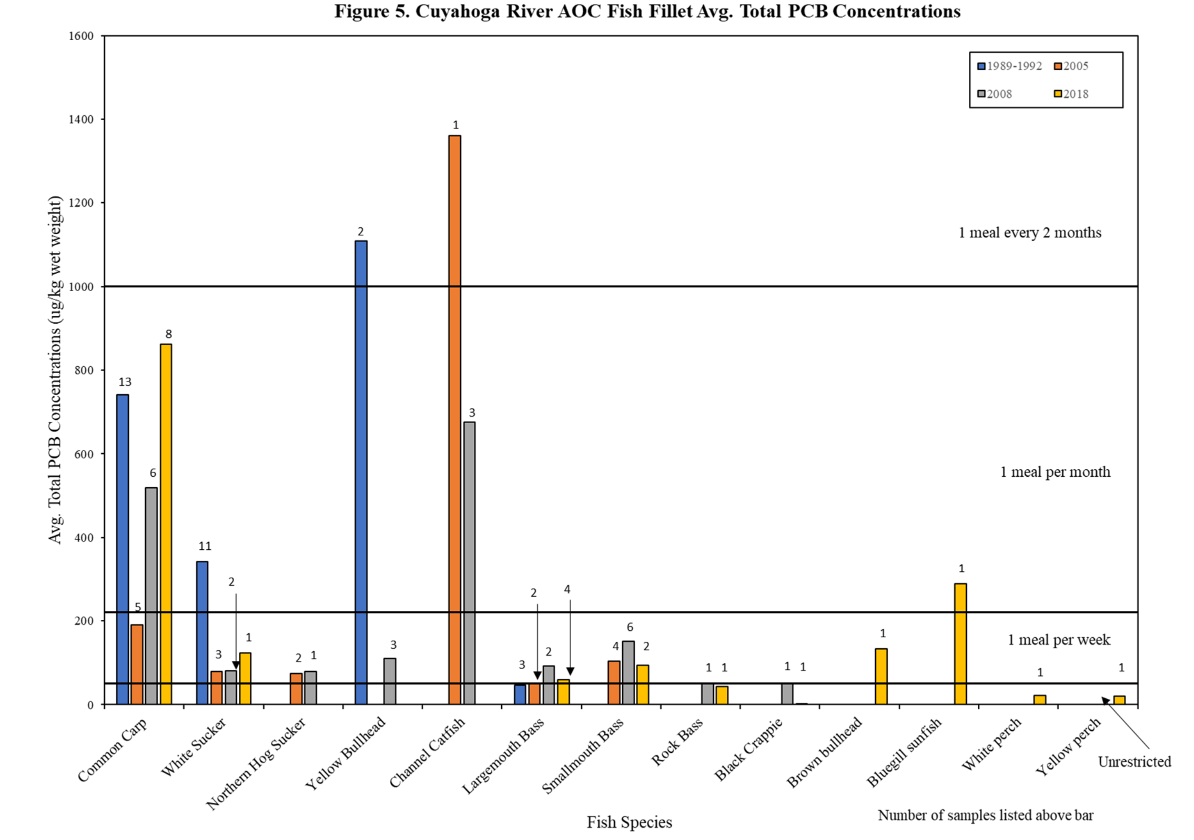
Figure 4. Fish Fillet Total PCB Concentrations
(Max., 75th Pctile., Median, 25th Pctile., Min.)



In September of 1993, the Great Lakes Sport Fish Advisory Task Force released the *Protocol for a Uniform Great Lakes Sport Fish Consumption Advisory* (Anderson et al., 1993). This document proposed categories based upon a health protection value of 5.0E-05 mg/kg/day PCB residue in sport fish. The health protection value takes into account available toxicological and epidemiological data, with an emphasis on adverse reproductive and neuro-developmental effects. A modified version of this protocol was used as the basis for the State of Ohio Fish Consumption Advisory Program (State of Ohio, 2010).

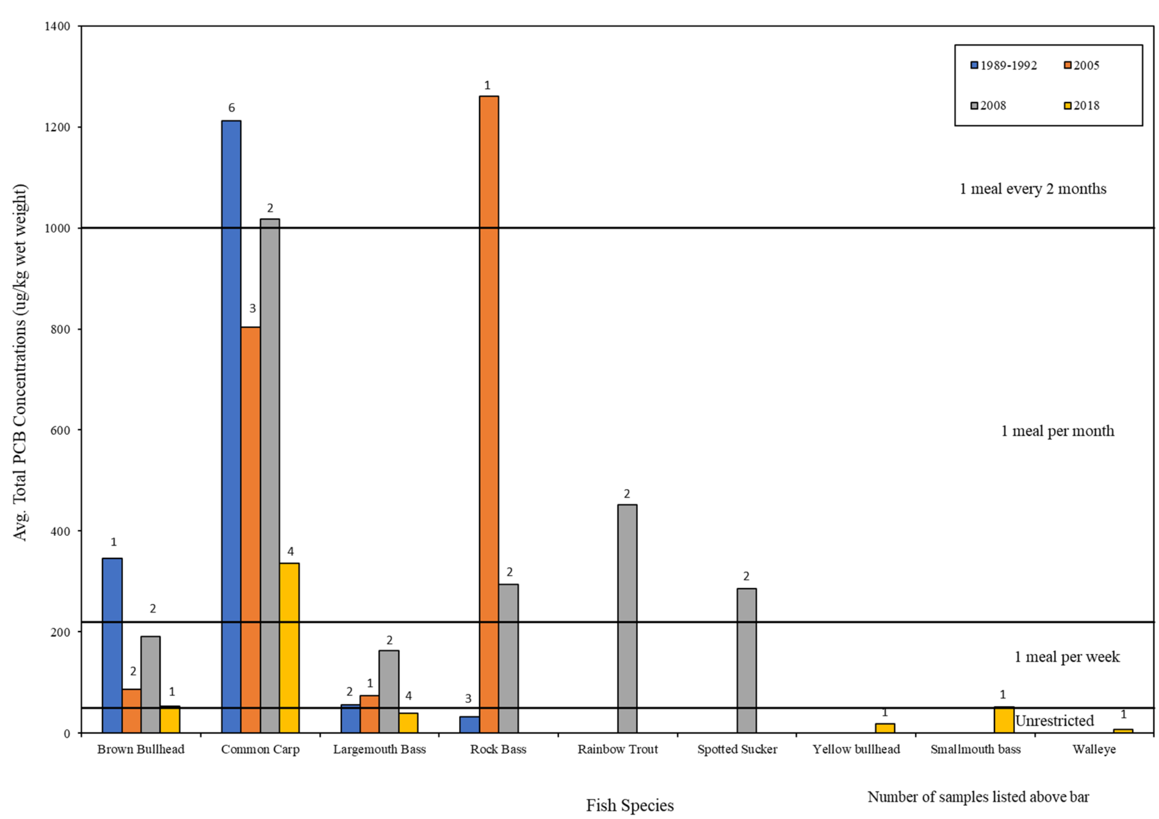
Using the categories developed by the Great Lakes Sport Fish Advisory Task Force and used by the State of Ohio in its Fish Consumption Advisory Program, four species collected in the Cuyahoga River AOC had mean total PCB concentrations *unrestricted* for fish consumption (Figure 5). Rock bass and black crappie total PCB concentrations were slightly lower than those collected in the 2008 study, both of which would be unrestricted to consumption. White sucker, largemouth bass, smallmouth bass, and brown bullhead had total PCB concentrations that would fall into the *one meal per week* range. The 2018 brown bullhead concentration, although representing one fish, is less stringent than the advisory listed in Table 2. Common carp displayed the highest total PCB concentrations and was assigned a *one meal per month* narrative, which represents the appropriate fish consumption advisory for common carp (Table 2). No species had PCB concentrations that would warrant a *one meal every two months* designation in 2018 in the Cuyahoga River AOC as historical data had shown. White perch and yellow perch were not analyzed in the previous studies so no temporal trends can be determined.

Figure 5. Cuyahoga River AOC Fish Fillet Avg. Total PCB Concentrations



For the Lake Erie portion of the AOC, three species (largemouth bass, yellow bullhead, and walleye) had total PCB concentrations that would be *unrestricted* for consumption (Figure 6). The composite of four largemouth bass yielded the lowest measured total PCB concentrations over the course of this study and would have an *unrestricted* fish consumption advisory for the first time. Brown bullhead and smallmouth bass all displayed total PCB concentrations that would fall into the *one meal per week* advisory. The 2018 smallmouth bass concentration, although representing one fish, is less stringent than the advisory listed in Table 2. The 2018 brown bullhead total PCB concentrations were the lowest found for that species during any of the studies and would fall under the *one meal per week* advisory. As found in the Cuyahoga River AOC reach, common carp displayed the highest total PCB concentrations in the Lake Erie AOC, with results falling into the *one meal per month* narrative. However, this narrative is consistent with the state advisory listed in Table 2. Yellow bullhead and walleye are new to the study so no temporal trends can be determined from them. No species had PCB concentrations that would warrant a *one meal every two months* designation in 2018. Once again, these comparisons should not be interpreted as an update to the State of Ohio advisory, since a more extensive data set may be needed before advisory changes can be made.

Figure 6. Lake Erie AOC Fish Fillet Avg. Total PCB Concentrations



Figures 7 and 8 below demonstrate the differences between bottom feeding species and sport fish species collected within both the Cuyahoga River and Lake Erie AOC areas. Bottom feeding species in both the Cuyahoga and Lake Erie AOC locations contained significantly higher total PCB concentrations between groups (Appendix C, Tables 10 and 11). Bottom dwelling species tend to accumulate higher contaminant concentrations through direct contact with contaminated sediments (non-bioaccumulation) or feeding on benthic organisms that inhabit the contaminated sediments (USEPA, 2009).

With sport fishing species more commonly sought after by fishermen, the total PCB concentrations would reflect lower consumption advisory restrictions if based solely off sportfish. Figures 5 and 6 display these differences as common carp, a bottom feeding species, have more restrictive consumption advisories than those from the sport fishing group. Once large enough to evade predation, bioaccumulation between trophic levels becomes less common, which may explain the differences in PCB contamination.

Figure 7. River AOC Fillet Total PCB Conc. by Fish Type

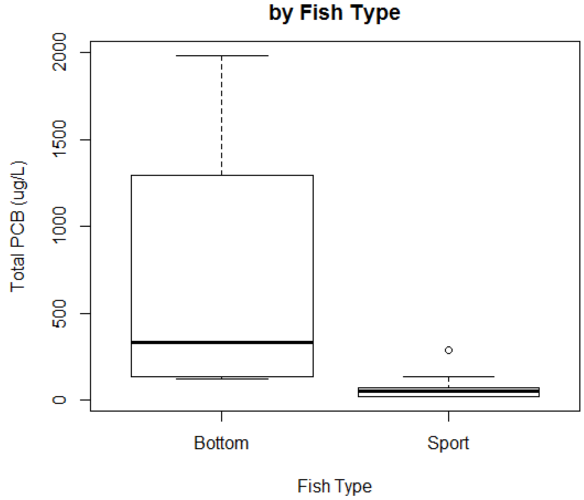
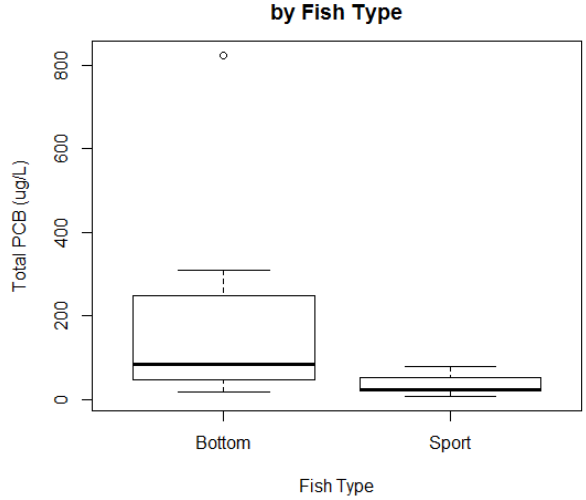


Figure 8. Lake Erie AOC Fillet Total PCB Conc. by Fish Type



A risk assessment was conducted to determine whether the PCB concentrations were at high enough concentrations to cause impacts to human health. Two values were compared to the results to determine potential noncancer human health effects. The first of these was the Great Lakes Sport Fish Advisory Task Force Health Protection Value of 5.0E-5 mg/kg-d, which applies to total PCB concentrations (1993). The second value that was used was the oral reference dose listed in the United States EPA Integrated Risk Information System (IRIS) for Aroclor 1254. This value was used because there is currently no reference dose established for total PCBs. While there is also a reference dose for Aroclor 1016, that PCB mixture was not detected in any of the samples. For this analysis, a weighted exposure dose was calculated using geometric mean concentrations for each trophic level and assumptions used by the Great Lakes Water Quality Initiative (U.S. EPA, 1995b).

Using both the Health Protection Value and the Aroclor 1254 reference dose, no fish fillet concentrations were high enough to cause adverse noncancer human health effects (Tables 6 and 7). The detection limit for PCB mixtures decreased from 50 ug/kg in the 2008 study to ~1.0 ug/kg in the 2018 study when analyzed by TestAmerica. This drastic increase in precision may have led to the lower total PCB and Aroclor 1254 geomean concentrations than those observed in previous studies.

Aroclor 1254 was only detected in fish collected at the AOC locations. For the Lake Erie AOC sites, Aroclor 1254 was only detected in the trophic level 3 fish, in which one common carp sample out of the six selected trophic level 3 fish samples had measurable concentrations. A total of 81% of samples in the Cuyahoga River AOC sites and 8% in the lake AOC sites displayed detectable Aroclor 1254 concentrations. As Aroclor 1254 geomean concentrations trended upward from 1989-2008, the 2018 sampling indicated a decrease compared to the 2008 study.

Overall, the calculated noncancer hazard indices decreased at all locations, with no noncancer hazard index exceeding the Great Lakes Sport Fish Advisory Task Force Health Protection Value. The 2018 results showed a decrease in lifetime cancer risk assessments compared to the 2008 study. The most significant reduction in risk associated with exposure to total PCBs was observed at the Lake Erie AOC sites in 2018 compared to those in 2008. The highest noncancer hazard risk was observed at the Cuyahoga River AOC sites in 2018, with the lowest risks associated with the two river reference sites. Lake Erie AOC and reference sites yielded the same noncancer hazard index, both of which are the lowest values observed in any Lake Erie sites during this long-term study.

The cancer potency factor given in IRIS for total PCBs was also used to determine lifetime cancer risks associated with consumption of fish fillets utilizing geometric mean concentrations in this study (Table 6). In doing so, it was found that the calculated cancer risks were greater than the risk goal of 1.0E-5 (one case per 100,000 population) used by the Ohio EPA (2004) at the Lake Erie AOC and reference locations and the Cuyahoga River AOC locations. All four groups of sites saw a decrease in cancer risk compared to the 2008 study. The Lake Erie AOC sites were calculated at the lowest geomean total PCB concentrations since the start of this study.

Table 6. Total PCB Noncancer Hazard Index and Lifetime Cancer Risk

	Geometric Mean Fillet Concentration*	Calculted 15.0 g/d Exposure Dose**	Health Protection Value***	Calculated 15.0 g/d Noncancer Hazard	IRIS Slope Factor	Calculated 15.0 g/d Lifetime Cancer Risk
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index	$(mg/kg\text{-}d)^{-1}$	
2018						
Lake AOC		9.71E-06	5.00E-05	0.19	2.0	**1.94E-05**
Trophic Level 3	0.116					
Trophic Level 4	0.023					
Lake Reference		9.23E-06	5.00E-05	0.18	2.0	**1.85E-05**
Trophic Level 3	0.056					
Trophic Level 4	0.039					
River AOC		2.30E-05	5.00E-05	0.50	2.0	**5.00E-05**
Trophic Level 3	0.325					
Trophic Level 4	0.051					

Table 6. Total PCB Noncancer Hazard Index and Lifetime Cancer Risk						
	Geometric Mean Fillet Concentration*	Calculted 15.0 g/d Exposure Dose**	Health Protection Value***	Calculated 15.0 g/d Noncancer Hazard	IRIS Slope Factor	Calculated 15.0 g/d Lifetime Cancer Risk
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index	(mg/kg-d)-1	
River Reference		1.97E-06	5.00E-05	0.04	2.0	3.94E-06
Trophic Level 3	0.013					
Trophic Level 4	0.008					
2008						
Lake AOC		6.65E-05	5.00E-05	1.33	2.0	**1.33E-04**
Trophic Level 3	0.319					
Trophic Level 4	0.307					
Lake Reference		1.83E-05	5.00E-05	0.37	2.0	**3.66E-05**
Trophic Level 3	0.074					
Trophic Level 4	0.089					
River AOC		3.56E-05	5.00E-05	0.71	2.0	**7.12E-05**
Trophic Level 3	0.181					
Trophic Level 4	0.161					
River Reference		5.60E-06	5.00E-05	0.11	2.0	**1.12E-05**
Trophic Level 3	0.030					
Trophic Level 4	0.025					
2005						
Lake AOC		5.58E-05	5.00E-05	1.12	2.0	**1.12E-04**
Trophic Level 3	0.184					
Trophic Level 4	0.285					
Lake Reference		1.67E-05	5.00E-05	0.33	2.0	**3.34E-05**
Trophic Level 3	0.150					
Trophic Level 4	0.055					
River AOC		2.23E-05	5.00E-05	0.45	2.0	**4.46E-05**
Trophic Level 3	0.112					
Trophic Level 4	0.101					
River Reference		3.68E-06	5.00E-05	0.07	2.0	7.36E-06
Trophic Level 3	0.019					
Trophic Level 4	0.017					
1989-1992						
Lake AOC		3.34E-05	5.00E-05	0.67	2.0	**6.68E-05**
Trophic Level 3	0.515					
Trophic Level 4	0.042					
Lake Reference		5.41E-05	5.00E-05	1.08	2.0	**1.08E-04**
Trophic Level 3	0.579					
Trophic Level 4	0.149					
River AOC		1.85E-05	5.00E-05	0.37	2.0	**3.70E-05**
Trophic Level 3	0.224					
Trophic Level 4	0.043					

Table 6. Total PCB Noncancer Hazard Index and Lifetime Cancer Risk

	Geometric Mean Fillet Concentration*	Calculted 15.0 g/d Exposure Dose**	Health Protection Value***	Calculated 15.0 g/d Noncancer Hazard	IRIS Slope Factor	Calculated 15.0 g/d Lifetime Cancer Risk
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index	(mg/kg-d)$^{-1}$	
River Reference		1.86E-06	5.00E-05	0.04	2.0	3.71E-06
Trophic Level 3	0.008					
Trophic Level 4	0.009					

*Concentrations below the detection limit assumed to be 1/2 detection limit if that Aroclor measured elsewhere in any similar site.
**Human body weight of 70kg and lifetime exposure are assumed. Weighted dose based on assumption that 3.6 g/day consumption of trophic level 3 and 11.4 g/day of trophic level 4 fish.
***Great Lakes Sport Fish Advisory Task Force Health Protection Value, 1993

Table 7. Aroclor 1254 Noncancer Hazard Index

	Geometric Mean Fillet Concentration*	Calculated 15.0 g/d Exposure Dose**	IRIS Reference Dose	Calculated 15.0 g/d Noncancer Hazard
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index
2018				
Lake AOC		NA	2.00E-05	NA
Trophic Level 3	0.001			
Trophic Level 4	ND			
Lake Reference		NA	2.00E-05	NA
Trophic Level 3	ND			
Trophic Level 4	ND			
River AOC		1.132E-05	2.00E-05	0.57
Trophic Level 3	0.158			
Trophic Level 4	0.020			
River Reference		NA	2.00E-05	NA
Trophic Level 3	ND			
Trophic Level 4	ND			
2008				
Lake AOC		2.50E-05	2.00E-05	1.25
Trophic Level 3	0.125			
Trophic Level 4	0.114			
Lake Reference		8.08E-06	2.00E-05	0.40
Trophic Level 3	0.038			
Trophic Level 4	0.038			
River AOC		1.40E-05	2.00E-05	0.70
Trophic Level 3	0.086			
Trophic Level 4	0.073			
River Reference		5.36E-06	2.00E-05	0.27
Trophic Level 3	0.025			
Trophic Level 4	0.025			

Table 7. Aroclor 1254 Noncancer Hazard Index

Location	Geometric Mean Fillet Concentration* (mg/kg)	Calculated 15.0 g/d Exposure Dose** (mg/kg-d)	IRIS Reference Dose (mg/kg-d)	Calculated 15.0 g/d Noncancer Hazard Index
2005				
Lake AOC		3.83E-05	2.00E-05	1.92
Trophic Level 3	0.131			
Trophic Level 4	0.194			
Lake Reference		1.10E-05	2.00E-05	0.55
Trophic Level 3	0.103			
Trophic Level 4	0.035			
River AOC		9.84E-06	2.00E-05	0.49
Trophic Level 3	0.045			
Trophic Level 4	0.046			
River Reference		3.79E-06	2.00E-05	0.19
Trophic Level 3	0.021			
Trophic Level 4	0.017			
1989-1992				
Lake AOC		3.69E-06	2.00E-05	0.18
Trophic Level 3	0.028			
Trophic Level 4	0.014			
Lake Reference		6.14E-06	2.00E-05	0.31
Trophic Level 3	0.082			
Trophic Level 4	0.012			
River AOC		7.12E-07	2.00E-05	0.04
Trophic Level 3	0.005			
Trophic Level 4	0.003			
River Reference		NA	2.00E-05	NA
Trophic Level 3	ND			
Trophic Level 4	ND			

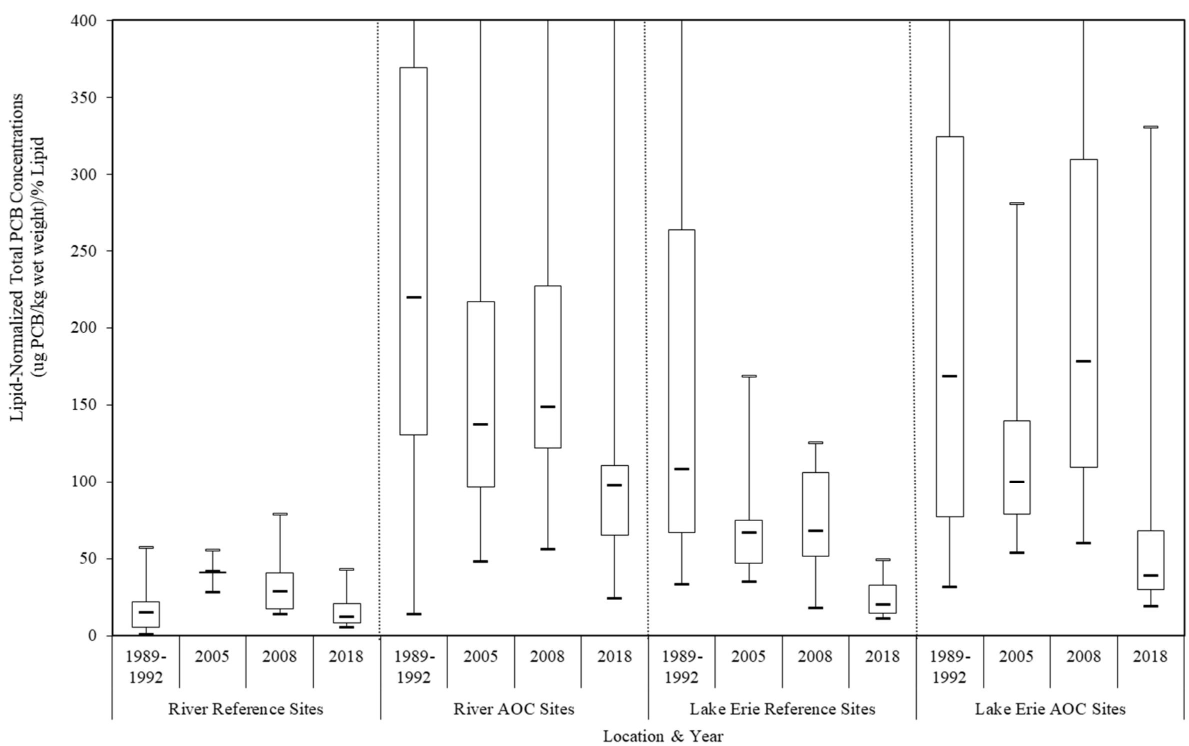
*Concentrations below the detection limit assumed to be 1/2 detection limit if measured elsewhere in any similar site.
**Human body weight of 70kg and lifetime exposure are assumed. Weighted dose based on assumption that 3.6 g/day consumption of trophic level 3 and 11.4 g/day of trophic level 4 fish.

Lipid-Normalized PCBs

In addition to total PCBs, lipid-normalized PCB concentrations were also examined in the fish tissue samples collected in 2018. Lipid-normalized concentrations take into account differences in fatty tissue that can accumulate PCBs (Rasmussen et al., 1990) and can provide a better measure of contamination than total PCBs. These concentrations were calculated by dividing the total PCB concentration in each sample by the percent lipids.

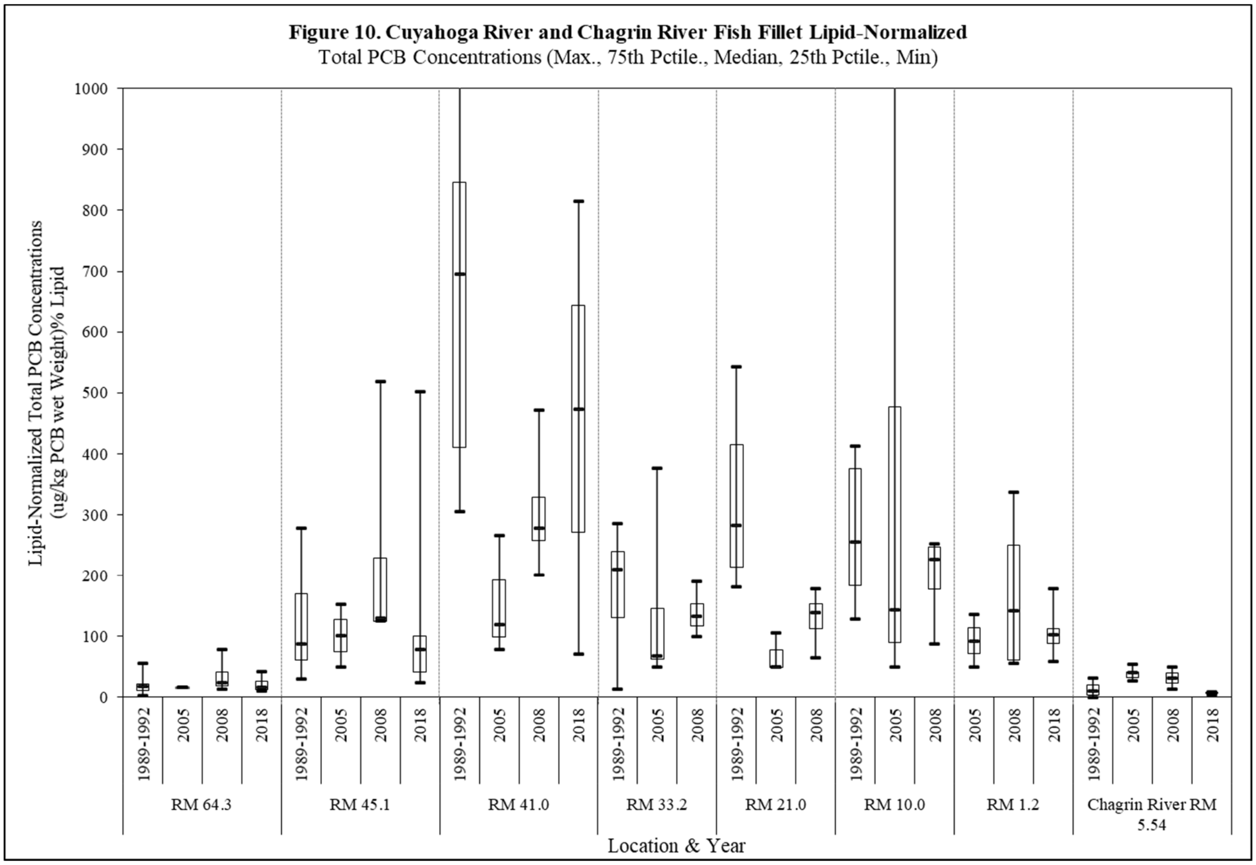
When the AOC and reference sites were compared to each other, median lipid-normalized PCB concentrations at both AOC sites were higher than their respective reference sites (Figure 9), with the difference being statistically significant (Appendix C, Table 21). The median concentration for the Lake Erie AOC sites was significantly lower than all three previous studies (Appendix C, Table 17). The Cuyahoga River AOC sites had lipid-normalized PCB concentrations significantly lower than in the 1989-1992 and 2008 studies, but not statistically different than the 2005 study (Appendix C, Table 13). At the river reference sites, 2018 median concentrations were significantly lower than both the 2005 and 2008 studies, and similar to those found during 1989-1992 (Appendix C, Table 15). Lipid-normalized PCB concentrations in fish at the Lake Erie reference locations have trended downward since the 1989-1992 study. Historical data shows a significantly lower difference between fish collected in the Lake Erie reference sites in 2018 than those collected in the previous three studies (Appendix C, Table 19). Laboratory detection limits have varied every year of the study and have also differed between labs. In 2018, a large difference between the detection limits by the Ohio EPA Environmental Services laboratory and the NEORSD sub lab, TestAmerica, was observed (Table 5). In sample locations where PCB contaminants were not detected, these lower detection limits between laboratory, as well as between each assessment year, may have led to lower median results between locations and years based on the assumptions that were made.

Figure 9. Fish Fillet Lipid Normalized Total PCB Concentrations
(Max., 75th Pctile., Median, 25th Pctile., Min.)

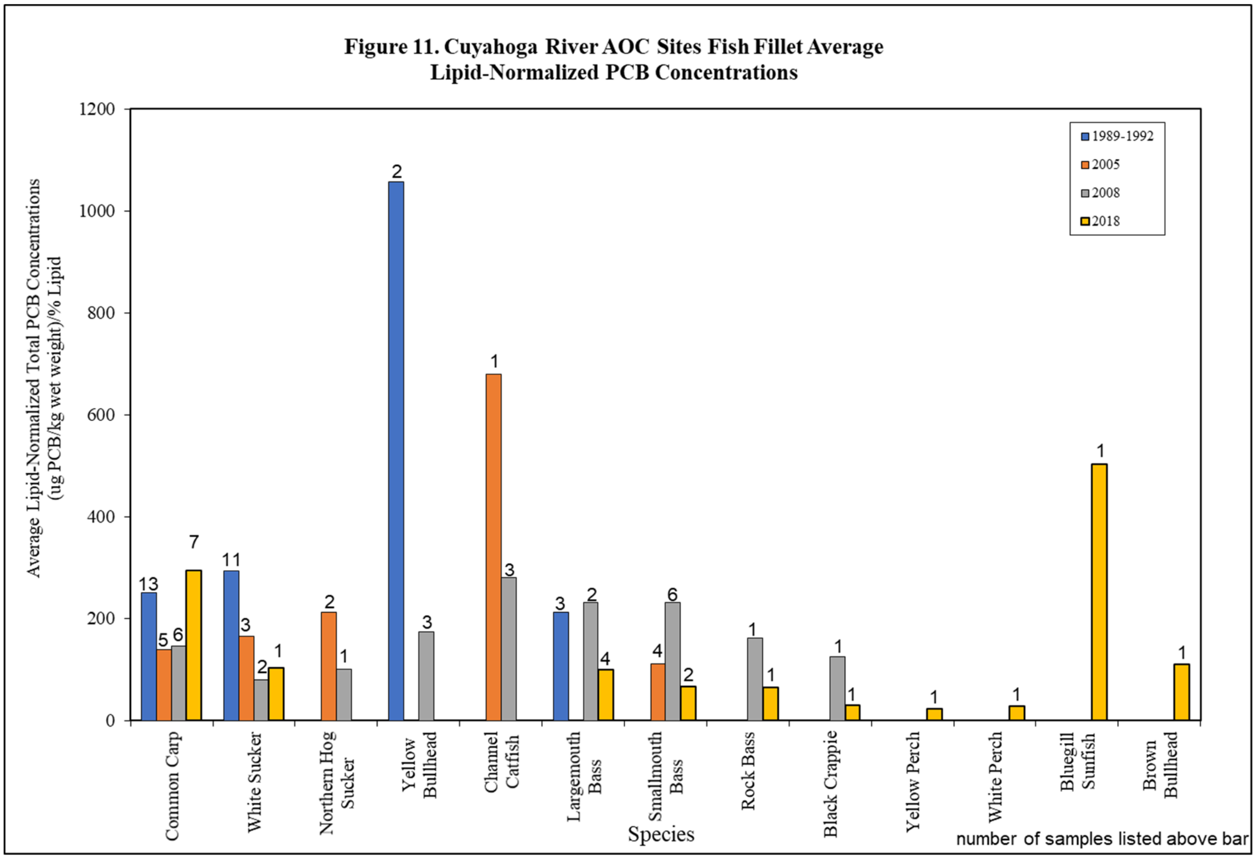


A site-to-site comparison of the river sites show that both reference sites had median lipid-normalized PCB concentrations approximately the same in both of the previous studies (Figure 10). For the AOC sites, the highest median concentration occurred at the site immediately upstream of Akron WRF (RM 41.0), while the lowest was at the Ohio Edison Dam Pool (RM 45.1). Both reference sites displayed lower lipid-normalized PCB concentrations than any

Cuyahoga River AOC locations. The median concentrations at these sites in 2018 were lower than the 2008 study at RMs 45.10 and 1.20, but higher at RM 41.00. Lipid-normalized PCB results have varied by location and each year and no downward trend is apparent.

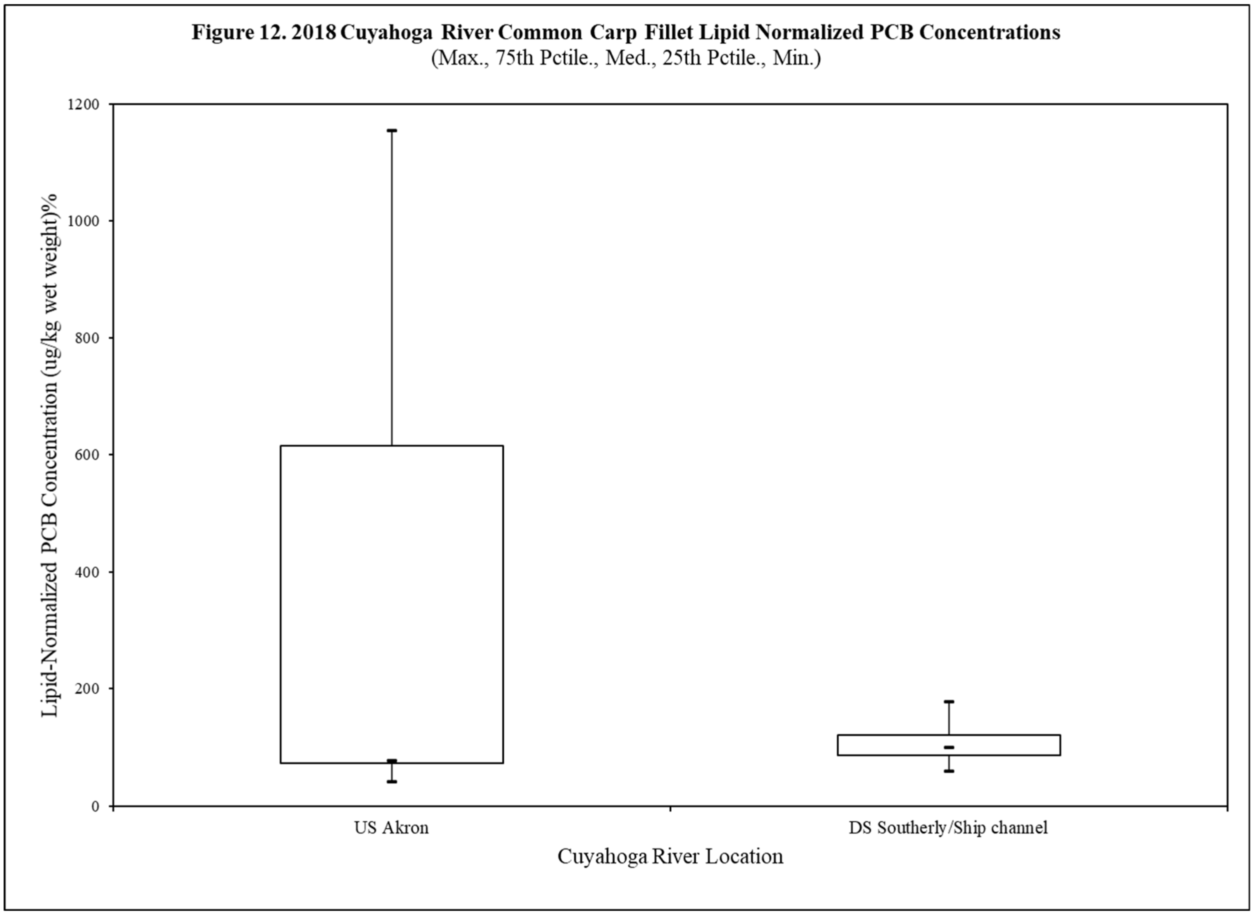


The results for the individual species collected in the Cuyahoga River AOC display differences among species (Figure 11). The average lipid-normalized PCB concentrations were higher than previous years for bottom feeding species (common carp and white sucker) and lower for sport fishing species (largemouth bass, smallmouth bass, rock bass, and black crappie). The highest average lipid-normalized PCB concentration in 2018 was observed in the one bluegill sunfish collected at the RM 45.10. Again, no apparent downward trend is observed in species that have been collected in multiple sampling years.

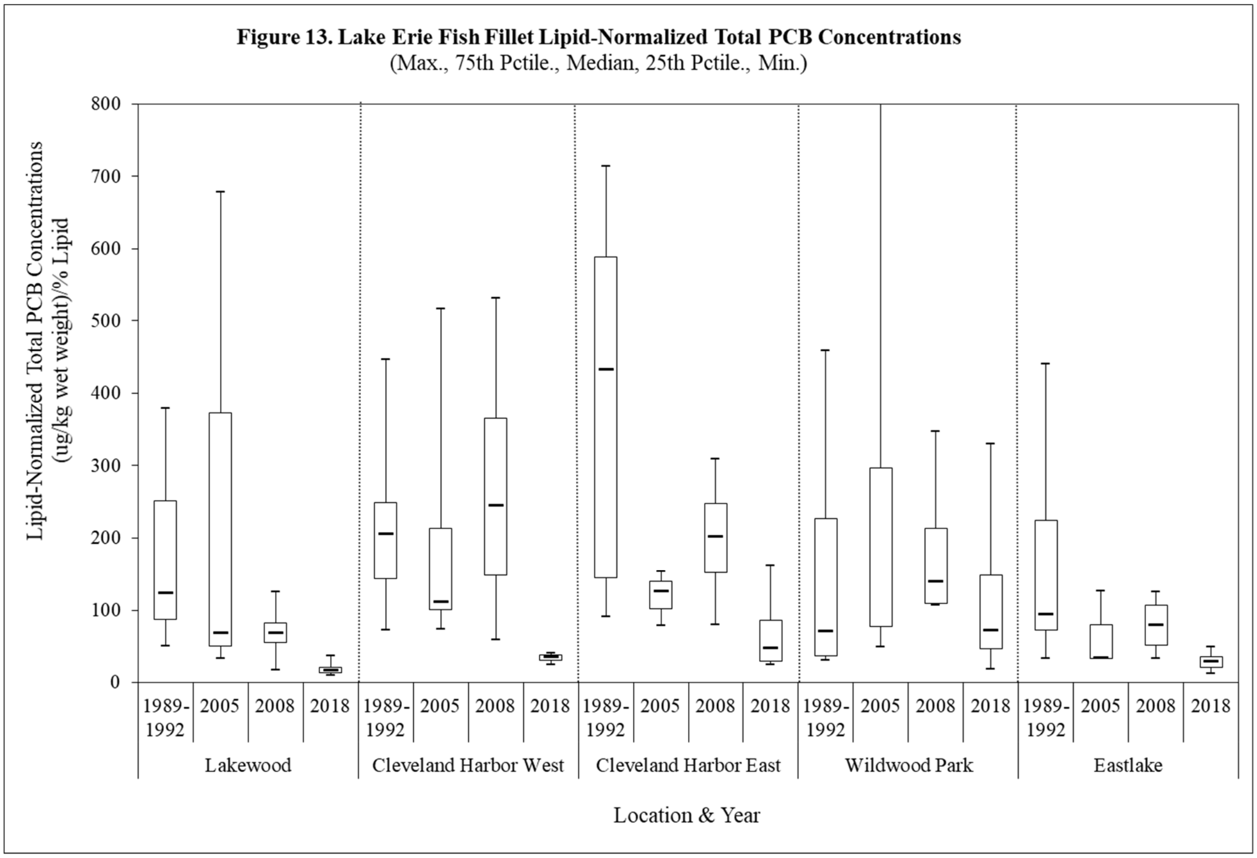


In addition to examining the species from the AOC as a whole, a comparison was also completed using data collected from the sites upstream of the Akron WRF and downstream of the NEORSD Southerly WWTC. This was done to evaluate whether effluent from the treatment plants could be having an impact on PCB concentrations in fish tissue. One issue associated with this type of analysis is that, due to fish mobility, the specific location at which fish are exposed to contaminants remains uncertain. For the purposes of this assessment, the concentrations measured are nevertheless assumed to be the result of exposure at the location in which the fish were collected, and the uncertainty associated with this assumption should be kept in mind throughout interpretation of the data.

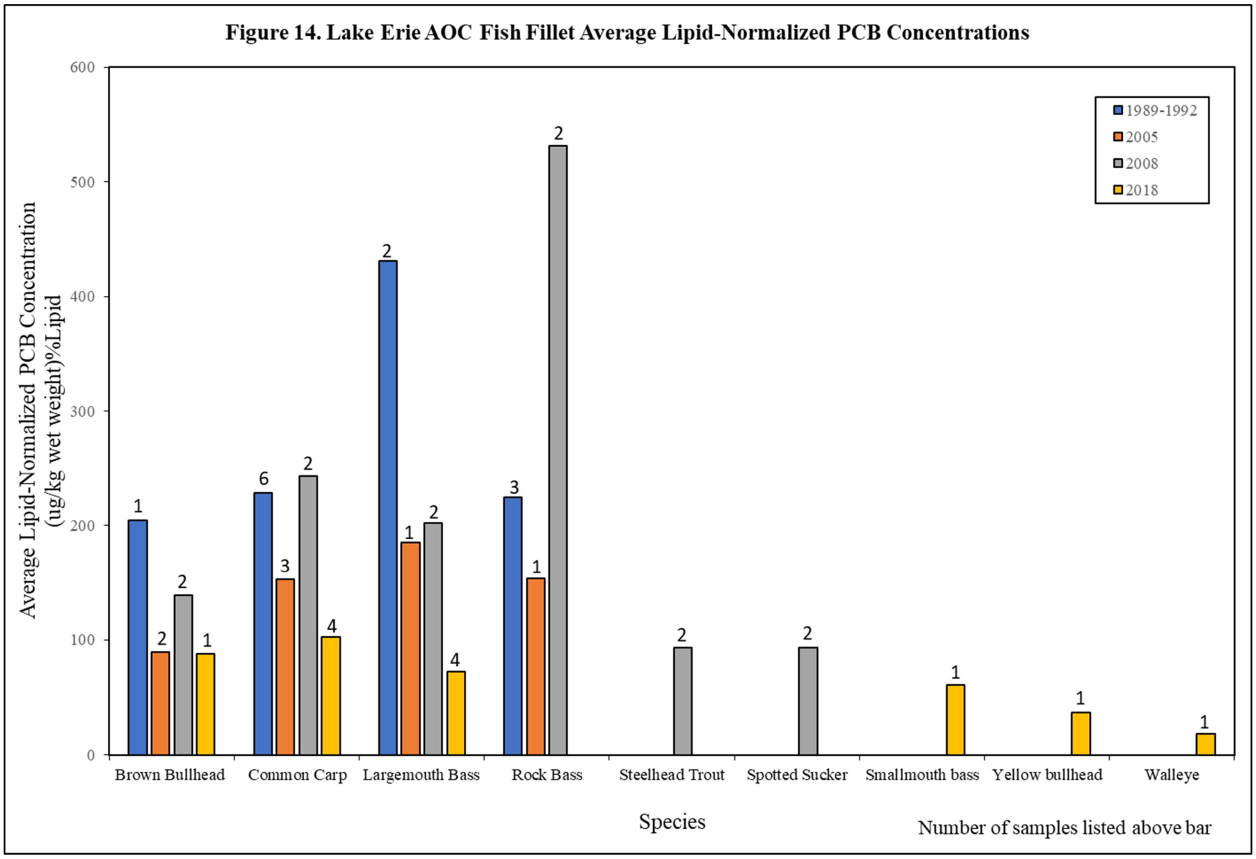
Sites classified as upstream of Akron WRF include RMs 64.30, 45.10, and 41.70. The only location downstream of the Akron and Southerly WWTPs from which fillets were collected was in the ship channel at RM 0.92. No fillet samples were collected between Akron WRF and Southerly WWTC in 2018, so no comparison can be made in this section of river. Five common carp samples were collected at the three sites upstream of Akron WRF and four were collected in the ship channel. The comparison completed for common carp shows similar median lipid-normalized PCBs, with the sites upstream of the Akron WRF displaying much higher quartiles 3 and 4 than fish in the ship channel (Figure 12). However, the difference between the median concentrations for both locations was not significant. (Appendix C, Table 22).



The lowest median lipid-normalized PCB concentration for the Lake Erie sites in 2018 occurred at the Lakewood reference site, while the highest occurred at the Wildwood Park location on the eastern end of the AOC (Figure 13). Compared to the 2008 study, the median concentrations decreased at all locations. The AOC locations had the lowest median concentrations compared to past studies, except for the Wildwood Park site where median concentrations were nearly identical in 1989-1992. Inside the Lake Erie AOC, higher lipid-normalized concentrations were observed at the east end of Cleveland Harbor and at Wildwood Park, as Cleveland West Harbor displayed concentrations similar to the two reference locations. The continued presence of PCBs within the Cuyahoga River and Lake Erie AOC locations may be due to the prevalence and persistence of these compounds in the environment and impediments to their removal from some areas.



Fish collected at the Lake Erie AOC sites have generally displayed a decrease in lipid-normalized PCB concentrations in similar species (Figure 14). In 2018, all three species that were collected in past studies displayed the lowest concentrations of the four studies. Concentrations in fish that were also collected in the Cuyahoga River AOC demonstrated much lower lipid-normalized PCB concentrations in the Lake Erie portion of the AOC. Bottom feeding species like the brown bullhead and common carp, again, displayed higher lipid-normalized PCB concentrations than those classified as a sport fish. This was the first study in which smallmouth bass, yellow bullhead, and walleye were analyzed, so no historical comparison could be made for them.



Pesticides

Thirty-four of the composite fillet samples were analyzed by TestAmerica for pesticides and their breakdown products listed in Table 8. The nineteen samples analyzed by Ohio EPA's Division of Environmental Services were tested for all the same pesticides except for chlordane and its breakdown products (alpha-, gamma-, and oxy-). These compounds are no longer monitored by the Ohio EPA because, in recent years, they have not detected them in high enough concentrations to be of concern. The Ohio EPA Environmental Services MDLs were higher than those from TestAmerica. For this reason, less detectable results occurred at sites assessed by the Ohio EPA than those sampled by NEORSD and analyzed by TestAmerica. In the 2005 study, no pesticides were detected. This was most likely the result of higher detection limits than in other studies. In 2008, nine different pesticides or breakdown products were detected. In 2018, fifteen pesticides or breakdown products were detected, with at least one breakdown product being found at all sites except the Cuyahoga River RM 64.30 (FTCS-01), including both reference and AOC sites. Pesticides that were detected included:

Table 8. 2018 Pesticides Detection Summary

Analyte	# detected	# analyzed	% detected
Aldrin	0	53	0%
alpha-BHC	0	53	0%
beta-BHC	0	53	0%

Table 8. 2018 Pesticides Detection Summary			
Analyte	# detected	# analyzed	% detected
delta-BHC	0	53	0%
gamma-BHC	5	53	9%
alpha-Chlordane	24	24	100%
gamma-Chlordane	10	24	42%
oxy-Chlordane	22	24	92%
4,4'-DDD	30	53	57%
4,4'-DDE	32	53	60%
4,4'-DDT	1	50	2%
Dieldrin	25	53	47%
Endosulfan I	0	53	0%
Endosulfan II	12	53	23%
Endosulfan sulfate	0	29	0%
Endrin	24	53	45%
Heptachlor	1	53	2%
Heptachlor epoxide	18	53	34%
Heptachlorobenzene	4	53	8%
Methoxychlor	1	53	2%
Mirex	3	53	6%
Sites assessed by NEORSD/TestAmerica: FTCS-08, 09, 10, 11, 12, 13 Sites assessed by the Ohio EPA: FTCS-01, 02, 03, 07			

These chemicals are of concern due to their persistence in the environment and the harmful effects that they can cause to humans and wildlife. For these reasons, use of these pesticides was banned in the U.S. in the 1970s and 80s. Although it has been at least thirty years since they were used, pesticides and their breakdown products can still be found in the environment because of their long half-live breakdowns. When comparing the 2018 pesticide concentrations to concentrations used to set advisory consumption rates by the State of Ohio (Table 9), none of fish sampled had concentrations high enough to warrant a fish consumption advisory.

Table 9. Ohio Fish Consumption Advisory Chemicals: Fillet Chemical Upper Bound Limit Concentrations (mg/kg) and Advisory Meal Consumption Rate Using the Great Lakes' Governors Procedure*					
Chemical	Unrestricted	1/Week	1/Month	6/Year	Do Not Eat
Aldrin	<0.030	0.131	0.568	1.135	>1.135
Total Chlordane	<0.500	2.188	9.459	18.919	>18.919
Total DDT	<0.500	2.188	9.459	18.919	>18.919
Dieldrin	<0.050	0.220	1.000	1.999	>1.999
Endosulfan	<6.000	26.25	131.514	227.027	>227.027
Endrin	<0.300	1.313	5.676	11.351	>11.351
Heptachlor	<0.500	2.188	9.459	18.919	>18.919
Heptachlor Epoxide	<0.013	0.057	0.246	0.492	>0.492

Table 9. Ohio Fish Consumption Advisory Chemicals: Fillet Chemical Upper Bound Limit Concentrations (mg/kg) and Advisory Meal Consumption Rate Using the Great Lakes' Governors Procedure*					
Chemical	Unrestricted	1/Week	1/Month	6/Year	Do Not Eat
Methoxychlor	<5.000	21.875	94.545	189.189	>189.189
Toxaphene	<0.250	1.094	4.73	9.459	>9.459
*Adapted from State of Ohio Cooperative Fish Tissue Monitoring Program (2010)					

An analysis of the noncancer hazard index and the lifetime cancer risk associated with chlordane and DDT and its metabolites indicates that the concentrations of these compounds detected in the fish samples were not high enough to be of concern in either the AOC or at the reference sites (Tables 10-13). The noncancer hazard index for both chlordane and DDT were well below one in all instances. In addition, the calculated cancer risks for both of those compounds, as well as for DDD and DDE, was lower than the risk goal of 1E-5 used by the Ohio EPA. These results are similar to what was found in previous studies.

Table 10. Chlordane Noncancer Hazard Index and Lifetime Cancer Risk						
	Average Fillet Concentration*	Calculated 15.0 g/d Exposure Dose**	IRIS Reference Dose	Calculated 15.0 g/d Noncancer Hazard	IRIS Slope Factor	Calculated 15.0 g/d Lifetime Cancer Risk
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index	$(mg/kg\text{-}d)^{-1}$	
2018						
Lake AOC	1.00E-02	2.14E-06	5.00E-04	0.00	3.50E-01	7.51E-07
Lake Reference	4.05E-03	8.69E-07	5.00E-04	0.00	3.50E-01	3.04E-07
River AOC	NA	NA	5.00E-04	NA	3.50E-01	NA
River Reference	7.97E-04	1.71E-07	5.00E-04	0.00	3.50E-01	5.98E-08
2008						
Lake AOC	5.27E-02	1.13E-05	5.00E-04	0.02	3.50E-01	3.95E-06
Lake Reference	1.96E-02	4.20E-06	5.00E-04	0.01	3.50E-01	1.47E-06
River AOC	6.92E-02	1.48E-05	5.00E-04	0.03	3.50E-01	5.19E-06
River Reference	0.00E+00	0.00E+00	5.00E-04	0.00	3.50E-01	0.00E+00
*Concentrations below the detection limit assumed to be zero. **Human body weight of 70kg and lifetime exposure are assumed. NA = Not Available **Note:** 2018 River Reference sites analyzed for Chlordane is only from FTCS-13 (Chagrin River RM 5.54)						

Table 11. Total DDT Noncancer Hazard Index and Lifetime Cancer Risk						
	Average Fillet Concentration*	Calculated 15.0 g/d Exposure Dose**	IRIS Reference Dose	Calculated 15.0 g/d Noncancer Hazard	IRIS Slope Factor	Calculated 15.0 g/d Lifetime Cancer Risk
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index	$(mg/kg\text{-}d)^{-1}$	
2018						
Lake AOC	3.66E-02	7.84E-06	5.00E-04	1.57E-02	3.40E-01	2.67E-06
Lake Reference	1.72E-02	3.69E-06	5.00E-04	7.38E-03	3.40E-01	1.25E-06
River AOC	1.35E-02	2.90E-06	5.00E-04	5.79E-03	3.40E-01	9.84E-07

Table 11. Total DDT Noncancer Hazard Index and Lifetime Cancer Risk

Location	Average Fillet Concentration* (mg/kg)	Calculated 15.0 g/d Exposure Dose** (mg/kg-d)	IRIS Reference Dose (mg/kg-d)	Calculated 15.0 g/d Noncancer Hazard Index	IRIS Slope Factor $(mg/kg\text{-}d)^{-1}$	Calculated 15.0 g/d Lifetime Cancer Risk
River Reference	1.43E-03	3.06E-07	5.00E-04	6.11E-04	3.40E-01	1.04E-07
2008						
Lake AOC	7.92E-03	1.70E-06	5.00E-04	3.39E-03	3.40E-01	5.77E-07
Lake Reference	0.00	0.00	5.00E-04	0.00	3.40E-01	0.00
River AOC	4.75E-03	1.02E-06	5.00E-04	2.04E-03	3.40E-01	3.46E-07
River Reference	0.00	0.00	5.00E-04	0.00	3.40E-01	0.00
1989-1992						
Lake AOC	3.30E-03	7.07E-07	5.00E-04	1.41E-03	3.40E-01	2.40E-07
Lake Reference	2.53E-03	5.43E-07	5.00E-04	1.09E-03	3.40E-01	1.85E-07
River AOC	4.21E-03	9.02E-07	5.00E-04	1.80E-03	3.40E-01	3.07E-07
River Reference	1.05E-03	2.25E-07	5.00E-04	4.50E-04	3.40E-01	7.65E-08

*Concentrations below the detection limit assumed to be zero.
**Human body weight of 70kg and lifetime exposure are assumed.

Table 12. DDE Noncancer Hazard Index and Lifetime Cancer Risk

Location	Average Fillet Concentration* (mg/kg)	Calculated 15.0 g/d Exposure Dose** (mg/kg-d)	IRIS Reference Dose (mg/kg-d)	Calculated 15.0 g/d Noncancer Hazard Index	IRIS Slope Factor $(mg/kg\text{-}d)^{-1}$	Calculated 15.0 g/d Lifetime Cancer Risk
2018						
Lake AOC	2.79E-02	5.97E-06	NA	NA	3.40E-01	2.03E-06
Lake Reference	3.50E-03	7.49E-07	NA	NA	3.40E-01	2.55E-07
River AOC	4.19E-02	8.98E-06	NA	NA	3.40E-01	3.05E-06
River Reference	3.53E-03	7.57E-07	NA	NA	3.40E-01	2.57E-07
2008						
Lake AOC	1.70E-02	3.64E-06	NA	NA	3.40E-01	1.24E-06
Lake Reference	6.00E-03	1.29E-06	NA	NA	3.40E-01	4.37E-07
River AOC	1.93E-02	4.14E-06	NA	NA	3.40E-01	1.41E-06
River Reference	1.04E-02	2.23E-06	NA	NA	3.40E-01	7.58E-07
1989-1992						
Lake AOC	3.22E-02	6.91E-06	NA	NA	3.40E-01	2.35E-06
Lake Reference	4.12E-02	8.83E-06	NA	NA	3.40E-01	3.00E-06
River AOC	2.34E-02	5.02E-06	NA	NA	3.40E-01	1.71E-06
River Reference	1.58E-02	3.39E-06	NA	NA	3.40E-01	1.15E-06

*Concentrations below the detection limit assumed to be zero.
**Human body weight of 70kg and lifetime exposure are assumed.
NA = Not available

Table 13. DDD Noncancer Hazard Index and Lifetime Cancer Risk						
	Average Fillet Concentration*	Calculated 15.0 g/d Exposure Dose**	IRIS Reference Dose	Calculated 15.0 g/d Noncancer Hazard	IRIS Slope Factor	Calculated 15.0 g/d Lifetime Cancer Risk
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index	$(mg/kg\text{-}d)^{-1}$	
2018						
Lake AOC	2.79E-02	5.97E-06	NA	NA	2.41E-01	1.44E-06
Lake Reference	3.50E-03	7.49E-07	NA	NA	2.41E-01	1.80E-07
River AOC	1.85E-02	3.96E-06	NA	NA	2.41E-01	9.54E-07
River Reference	7.48E-04	1.60E-07	NA	NA	2.41E-01	3.86E-08
2008						
Lake AOC	7.21E-03	1.55E-06	NA	NA	2.41E-01	3.72E-07
Lake Reference	1.26E-03	2.70E-07	NA	NA	2.41E-01	6.51E-08
River AOC	5.52E-03	1.18E-06	NA	NA	2.41E-01	2.85E-07
River Reference	0.00E+00	0.00E+00	NA	NA	2.41E-01	0.00E+00
1989-1992						
Lake AOC	2.03E-02	4.35E-06	NA	NA	2.41E-01	1.05E-06
Lake Reference	1.92E-02	4.12E-06	NA	NA	2.41E-01	9.92E-07
River AOC	1.37E-02	2.93E-06	NA	NA	2.41E-01	7.07E-07
River Reference	6.36E-03	1.36E-06	NA	NA	2.41E-01	3.29E-07

*Concentrations below the detection limit assumed to be zero.
**Human body weight of 70kg and lifetime exposure are assumed.
NA = Not available

Mercury

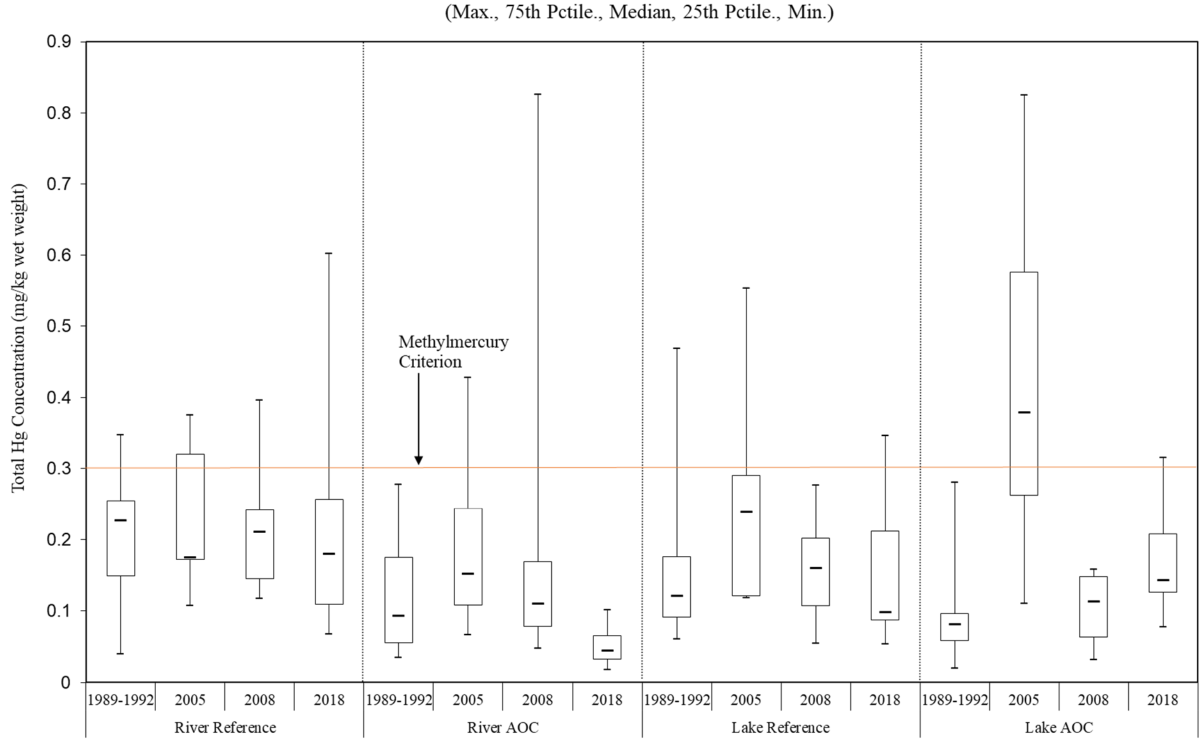
Fifty-three composite fish fillet samples were analyzed to determine consumption advisories for total mercury concentrations (USEPA method 245.1). A total of 127 whole-body fish samples were analyzed to determine worst case scenarios, and risk to evaluate the potential for impacts to piscivorous wildlife. Analysis was completed by NEORSD Analytical Services and the Ohio EPA Division of Environmental Services. Detectable quantities of mercury were observed in every fish analyzed.

Composite Fillet Samples

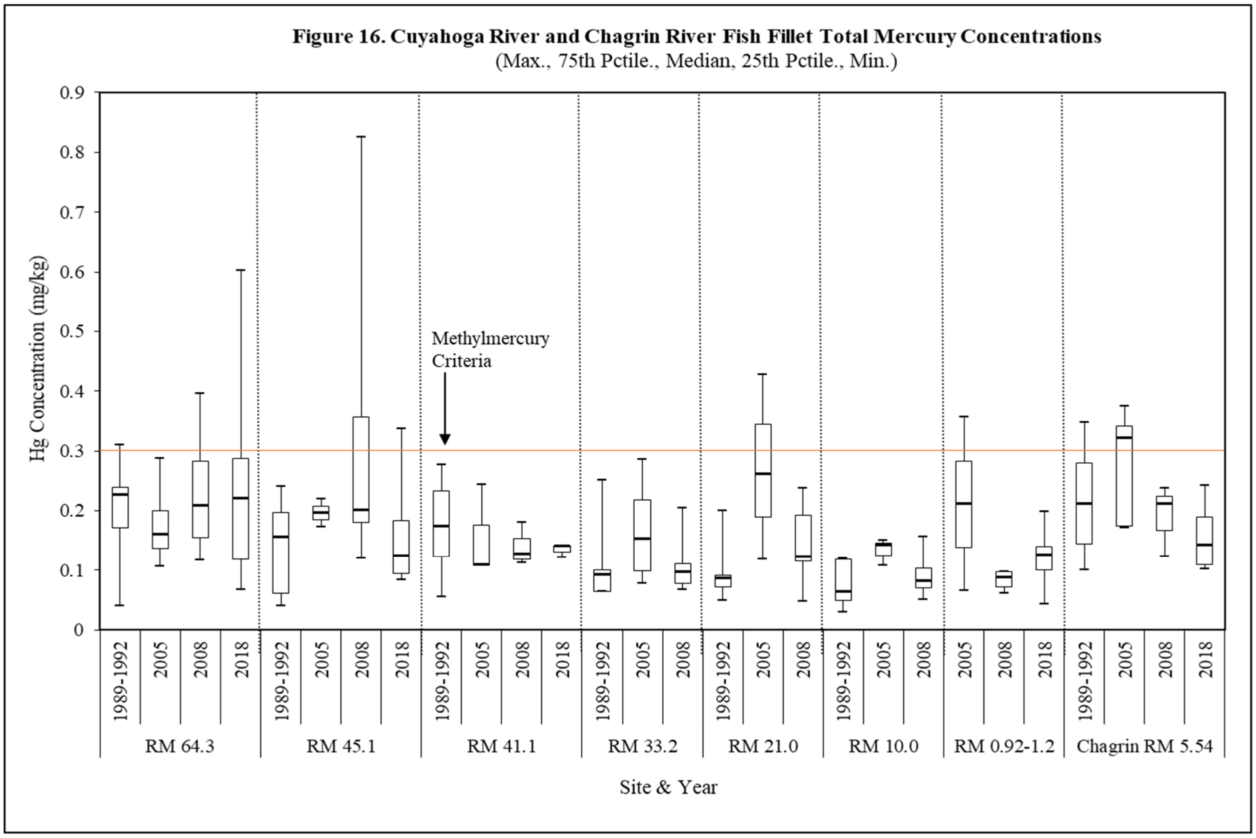
Analysis of mercury concentrations in composite fillet samples was performed to evaluate the potential for impacts if consumed by humans. Results were evaluated in terms of changes over time and differences among locations. Results were compared to the U.S. EPA human health water quality criterion for methylmercury, which is 0.3 mg methylmercury/kg fish tissue wet weight. The methylmercury criterion was adopted in 2001 and is intended to protect consumers of fish and shellfish. It is assumed that virtually all mercury in fish tissue is in the form of methylmercury, and therefore, analysis of mercury serves as a substitute for measuring methylmercury (U.S. EPA, 2006). The fillet concentrations were also compared to those used by the State of Ohio to set meal consumption advisories (State of Ohio, 2010). The advisory is currently based upon a health protection value of 0.1 ug mercury/kg/day for those people consuming sport fish (Great Lakes Fish Advisory Workgroup, 2007).

When comparing the AOC to their respective reference sites, median mercury concentrations for both types of AOC sites were lower than the reference locations. However, the differences were not statistically significant between groups (Appendix C, Table 28). All median concentrations were well below the methylmercury criterion (Figure 15). Compared to the previous two studies, the median concentrations in 2018 were generally about the same in the river reference, river AOC and Lake Erie reference sites, with mercury concentrations in the Lake Erie AOC sites differing over the last 30 years. In the Lake Erie AOC locations, the 2018 mercury concentrations were significantly higher than the 1989-1992 and 2008 studies, but significantly lower than the 2005 study (Appendix C, Table 26).

Figure 15. Fish Fillet Total Mercury Concentrations
(Max., 75th Pctile., Median, 25th Pctile., Min.)



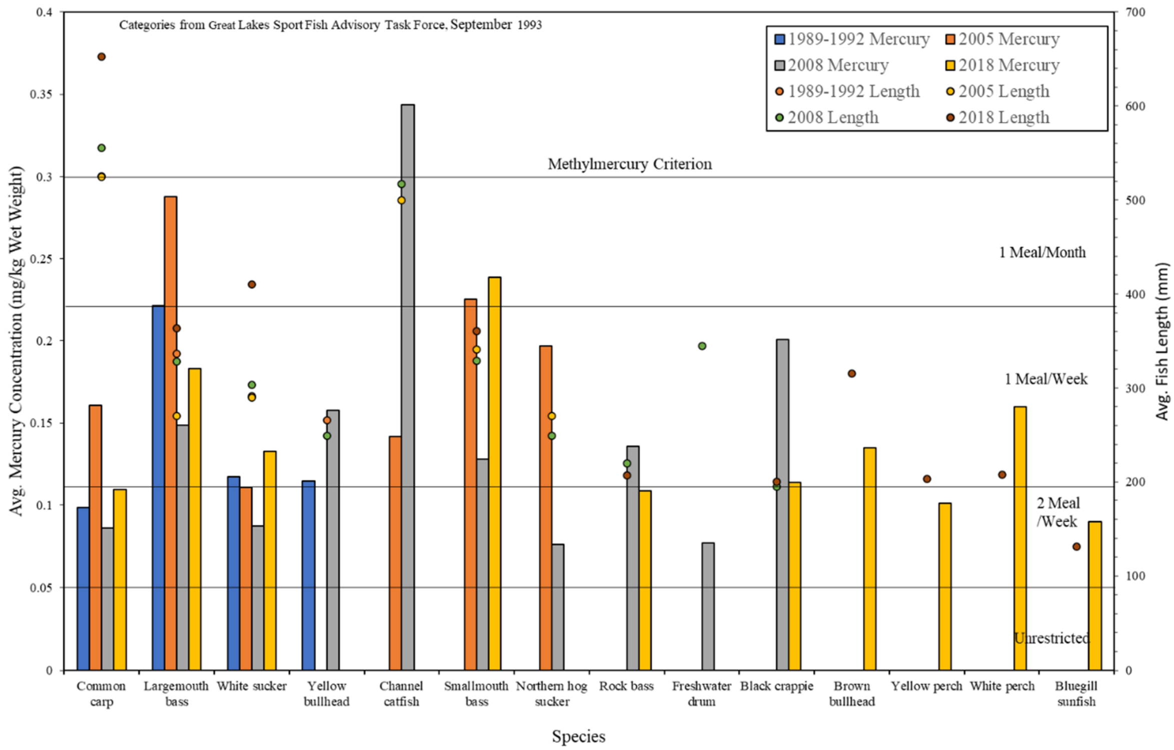
In the Cuyahoga River, the highest median mercury concentrations occurred at the RM 64.30 reference location (see Figure 16) with the concentrations at RM 45.10, 41.10, 0.92, and the Chagrin River RM 5.54 locations yielding similar results to each other. All median concentrations in 2018 were below the human health water quality criterion, with only the Cuyahoga River RM 64.30 and 45.10 sites having a maximum mercury fish tissue concentration above that value. These samples were collected from the sites near Shalersville and at the Ohio Edison Dam Pool.



There was an increase in mercury concentrations from the previous study in four of the six species previously collected, shown in Figure 17. Rock bass and black crappie were the only species with lower mercury concentrations than the previous study. Brown bullhead, yellow perch, white perch, and bluegill sunfish were collected for the first time in this study with consumption advisories ranging from 1-2 meals per week. Generally, mercury concentrations increase as fish become larger due to bioaccumulation in muscle tissue (Great Lakes Fish Advisory Workgroup, 2007). The increased mercury concentrations in 2018 for common carp, largemouth bass, white sucker, and smallmouth bass may be due to the increased size of the fish. These four species all had the highest average length compared to previous studies.

The State of Ohio currently has a statewide fish consumption advice in place for mercury that recommends not eating more than one meal per week of most fish, shown in Table 1 (Ohio EPA et al., 2019). When compared to these recommendations, mercury concentrations in all fish except for smallmouth bass met this statewide fish consumption advisory (Figure 17). Species were compared to the mercury-based Ohio Fish consumption advisories within the Cuyahoga River AOC section (Ohio Edison dam pool, RM~46.50 to the mouth, Table 2). Two fish species had mercury-based fish consumption advisories in the Cuyahoga River AOC that are more stringent than the statewide standards: white sucker 16” and over and smallmouth bass 15” and over. One white sucker was collected above 16 inches, containing a mercury concentration of 0.133 mg/kg and falling in the *one meal per week* advisory, less stringent than the site-specific advisory. One rock bass was collected in this area, with a mercury concentration of 0.109 mg/kg, falling in the two meals per week advisory which is consistent with the site-specific standard. No smallmouth bass collected in 2018 were larger than 15 inches, but the shorter smallmouth bass fillets averaged a concentration that would fall within the *one meal per month* category. No composited fish fillets collected in 2018 averaged a mercury concentration above the methylmercury criterion.

Figure 17. Cuyahoga River AOC Fish Fillet Average Mercury Concentrations



Figures 18 and 19 demonstrate differences in fish fillet mercury concentrations between bottom feeding species and sport fishing species. At both the Cuyahoga River and Lake Erie AOC locations, sport fish contained a higher mercury concentration than bottom feeding species, with the difference in the Lake Erie AOC locations being statistically significant (Appendix C, Table 30). This differs from the PCB fish tissue concentrations, where bottom feeding species had higher concentrations than sport feeding fish (Figures 7 & 8). The International Joint Commission states that mercury accumulates in fish from ingestion of mercury in the water and the prey upon which they feed on (2004), leading to higher concentrations of mercury in higher trophic level species, which was observed during this study.

Figure 18. River AOC Sites Fillet Hg Concentration by Fish Type

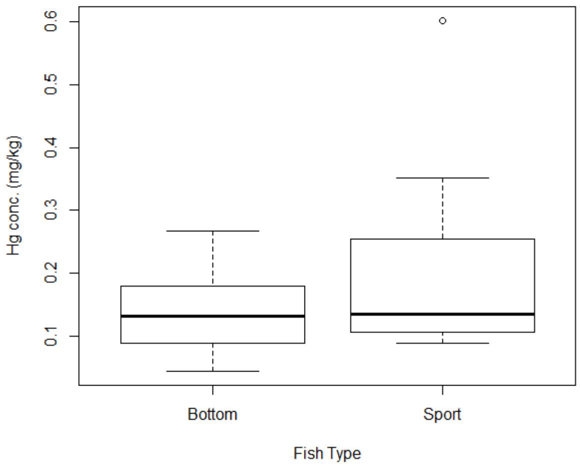
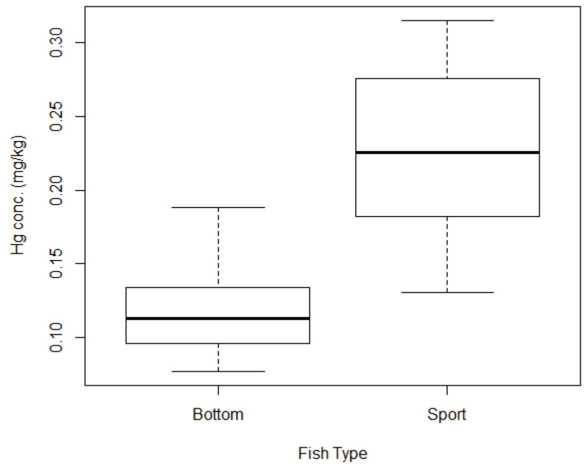


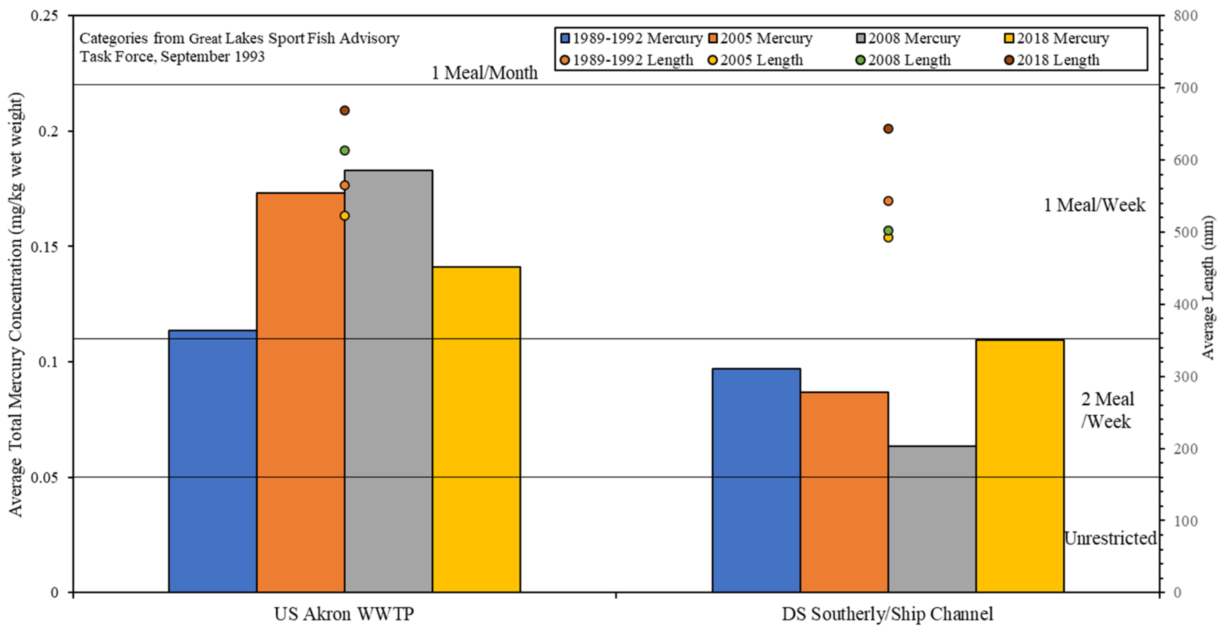
Figure 19. Lake Erie AOC Fillet Hg Concentration by Fish Type



Trace concentrations of mercury are present in effluent that is discharged from WWTPs. The significance of these discharges in terms of bioaccumulation in fish tissue is still not completely understood. Common carp collected upstream of the Akron WRF and downstream of the Southerly WWTC within the shipping channel were compared to evaluate any possible effects from these major WWTPs. Lower mercury concentrations were found every year in the sections of the river downstream from both treatment plants (Figure 20). The average size of common carp in 2018 was larger than any of the previous studies, but only saw an increased mercury concentration at the downstream location in the shipping channel at RM 0.92. The higher mercury concentration at the shipping channel site may be attributable to the larger fish, which tend to have higher mercury concentrations.

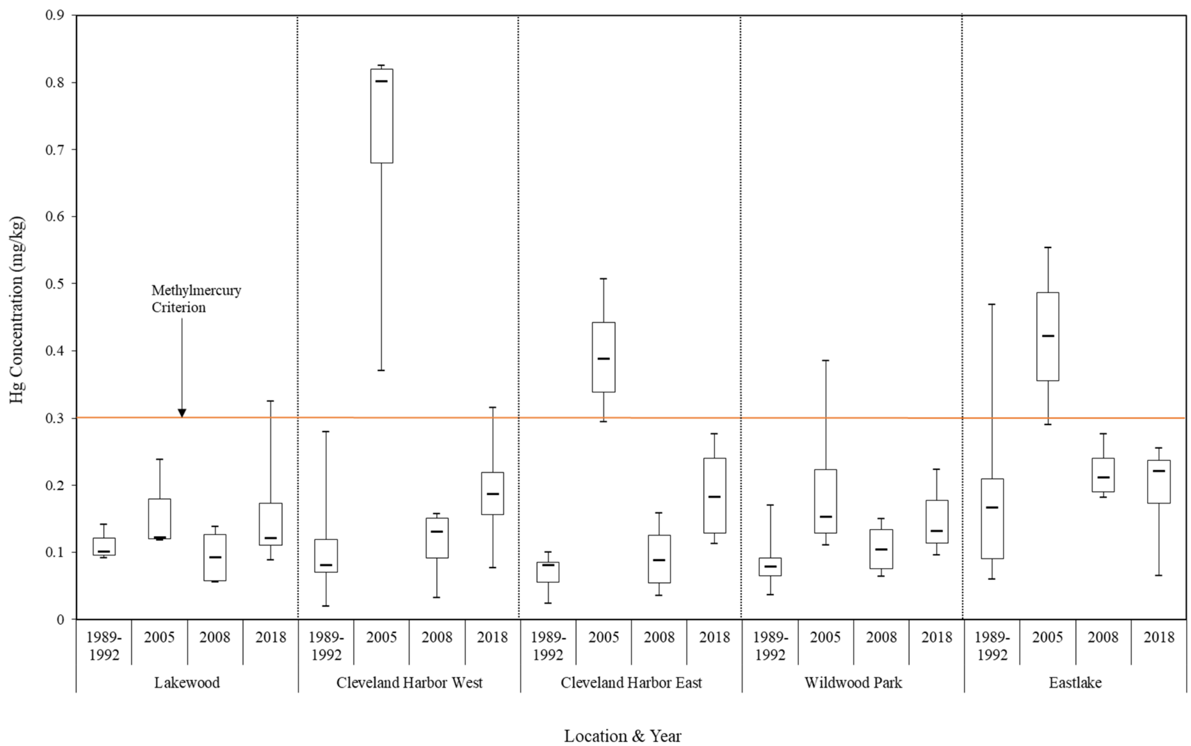
The NEORSD Southerly WWTC has been granted a mercury variance for their NPDES permit because the permittee has demonstrated the facility is currently unable to comply with the monthly average water quality-based effluent limit of 1.3 ng/L without costly control measures (Ohio EPA 2017b). In 2018, Southerly WWTC averaged an effluent mercury loading of 0.62 g/day and achieved a mercury removal efficiency of 96.2-98.8% (NEORSD, 2018). The Akron WRF (90MGD design flow) also has a mercury variance for their NPDES permit. In 2018, the Akron WRF achieved a high mercury removal efficiency at approximately 98.54%, averaging an effluent mercury loading of 0.60 g/day. With the ability of both WWTPs to remove mercury at an extremely efficient rate and lower fish tissue mercury concentrations in the lower reaches of the Cuyahoga River, mercury contamination in the Cuyahoga River is likely originating from other sources.

Figure 20. Cuyahoga River Common Carp Fillet Average Mercury Concentrations & Lengths



The results for the individual sites in Lake Erie indicate that mercury concentrations were highest at the Eastlake site, but no significant difference was observed between groups (Figure 21, Appendix C, Table 28). All fillet samples had a median concentration lower than the 0.3 mg/kg criterion, however, the Lakewood and Cleveland West Harbor locations had a maximum value exceed the criterion. The median concentrations in 2018 were all slightly higher than those collected at the same sites in 2008, but lower than the 2005 results. The reason for the much higher levels in 2005 remains unknown.

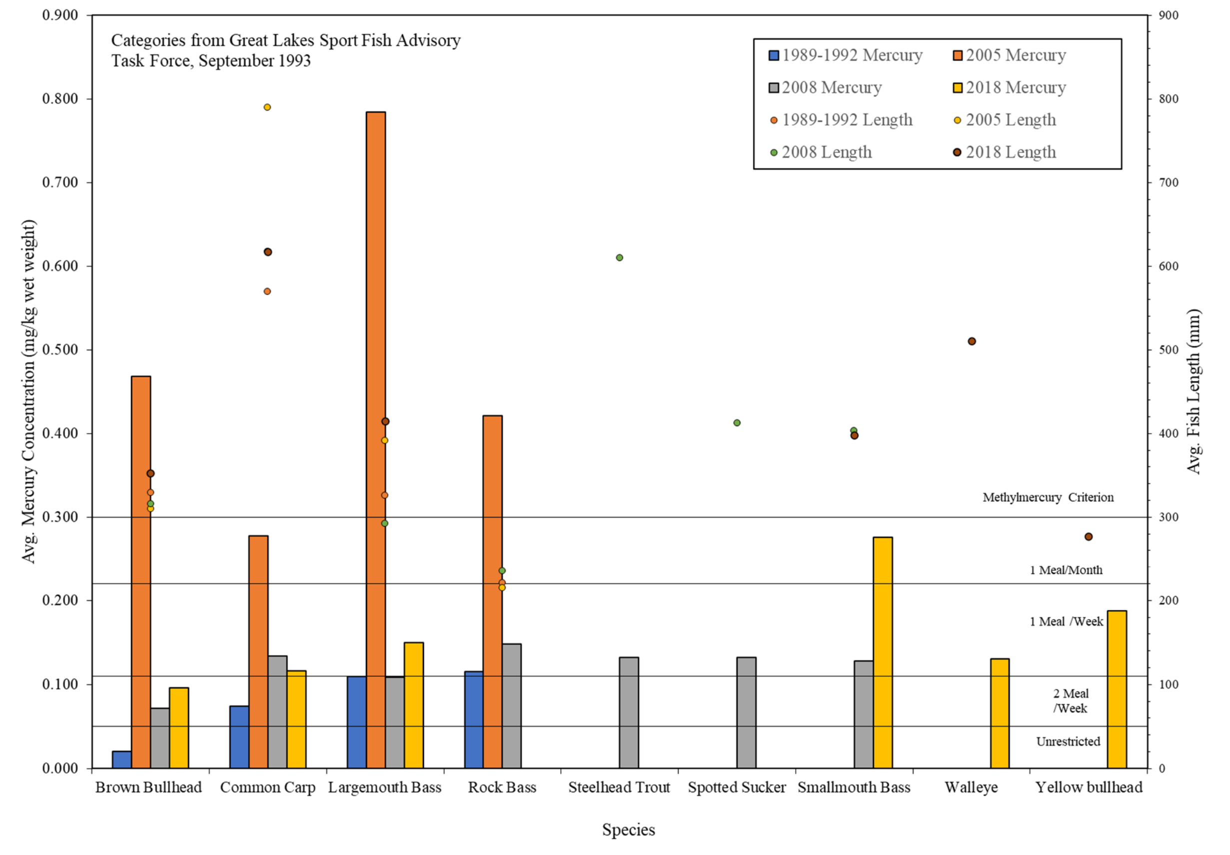
Figure 21. Lake Erie Fish Fillet Total Mercury Concentrations
(Max., 75th Pctile., Median, 25th Pctile., Min.)



When examining the results for individual species in the Lake Erie portion of the AOC, smallmouth bass had the highest mercury concentrations placed in the *one meal per month* category (Figure 22). Common carp, largemouth bass, walleye, and yellow bullhead all had concentrations within the *one meal per week* category, with brown bullhead having the lowest mercury concentration and in the *two meals per week* advisory. Comparing each species to the mercury-based Ohio fish consumption advisories in Lake Erie (Table 1), smallmouth bass displayed results consistent with the advisory at *one meal per month*, while brown bullhead concentrations were lower than the advisory listed at *one meal per month*.

Four of the species that were collected in 2018 were also collected in the previous three studies. Brown bullhead and largemouth bass displayed higher mercury concentrations than the 1989-1992 and 2008 studies. Common carp had a slight reduction in mercury concentration compared to the 2008 study, but still higher than the 1989-1992 study. All the average fish fillet mercury concentrations measured in 2018 were lower than in 2005. Brown bullhead and largemouth bass were larger in 2018 than those from 2008, which may account for some of the differences in mercury concentration. However, the sizes of common carp and smallmouth bass were similar, so environmental heterogeneity or fish migration throughout the area may be causing dissimilar results from previous studies.

Figure 22. Lake Erie AOC Fish Fillet Average Mercury Concentration



As with the pesticide and PCB results, a risk assessment was completed for mercury at the AOC and reference sites to evaluate the potential for harm to humans consuming fish caught within those areas. Noncancer hazard index results greater than one can cause adverse effects on human health. Based on the current reference dose for methylmercury, the calculated noncancer hazard index, assuming a consumption of 15.0 g/day, a body weight of 70 kg, and lifetime exposure, does not exceed one for any of the locations (Table 14). These results are similar to past studies, as the noncancer hazard index has never exceeded one.

Table 14. Methylmercury Noncancer Hazard Index

	Geometric Mean Fillet Concentration	Calculated 15.0 g/d Exposure Dose*	IRIS Reference Dose	Calculated 15.0 g/d Noncancer Hazard
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index
2018				
Lake AOC		4.15E-05	1.00E-04	0.42
Trophic Level 3	0.12			
Trophic Level 4	0.22			
Lake Reference		3.62E-05	1.00E-04	0.36

Table 14. Methylmercury Noncancer Hazard Index				
	Geometric Mean Fillet Concentration	Calculated 15.0 g/d Exposure Dose*	IRIS Reference Dose	Calculated 15.0 g/d Noncancer Hazard
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index
Trophic Level 3	0.11			
Trophic Level 4	0.19			
River AOC		3.21E-05	1.00E-04	0.32
Trophic Level 3	0.11			
Trophic Level 4	0.16			
River Reference		4.00E-05	1.00E-04	0.40
Trophic Level 3	0.16			
Trophic Level 4	0.19			
2008				
Lake AOC		2.31E-05	1.00E-04	0.23
Trophic Level 3	0.07			
Trophic Level 4	0.12			
Lake Reference		2.90E-05	1.00E-04	0.29
Trophic Level 3	0.14			
Trophic Level 4	0.13			
River AOC		2.60E-05	1.00E-04	0.26
Trophic Level 3	0.10			
Trophic Level 4	0.13			
River Reference		4.55E-05	1.00E-04	0.46
Trophic Level 3	0.18			
Trophic Level 4	0.22			
2005				
Lake AOC		8.31E-05	1.00E-04	0.83
Trophic Level 3	0.31			
Trophic Level 4	0.41			
Lake Reference		5.03E-05	1.00E-04	0.50
Trophic Level 3	0.19			
Trophic Level 4	0.25			
River AOC		4.00E-05	1.00E-04	0.40
Trophic Level 3	0.14			
Trophic Level 4	0.20			
River Reference		4.56E-05	1.00E-04	0.46
Trophic Level 3	0.22			
Trophic Level 4	0.21			
1989-1992				
Lake AOC		1.99E-05	1.00E-04	0.20
Trophic Level 3	0.05			
Trophic Level 4	0.11			

Table 14. Methylmercury Noncancer Hazard Index				
	Geometric Mean Fillet Concentration	Calculated 15.0 g/d Exposure Dose*	IRIS Reference Dose	Calculated 15.0 g/d Noncancer Hazard
Location	(mg/kg)	(mg/kg-d)	(mg/kg-d)	Index
Lake Reference		3.99E-05	1.00E-04	0.40
Trophic Level 3	0.08			
Trophic Level 4	0.22			
River AOC		4.10E-05	1.00E-04	0.41
Trophic Level 3	0.10			
Trophic Level 4	0.22			
River Reference		3.72E-05	1.00E-04	0.37
	0.20			
	0.17			
*Human body weight of 70kg and lifetime exposure are assumed. Weighted dose based on assumption that 3.6 g/day consumption of trophic level 3 and 11.4 g/day of trophic level 4 fish.				

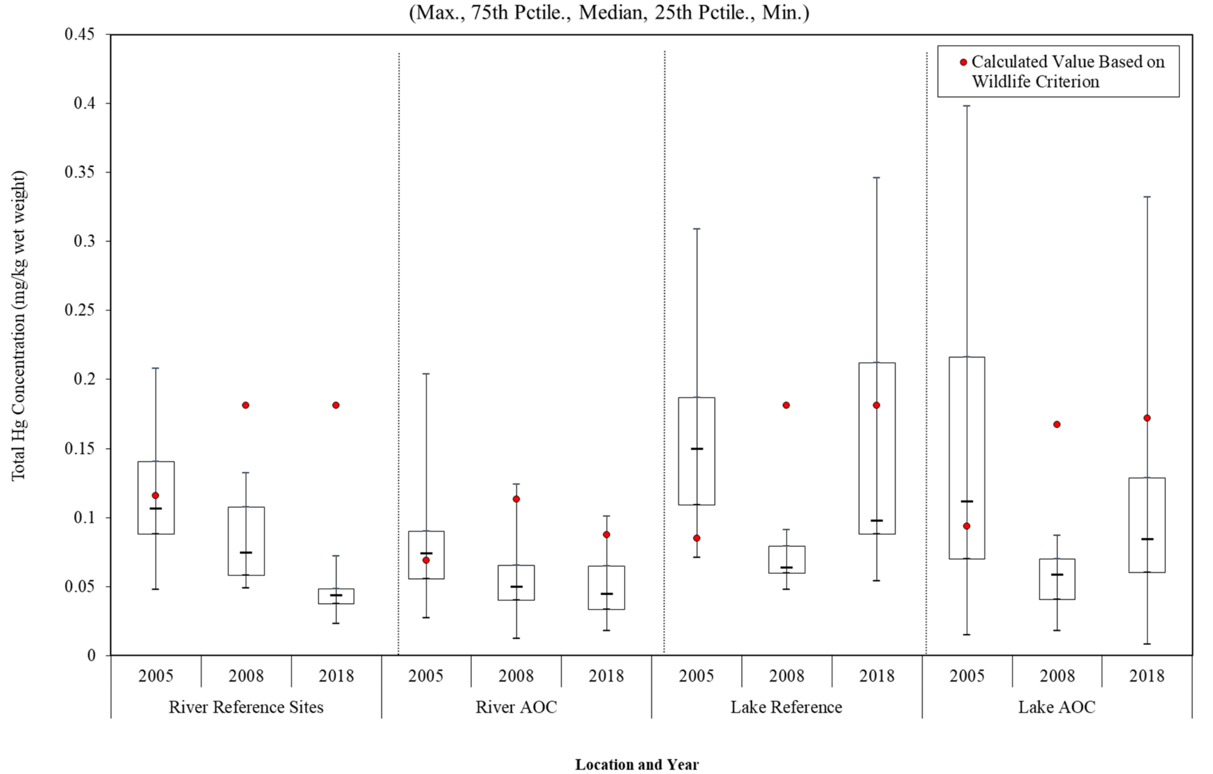
With the desire to control mercury emissions from coal fired power plants, national standards were established by the USEPA in 2011 (US Department of Energy, 2011). These standards have caused many energy companies to make the switch from coal fired to natural gas power plants which are much "cleaner". In 2015, three major coal fired powerplants along Lake Erie east of downtown Cleveland ceased operations, including the Lake Shore Power Plant located within the Cleveland East Harbor AOC location (Cleveland.com, 2015). With the reduction of coal burning at power plants, mercury emissions and overall mercury concentrations in Lake Erie should see a decrease locally.

Whole-Body Samples

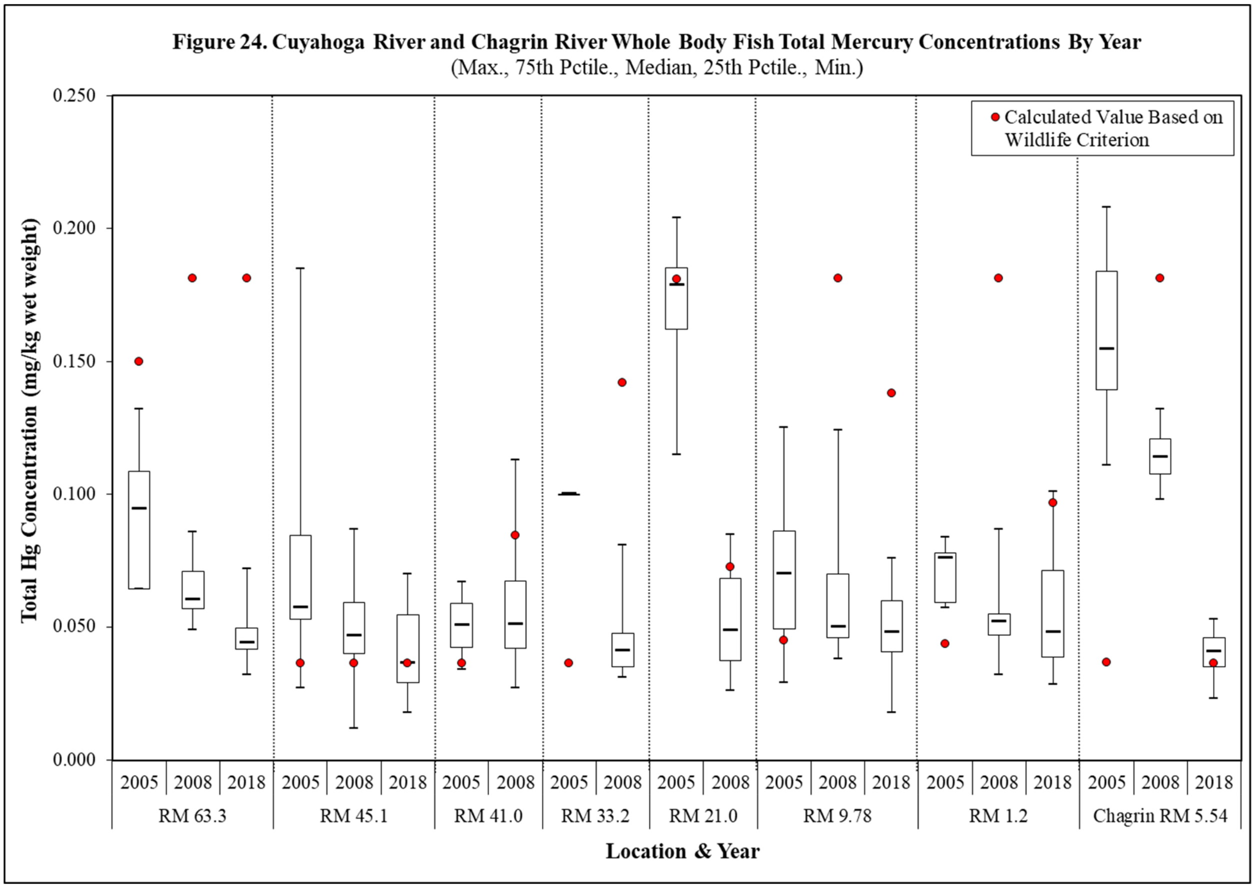
In addition to composite fillet samples, whole-body samples were also analyzed for total mercury concentrations. These samples were collected to evaluate the potential for impacts to piscivorous wildlife. The wildlife criterion for mercury according to the Great Lakes Water Quality Initiative (U.S. EPA, 1995a) is 1.3 ng/L. This criterion for ambient water quality can be converted to a fish-tissue basis and adjusted based on trophic level-specific bioaccumulation factors (BAFs). For trophic level 3 species, the BAF is 27,906 L/kg, while the BAF for trophic level 4 species is 139,532 L/kg (U.S. EPA, 1995a). A weighted average for trophic level 4 and trophic level 3 is used to calculate the wildlife criteria.

Median whole-body mercury concentrations were all below the trophic level adjusted fish-tissue basis wildlife criterion in 2018, whereas in 2005, only the river reference sites had median concentrations below this value (Figure 23). Whole-body mercury concentrations were similar between the Cuyahoga River AOC and reference sites. The Lake Erie AOC sites were significantly lower than their respective reference sites, and Lake Erie sites in general were significantly higher than those from the Cuyahoga River locations (Appendix C, Table 39). Whole-body mercury concentrations in river reference locations have declined significantly for each assessment year (Appendix C, Table 32). In the Cuyahoga River AOC section, the 2018 results were similar to those found in 2008, but significantly lower than the 2005 results (Appendix C, Table 34). Both the Lake Erie reference sites and AOC sites had a significant increase in whole-body mercury concentrations from the 2008 study, but still lower than concentrations in the 2005 assessment.

Figure 23. Whole Body Fish Total Mercury Concentrations
(Max., 75th Pctile., Median, 25th Pctile., Min.)

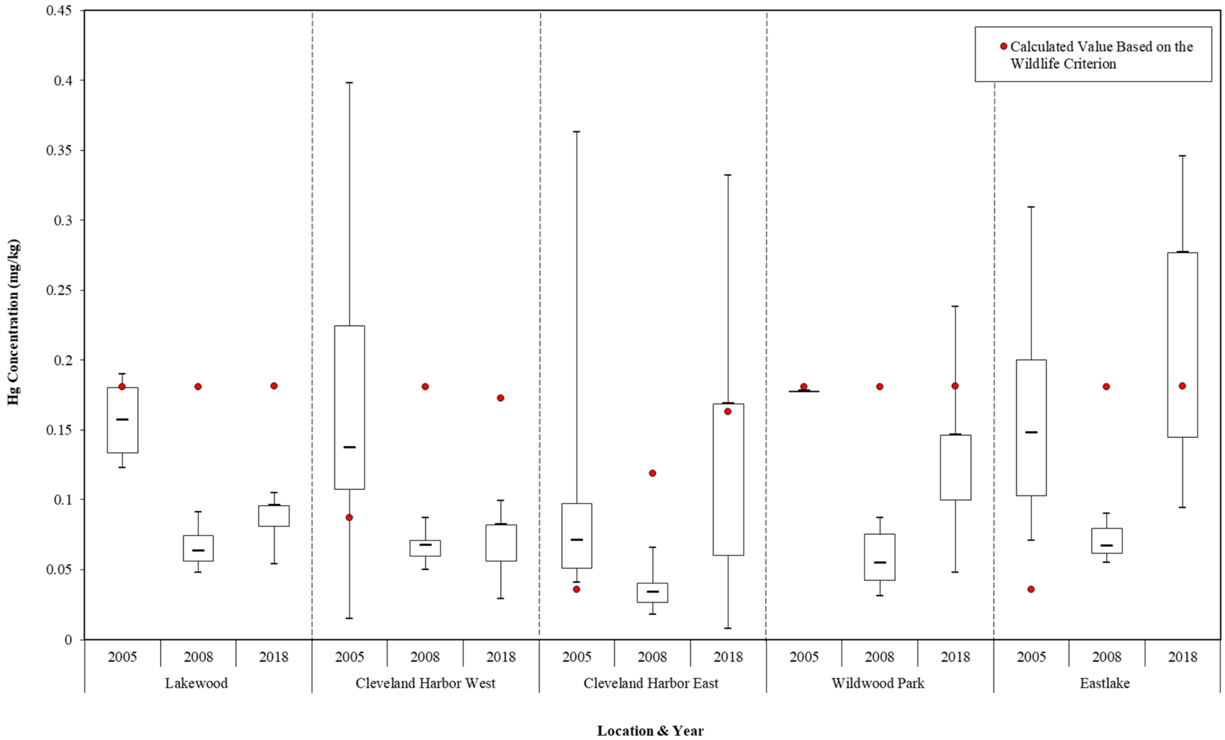


For river locations assessed in 2018, whole-body mercury concentrations were fairly consistent between sites with median values ranging from 0.046-0.071 mg/kg (Figure 24). Two sites, the Chagrin River at RM 5.54 and the Cuyahoga River at RM 45.10, had median mercury concentrations that exceeded the calculated wildlife criteria. Although the Cuyahoga River RM 45.1 exceeded the wildlife criteria, all sample locations assessed in 2018 displayed a downward trend in whole-body mercury concentrations. Of note, all whole-body specimens collected from the Chagrin River in 2018 were young-of-year walleye and may not represent that of a mature trophic level 4 species.



At the Lake Erie locations, the highest median concentrations, which were also above the calculated value based on the wildlife criterion, occurred in the Cleveland East Harbor and Eastlake locations (Figure 25). Both these locations had a First Energy coal-fired power plant within the sampling location until decommissioned in 2015. Historical pollutants from these plants may be the cause of the elevated whole-body mercury results. The lowest concentrations occurred at the Cleveland West Harbor and Lakewood locations. All locations displayed an increase in median whole-body mercury from the 2008 study, displaying no signs of an overall decrease in Lake Erie fish tissue mercury concentrations.

Figure 25. Lake Erie Whole Body Fish Total Mercury Concentrations By Year
(Max., 75th Pctile., Median, 25th Pctile., Min.)



Freshwater drum were the primary sport fish collected for whole-body mercury analysis at the Cleveland East Harbor, Wildwood, and Eastlake locations. At both the Lake Erie AOC and reference sites, freshwater drum had a significantly higher whole-body mercury concentration than other sport fishing species (Figures 26 and 27) (Appendix C, Tables 40 and 41). The selected freshwater drum had a higher average age at 7.6 years than the largemouth bass and other species, which averaged 4.2 years old. These older freshwater drum allow increased bioaccumulation over time and may be the reason for the increased mercury concentrations found in freshwater drum.

Freshwater drum are a bottom dwelling species (Rice and Zimmerman, 2019) that have specialized, shell crushing pharyngeal teeth which allows them to forage on zebra mussels (French III and Burr, 1992). No other sport fish in Lake Erie have this adaptation. Rice and Zimmerman (2019) refer to freshwater drum as benthic feeders operating by touch and smell, and not necessarily a top predator like most sport fish. The freshwater drum's feeding strategy may have an impact on their ability to ingest and bioaccumulate mercury at a higher rate than traditional sport fish species that forage on lower trophic level fish instead of shellfish. While looking at traditional sportfish only, whole-body mercury concentrations were closer to the concentrations observed at the river locations.

Figure 26. Lake Erie AOC Freshwater Drum vs. Other Species Whole Body Mercury Concentrations

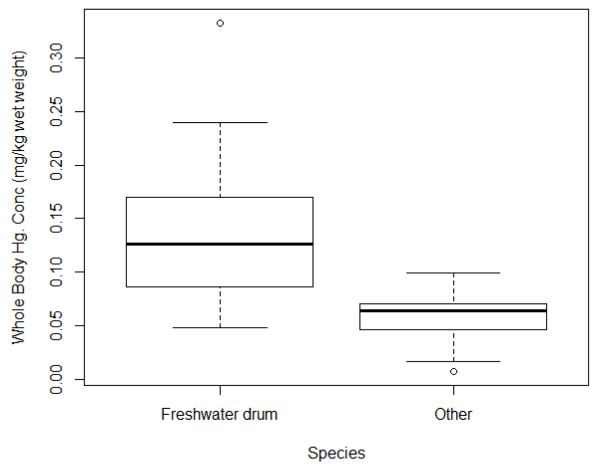
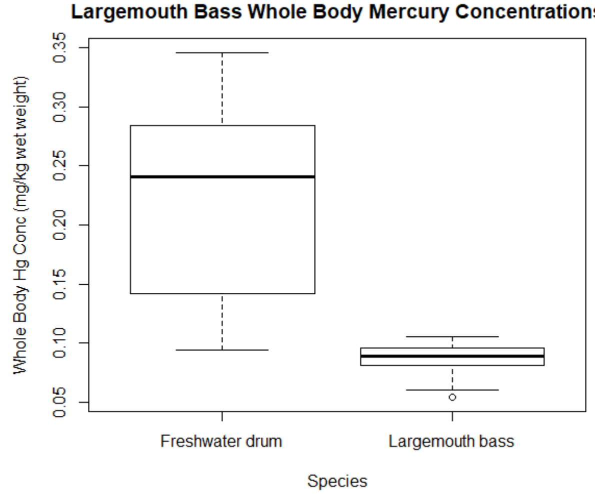


Figure 27. Lake Erie Reference Freshwater Drum vs. Largemouth Bass Whole Body Mercury Concentrations



Evaluation of the Cuyahoga River AOC BUI #1: Fish Consumption

Comparing the 2018 fish tissue results to the Cuyahoga River AOC BUI #1 fish tissue removal guidance, all species within the Cuyahoga River portion of the AOC (upstream of lacustuary zone) had contaminant concentrations that recommend fish consumption advisories the same or less stringent than *one meal per month* (Appendix C, Table 49). In 2018, only the RM 45.10 and 41.70 locations were used for the Cuyahoga River AOC locations as the RM 0.92 location is considered a lacustuary site and was grouped with the Lake Erie AOC sites. More downstream locations are needed for a better representation of the Cuyahoga River AOC fish tissue contaminants. In the Lake Erie affected waters of the AOC, all species that have Lake Erie specific advisories displayed the same or less stringent criteria than the current advisories (Appendix C, Table 50). Additionally, all species that do not have Lake Erie specific advisories met statewide fish consumption advice listed in Table 1. Although AOC locations generally had significantly higher contaminant concentrations than those found at reference locations, the data in this report supports the removal of BUI #1: fish consumption, which was removed in early 2019.

Determination of Ohio EPA Human Health Water Quality Standards Attainment

The Ohio EPA uses USEPA Water Quality Standards (WQS) guidance which base fish consumption advisories on waterbody-specific information in order to demonstrate an impairment of Clean Water Act section 101(a) "fishable" uses (USEPA, 2010). In this study, waterbodies in the Cuyahoga River were classified by their hydrologic unit twelve-digit code (HUC-12), and Lake Erie sites were classified by either an AOC location or a reference location. Contaminants for each HUC-12 code that were listed in the 2020 integrated report 303d list of impaired waters are displayed in Table 15. Only composited fillet samples were used to determine attainment of Human Health WQS. Ohio EPA lists six contaminants in Table 16 which are used to determine the attainment status. Three narratives can be assigned to a HUC-12 area based on the fish contaminant concentrations: Category 1 is assigned to unimpaired sites where concentrations are below the WQS criterion, Category 5 is assigned to impaired sites where concentrations are above the WQS criterion, and Category 3 is assigned to sites that do not meet minimum data requirements, or data is not available.

Table 15. Waters not supporting human health WQS use because of fish tissue contaminant; listed in the 2020 Ohio EPA Integrated Report.

Contaminant	HUC-12 Code	HUC-12 Description	Section of stream	2018 Fish Tissue sample location
Historical	04110002 05 05 04110002 06 02 04110002 06 04 04110002 06 05	Willow Lake-Cuyahoga River Independence-Cuyahoga River Cuyahoga Heights-Cuyahoga River Cleveland-Cuyahoga River	Cuyahoga River -lower 24.16 miles	FTCS 06 (RM 9.78) & FTCS-07 (RM 0.92)
PCBs	04110002 04 05	Boston Run-Cuyahoga River	Cuyahoga River -RMs 42.27 - 24.16	FTCS-03 (RM 41.20)
PCBs	04110002 02 03	Fish Creek-Cuyahoga River	Cuyahoga River -RMs 56.82-42.27	FTCS-02 (RM 45.70)
PCBs	04110002 03 04	City of Akron-Little Cuyahoga River	Little Cuyahoga River - lower 7.09 miles	Not assessed

The purpose of the water quality criteria for the protection of human health (fish consumption) is to ensure levels of a chemical in water do not bioaccumulate in fish to levels harmful to people who catch and eat the fish (Ohio EPA, 2020). For streams in each assessment unit, a weighted average based on species and trophic level was calculated for each contaminant and compared to the values in Table 16. The formula for calculating the weighted average is displayed in Figure 28.

Table 16. Comparison between fish concentration values and fish contaminant advisory values (Ohio EPA, 2020)

Basin/Parameter	Fish concentration on which the WQS is based [1]	Range of fish concentrations triggering an "eat no more than one meal per week" advisory	Range of fish concentrations triggering an "eat no more than one meal per month" advisory
Lake Erie/PCB	23 µg/kg	**50 - 220 µg/kg**	**221 - 1,000 µg/kg**
Ohio River/PCB	54 µg/kg	**50 - 220 µg/kg**	**221 - 1,000 µg/kg**
Lake Erie/mercury	350 µg/kg	110 - 220 µg/kg	221 - 1,000 µg/kg
Ohio River/mercury	1,000 µg/kg	110 - 220 µg/kg	221 - 1,000 µg/kg
Lake Erie/DDT	140 µg/kg	**500 - 2,188 µg/kg**	**2,189 – 9,459 µg/kg**
Ohio River/DDT	320 µg/kg	**500 - 2,188 µg/kg**	**2,189 – 9,459 µg/kg**
Lake Erie/Chlordane	130 µg/kg	**500 - 2,188 µg/kg**	**2,189 – 9,459 µg/kg**
Ohio River/Chlordane	310 µg/kg	**500 - 2,188 µg/kg**	**2,189 – 9,459 µg/kg**
Lake Erie/Hexachlorobenzene	29 µg/kg	**800 - 3,499 µg/kg**	**3,500 - 15,099 µg/kg**
Ohio River/hexachlorobenzene	67 µg/kg	**800 - 3,499 µg/kg**	**3,500 - 15,099 µg/kg**
Lake Erie/mirex	88 µg/kg	**200 - 874 µg/kg**	**875 - 3,783 µg/kg**
Ohio River/mirex	200 µg/kg	**200 - 874 µg/kg**	**875 - 3,783 µg/kg**

Key	
Values	Advisory is less protective than the WQS criterion, WQS exceeded, water body impaired
Values	Advisory is more protective than WQS criterion, WQS not exceeded, no impairment from FCA
Values	Advisory may be more, or less, protective than WQS criterion

Figure 28. Weighted Average Formula Based on Species and Trophic Level Formula

For the Lake Erie Basin:

$$C_{avgLEB} = \frac{3.6 * C_3 + 11.4 * C_4}{15} = 0.27\ mg/kg$$

For the Ohio River Basin:

$$C_{avgORB} = \frac{11.8 * C_3 + 5.7 * C_4}{17.5} = 0.18\ mg/kg$$

Where:

C_3 = average concentration for trophic level 3

C_4 = average concentration for trophic level 4

All HUC-12 assessment units assessed in 2018 met applicable human health fish tissue WQS for DDT and mercury concentrations (Table 17). However, total PCB concentrations at every assessment unit except the two reference locations exceeded the PCB human health WQS criterion. Fish collected within the Cuyahoga River AOC displayed higher PCB concentrations than fish collected from Lake Erie. Fish collected at the sample location near the Akron WRF contained the highest total PCB concentrations at more than 20 times the current WQS. Total chlordane WQS for fish consumption was analyzed only at the two Lake Erie locations and the Chagrin river location but was not analyzed at any site in the Cuyahoga River AOC that Ohio EPA was the primary sample collector. All locations sampled for total chlordane displayed fish tissue concentrations well below the WQS criterion. The remaining parameters listed in Table 16 had very few, if any, concentrations above the laboratory detection limit and did not exceed the WQS based criteria.

Although the production-based discharge of PCBs was banned in 1977 and their manufacturing, processing, and distribution in commerce were banned in 1979, their tendency to remain in sediments allows PCBs to bioaccumulate in fish tissue to this day. This is evident in the PCB concentrations found in the Cuyahoga River AOC fish, where the WQS criterion was exceeded and concentrations were much higher than those at the two reference sites and the Lake Erie locations.

The U.S. Army Corps of Engineers (USACE) is required to maintain proper water depth of the federal navigation channel in the lower six miles of the Cuyahoga River by dredging accumulated fill material. Since dredged material has displayed potentially toxic concentrations of heavy metals, PCBs, and polycyclic aromatic hydrocarbons (PAHs), and may threaten water quality if discharged into Lake Erie, the Ohio EPA has denied the USACE a Clean Water Act section 404 permit and require the dredged material to be placed in confined, onshore disposal locations.

Table 17. Cuyahoga River and Lake Erie Water Quality Standards Calculations

HUC-12 Code / Location	Weighted DDT Average (ug/kg)	Weighted Hg Average (ug/kg)	Weighted PCB Average (ug/kg)	Weighted Chlordane Average (ug/kg)	Attainment Narrative, Contaminant
04110003 04 02 *Griswold Creek-Chagrin River* RM 5.54	2.943	130.285	5.335	0.574	Category 1
04110002 02 03 *Lake Rockwell-Cuyahoga River* RM 64.30	ND	293.985	21.678	N/A	Category 1
04110002 03 05 *Fish Creek-Cuyahoga River* (RM 45.10 site)	7.590	181.092	**68.972**	N/A	Category 5, PCBs
04110002 04 05 *Boston Run-Cuyahoga River* (RM 41.70)	13.376	137.989	**487.551**	N/A	Category 5, PCBs
04110002 06 05 *Cleveland-Cuyahoga River* RM 0.92)	11.144	123.043	**121.803**	N/A	Category 5, PCBs
Lake Erie AOC sites	12.197	194.450	**47.361**	3.181	Category 5, PCBs
Lake Erie Reference sites	16.513	186.079	**92.967**	2.911	Category 5, PCBs

WQS in Lake Erie drainage basin:140 ug/kg DDT; 350 ug/kg Hg; 23 ug/kg PCBs; 310 ug/kg Chlordane
Bold indicates non-attainment
N/A = Not analyzed
ND = Contaminant was “not detected” in all samples

Evaluation of the Cuyahoga River AOC BUI #4: Fish Tumors or Other Deformities

BUI #4 for the Cuyahoga River AOC states the prevalence of fish tumors or other deformities in the Cuyahoga River exceed the rates at unimpacted control sites (Ohio EPA, 2017a). Deformities, eroded fins, lesions, and tumors (DELTs) are commonly observed in a higher proportion of fish located in highly contaminated waters (Ohio EPA, 1987b). Figure 29 displays DELT percentages compared to BUI #4 delisting criteria. Data for this figure used both fish tissue site data, as well as other fish community biology survey data. When two surveys were performed at the same site in one year, the results were averaged. Five of the twenty-one surveys in the Cuyahoga River and one sampling location in Lake Erie exceeded the BUI #4 criteria. Of the four reference sites, only the Cuyahoga River at RM 64.30 exceeded the BUI #4 delisting criteria. Legacy pollutants like PCBs, PAHs, and heavy metals that remain in the Cuyahoga River sediments (Zeitler, 2001) and other water quality issues are likely the cause of elevated DELT anomalies.

Figure 29. 2018-2019 Percent Fish DELT Anomalies by Location

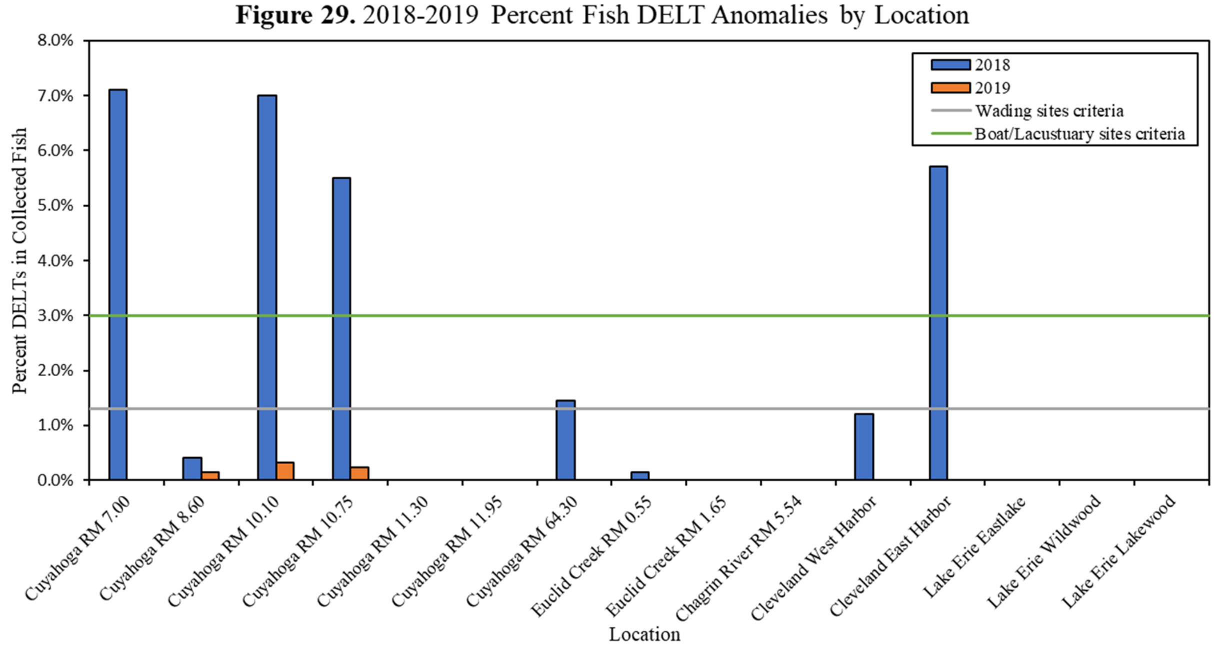
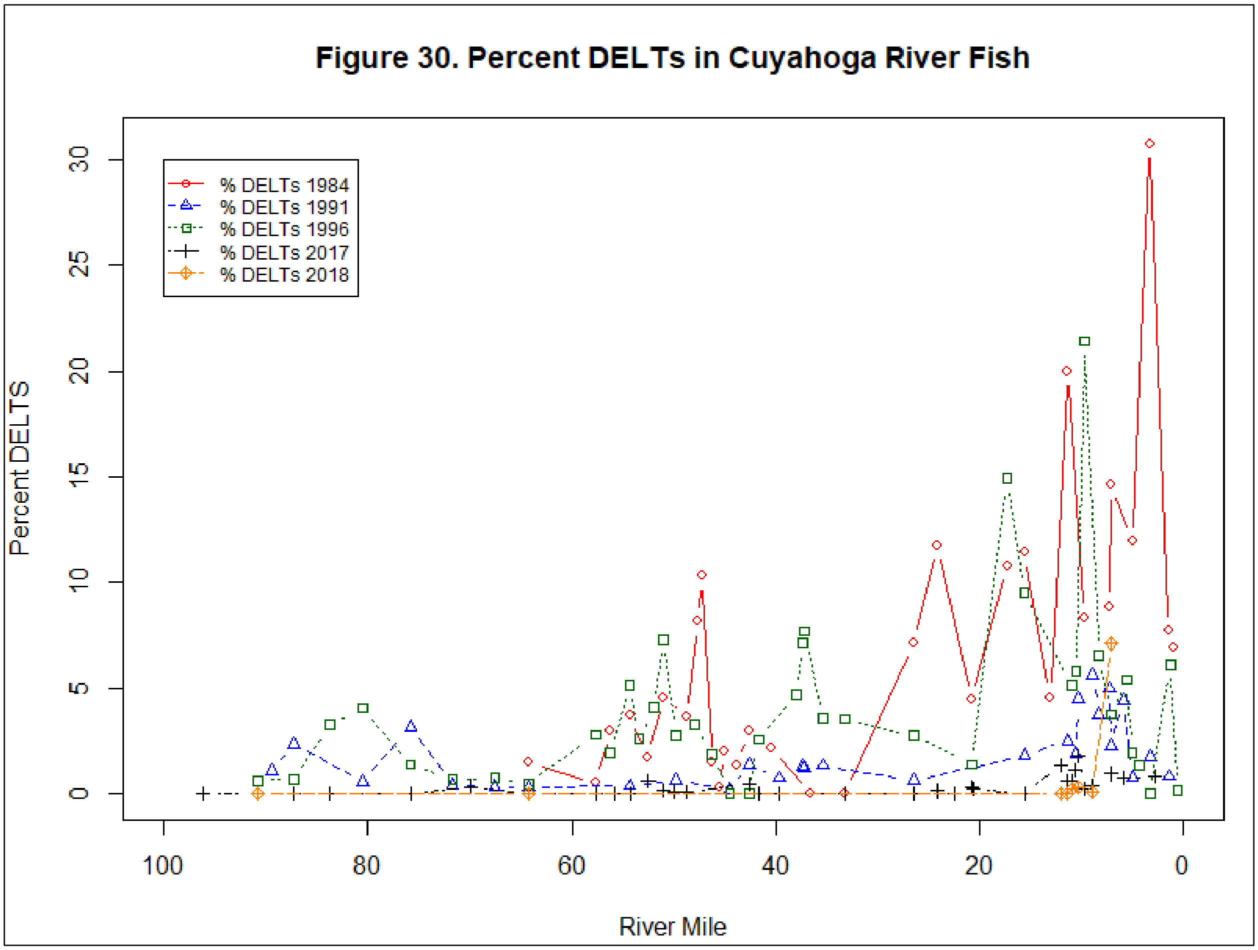


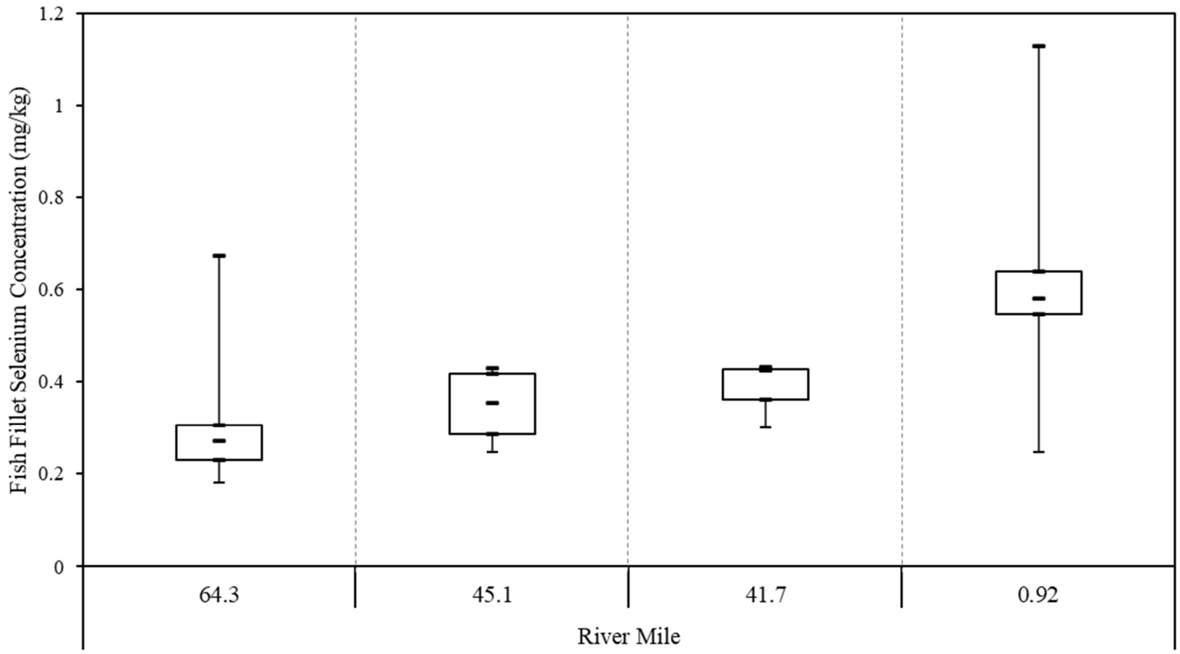
Figure 30 below displays the percentage of DELTs observed in the Cuyahoga River during each of Ohio EPA's major watershed assessments. NEORSD data was used in 2018 at locations where Ohio EPA did not conduct a fish community survey. Fish DELTs were observed in nearly every sampling event in an alarming proportion of the samples during the 1984 assessment year. Regulations to limit point source water pollution and improve statewide water quality were developed due to the passing of the Clean Water Act in the late 1970s. As a result of statewide regulations to protect receiving waterways, DELT anomalies in Cuyahoga River fish are far less frequent, although three sample locations exceeded the delisting criteria of <3% in the Cuyahoga River portion of the AOC (Figure 29).



Selenium Analysis: *Composite Fillet Samples*

Selenium is another metal that was analyzed in composite fish fillet samples in the Cuyahoga River during this study. Similar to mercury, selenium has the ability to bioaccumulate in fish and wildlife and is toxic at high concentrations (USGS, 2005). Figure 31 below displays an increase in median fish fillet selenium concentrations as the river flows downstream. Even though the highest concentrations occurred within the AOC section of the Cuyahoga River, all sample locations have unrestricted fish consumption advisory values (<2.5 mg/kg) based on the State of Ohio Cooperative Tissue Monitoring Program Sport Fish Tissue Consumption Advisory Program (2010).

Figure 31. Cuyahoga River Selenium Concentrations by River Mile
(Max, 75th Pctile., Median, 25th Pctile., Min)



Conclusions

Fish tissue samples from Lake Erie, the Cuyahoga River, and the Chagrin River were analyzed for PCB, pesticide, mercury, and selenium concentrations and compared to past studies dating back to 1989. Contaminant concentrations varied both among sample locations, species, and historically, but trends were observed.

Generally, total and lipid-normalized PCB fish tissue concentrations were greater in AOC locations than the selected reference sites (Figures 4 and 9) with most comparisons demonstrating a statistically significant difference. PCB concentrations were generally less in fish collected in 2018 than those from the 2008 study, with the river reference locations remaining relatively low. Fish collected in 2018 at the AOC locations displayed a decline in lipid-normalized PCB concentrations from the 2005 study, with some locations having the lowest PCB concentrations measured during this study. PCB concentrations were highest in bottom dwelling fish species (Figures 7 and 8) which suggests anglers commonly seeking sport fishing species are at less risk of PCB exposure.

Risk assessments utilizing both the noncancer hazard index and the cancer potency factor indicate the potential for adverse health effects from eating fish contaminated with PCBs from the Lake Erie AOC, Lake Erie reference, and Cuyahoga River AOC locations (Table 6). The river reference locations did not demonstrate the potential for adverse health effects for the first time during the course of this study. With a sufficient data set, observed concentrations would result in fish consumption advisories more stringent than the statewide advice listed in Table 1, but were not more stringent than those currently in place for site specific advisories listed in Table 2 (Figures 5 and 6).

Organochlorine pesticides were also detected in many of the composite fillet samples. However, when assessed using available reference doses and cancer potency factors for chlordane and DDT and its metabolites, lifetime exposure at the measured concentrations falls within accepted risk guidelines.

The results obtained from this study indicate that mercury contamination may be widespread and not just associated with fish found in the AOC. Composite fillet and whole-body fish tissue concentrations of mercury in samples collected from reference sites were generally equal to or greater than those found in the AOC. The 2018 results also indicate that although some of the concentrations measured were high enough to warrant a fish consumption advisory, they were all below the U.S. EPA human health criterion for methylmercury. The noncancer hazard index for both the AOC and reference sites also did not indicate a high enough risk to be of concern. Concentrations of mercury in fish tissue were higher upstream of the Cuyahoga AOC than those found in similar species in the ship channel (RM 0.92) (Figure 20), suggesting there is not an adverse impact from municipal WWTPs. Selenium concentrations at four Cuyahoga River locations displayed slightly higher concentrations in the lower Cuyahoga River (Figure 31) than the upper river; however, all concentrations were well below recommended consumption advisories.

Higher mercury concentrations were observed in sport fish species within the AOC than bottom feeding species (Figures 18 and 19) and have the potential to pose an increased exposure risk to anglers who pursue sport fish. Lake Erie sites where whole-body mercury concentrations were higher than previous studies may have been attributable to the collection of freshwater drum as the primary sport fish, as freshwater drum had significantly higher mercury concentrations than other sport fish at the same locations (Figures 26 and 27). The collected freshwater drum were much older than others collected in the sport fish category, which may result in a higher overall mercury concentration due to bioaccumulation over time. The freshwater drum's feeding strategies also may have an impact on their ability to ingest and bioaccumulate mercury at a higher rate than traditional sport fish species that forage on lower trophic level fish. The collection of traditional sport fishing species may have resulted in lower overall whole-body mercury concentrations.

Results from this study support the delisting of BUI #1 fish consumption in the Cuyahoga River AOC. Species within the Cuyahoga River portion of the AOC demonstrated contaminant concentrations that recommend fish consumption advisories the same or less stringent than *one meal per month* and in the Lake Erie affected waters of the AOC, all species that have Lake Erie specific advisories, displayed the same or less stringent criteria than the current advisories. All HUC-12 watersheds and Lake Erie locations met applicable DDT, mercury, and chlordane (where collected) human health fish tissue WQS criteria (Table 17). However, the Chagrin River location is the only location which met its applicable human health fish tissue WQS for all collected contaminants and was assigned a category 1 narrative. All Cuyahoga River HUC-12 watersheds, and both the Lake Erie AOC and reference locations exceeded the human health WQS PCB criteria and therefore received category 5 "impaired" narratives.

Occurrences of fish DELTs in the Cuyahoga River have drastically decreased since the Ohio EPA's first watershed study in 1984 (Figure 30). Proportions of fish DELTs in the early bioassessments commonly exceeded 10 percent of the collected fish, which is now a rarity. Fish DELTs now are meeting BUI #4 requirements during most sampling events; however, there were still multiple locations sampled in 2018 and 2019 which exceeded the BUI #4 delisting criterion. The decline in fish DELT frequencies are likely due to the improvements in water quality the Cuyahoga River has experienced over the last 35 years, although legacy pollutants like PCBs are still an issue.

Overall, the results from this study suggest there are still some problems associated with contaminated fish tissue throughout the greater Cleveland area. Some problems such as mercury contamination may not be limited to the AOC, as samples collected outside of the AOC were also found in some instances to have contaminant concentrations greater than those inside the AOC. It also does not appear that either of the major municipal WWTPs discharging to the Cuyahoga River is adversely impacting fish contaminant concentrations, as higher concentrations were observed in the upstream reaches. Future fish tissue monitoring from these areas is needed to further track changes in contaminants, human health fish tissue WQS attainment, and DELT anomalies over time. Additional sampling will also fill in sampling gaps, evaluate the validity of current fish consumption advisories, and further evaluate the delisting of BUI #1: fish consumption. This will help to determine the effectiveness of pollutant reduction efforts, measure the degradation of pollutants already present in the environment, and provide necessary information for updating the Ohio Sport Fish Consumption Advisory Program and the Cuyahoga River AOC BUIs.

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Northeast Ohio Regional Sewer District

2018 Cuyahoga River and Nearshore Lake Erie
Fish Tissue Study Appendices

Northeast Ohio Regional Sewer District
Water Quality and Industrial Surveillance
Environmental Assessment Division

Ohio Environmental Protection Agency

July 2020

Appendix A. Completed Collection Forms

2018 Fish Tissue Study Sample Form					
Date:	8/13/2018				
Location:	Cuyahoga River RM 64.30 (FTCS-01) (F01S19)				
Collection Method:	Boat Electrofish				
Names of Samplers:	M. Matteson, J. Telep, H. Boesinger, M. Jenkins				
Weather:	Sunny, dry, mid to upper 80s				
Comments:	Ohio EPA collected fish				
Composite Fillet Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species 1					
18081304-01	Northern Pike	872	3950		Ohio EPA
Sport Fish Species 2					
18081304-02	Smallmouth bass	410	850		Ohio EPA
18081304-02	Smallmouth bass	371	704		Ohio EPA
Sport Fish Species 3					
18081304-03	Smallmouth bass	285	268		Ohio EPA
18081304-03	Smallmouth bass	286	346		Ohio EPA
18081304-03	Smallmouth bass	289	334		Ohio EPA
18081304-03	Smallmouth bass	297	328		Ohio EPA
Sport Fish Species 4					
18081304-05	Rock bass	196	152		Ohio EPA
18081304-05	Rock bass	186	116		Ohio EPA
Bottom Feeder Species 1					
18081304-04	Yellow bullhead	223	164		Ohio EPA
18081304-04	Yellow bullhead	240	194		Ohio EPA
18081304-04	Yellow bullhead	216	144		Ohio EPA
Bottom Feeder Species 2					
18081304-06	White sucker	405	590		Ohio EPA
Bottom Feeder Species 3					
18081304-07	White sucker	405	650		Ohio EPA
Bottom Feeder Species 4					
18081304-08	Common carp	700	4850		Ohio EPA

Whole Body Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species					
R-1808100003	Rock bass	160	71		8/14/2018
R-1808100004	Rock bass	165	70		8/14/2018
R-1808100005	Rock bass	155	65		8/14/2018
R-1808100006	Rock bass	161	72		8/14/2018
R-1808100007	Rock bass	162	76		8/14/2018
R-1808100008	Rock bass	152	56		8/14/2018
R-1808100009	Rock bass	168	89		8/14/2018
R-1808100010	Rock bass	159	69		8/14/2018
R-1808100011	Rock bass	154	60		8/14/2018
R-1808100012	Rock bass	152	63		8/14/2018
R-1808100013	Rock bass	160	65		8/14/2018
R-1808100014	Rock bass	153	60		8/14/2018
Other Fish Collected					

2018 Fish Tissue Study Sample Form					
Date:	6/20/2018				
Location:	Ust. Gorge Dam RM 45.10 (FTCS-02) (F01S74)				
Collection Method:	Boat Electrofish				
Names of Samplers:	Andrew Phillips (OEPA)				
Weather:	Overcast				
Comments:	Ohio EPA collected fish				
Composite Fillet Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species 1					
18071006-01	Smallmouth bass	350	590		Ohio EPA
18071006-01	Smallmouth bass	370	610		Ohio EPA
Sport Fish Species 2					
18071006-02	Largemouth bass	420	1060		Ohio EPA
18071006-02	Largemouth bass	395	1000		Ohio EPA
Sport Fish Species 3					
18071006-03	Largemouth bass	355	730		Ohio EPA
18071006-03	Largemouth bass	330	490		Ohio EPA
Sport Fish Species 4					
18071006-04	Yellow perch	200	100		Ohio EPA
18071006-04	Yellow perch	205	110		Ohio EPA
18071006-04	Yellow perch	205	100		Ohio EPA
Sport Fish Species 5					
18071006-05	White perch	225	150		Ohio EPA
18071006-05	White perch	190	90		Ohio EPA
Sport Fish Species 6					
18071006-06	Black crappie	200	100		Ohio EPA
Sport Fish Species 7					
18071006-08	Bluegill sunfish	137	42		Ohio EPA
18071006-08	Bluegill sunfish	125	36		Ohio EPA
18071006-08	Bluegill sunfish	127	40		Ohio EPA
18071006-08	Bluegill sunfish	135	44		Ohio EPA
18071006-08	Bluegill sunfish	127	42		Ohio EPA
18071006-08	Bluegill sunfish	134	46		Ohio EPA
Bottom Feeder Species 1					
18071006-07	White sucker	410	624		Ohio EPA
Bottom Feeder Species 2					
18071006-09	Common carp	690	5425		Ohio EPA
18071006-09	Common carp	700	5500		Ohio EPA
18071006-09	Common carp	712	5200		Ohio EPA
18071006-09	Common carp	690	5525		Ohio EPA
18071006-09	Common carp	712	7675		Ohio EPA
Bottom Feeder Species 3					
18071006-10	Common carp	682	4300		Ohio EPA
18071006-10	Common carp	676	4400		Ohio EPA

18071006-10	Common carp	661	3850		Ohio EPA
18071006-10	Common carp	640	3725		Ohio EPA
18071006-10	Common carp	655	3550		Ohio EPA

Whole Body Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species					
R-180609003	Pumpkinseed	175	84		
R-180619004	Bluegill	170	86		
R-180619005	Pumpkinseed	165	88		
R-180619006	Pumpkinseed	170	81		
R-180619007	Pumpkinseed	155	70		
R-180619008	Bluegill	155	68		
R-180619009	Bluegill	155	55		
R-180619010	Bluegill	155	64		
R-180619011	Bluegill	152	52		
R-180619012	Pumpkinseed	142	60		
R-180619013	Bluegill	145	60		
R-180619014	Bluegill	140	58		
Other Fish Collected					

2018 Fish Tissue Study Sample Form					
Date:	10/15/2019				
Location:	Cuyahoga River RM 41.20 (FTCS-03) (F01W64)				
Collection Method:	Boat Electrofish				
Names of Samplers:	Ben Rich (Ohio EPA)				
Weather:					
Comments:	Ohio EPA collected fish. Upstream of Akron WWTP				
Composite Fillet Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species 1					
19101501-01	Smallmouth bass	362	650		
19101501-01	Smallmouth bass	370	750		
19101501-01	Smallmouth bass	350	558		
Bottom Feeder Species 1					
19101501-02	Common carp	650	5600		
19101501-02	Common carp	703	4650		
19101501-02	Common carp	666	4375		
19101501-02	Common carp	665	4450		
19101501-02	Common carp	692	4550		
Bottom Feeder Species 2					
19101501-03	Common carp	610	3125		
19101501-03	Common carp	620	3525		
19101501-03	Common carp	599	2900		
19101501-03	Common carp	595	3100		

Whole Body Samples					
Sample #	Species	Length (mm)	Weight (g)	DELTs	Processed
Sport Fish Species					
Other Fish Collected					

2018 Fish Tissue Study Sample Form

Date:	10/25/2018
Location:	Cuyahoga RM 9.78 (FTCS-06) (F99Q02)
Collection Method:	Boat Electrofish
Names of Samplers:	M. Matteson/K. Amidon
Weather:	
Comments:	

Composite Fillet Samples

Sample #	Species	Length (mm)	Weight (g)	DELTs	Processed
Sport Fish Species 1					

Sport Fish Species 2					

Bottom Feeder Species 1					
Bottom Feeder Species 2					

Whole Body Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species					
R-1810250002	Smallmouth	310	430		10/26/2018
R-1810250003	Smallmouth	300	418		10/26/2018
R-1810250004	Smallmouth	275	286		10/26/2018
R-1810250005	Smallmouth	250	206		10/26/2018
R-1810250006	Smallmouth	225	142		10/26/2018
R-1810250007	Smallmouth	165	65		10/26/2018
R-1810250008	Smallmouth	157	52		10/26/2018
R-1810250009	Pumpkinseed	115	28		10/26/2018
R-1810250010	White Crappie	250	200		10/26/2018
R-1810250011	Black Crappie	195	110		10/26/2018
Other Fish Collected					

2018 Fish Tissue Study Sample Form					
Date:	10/2/2018				
Location:	Cuyahoga Ship Channel RM 0.92 (FTCS-07) (F01W47)				
Collection Method:	Boat Electrofish				
Names of Samplers:	Andrew Philips (Ohio EPA)				
Weather:					
Comments:	Ohio EPA collected fish				
Composite Fillet Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species 1					
18101017-01	Largemouth bass	383	950		Ohio EPA
18101017-01	Largemouth bass	360	784		Ohio EPA
18101017-01	Largemouth bass	352	660		Ohio EPA
Sport Fish Species 2					
18101017-02	Largemouth bass	345	720		Ohio EPA
18101017-02	Largemouth bass	331	640		Ohio EPA
Sport Fish Species 3					
18101017-08	Rock bass	205	180		Ohio EPA
18101017-08	Rock bass	203	178		Ohio EPA
18101017-08	Rock bass	212	200		Ohio EPA
Bottom Feeder Species 1					
18101017-03	Common carp	690	4650		Ohio EPA
18101017-03	Common carp	725	6700		Ohio EPA
Bottom Feeder Species 2					
18101017-04	Common carp	600	3750		Ohio EPA
18101017-04	Common carp	603	3200		Ohio EPA
18101017-04	Common carp	608	4600		Ohio EPA
Bottom Feeder Species 3					
18101017-05	Common carp	555	2750		Ohio EPA
18101017-05	Common carp	515	2375		Ohio EPA
Bottom Feeder Species 4					
18101017-06	Common carp	730	7300		Ohio EPA
Bottom Feeder Species 5					
18101017-07	Brown bullhead	315	482		Ohio EPA

Whole Body Samples					
Sample #	Species	Length (mm)	Weight (g)	DELTs	Processed
Sport Fish Species					
R-1810030001	Rockbass	210	200		10/3/2018
R-1810030002	Rockbass	162	82		10/3/2018
R-1810030003	Rockbass	120	32		10/3/2018
R-1810030004	Bluegill	152	67		10/3/2018
R-1810030005	Bluegill	170	103		10/3/2018
R-1810030006	Bluegill	152	76		10/3/2018
R-1810030007	Bluegill	100	20		10/3/2018
R-1810030008	Rockbass	195	144		10/3/2018
R-1810030009	Green Sunfish	150	70		10/3/2018
R-1810030010	Pumpkinseed Sunfish	111	28		10/3/2018
R-1810030011	Green/Pumpkinseed Hybrid	165	98		10/3/2018
R-1810030015	Rockbass	200	180		10/3/2018
Other Fish Collected					

2018 Fish Tissue Study Sample Form					
Date:	9/5/2018 1100hrs				
Location:	Lake Erie West Harbor (FTCS-08)				
Collection Method:	Boat Electrofish				
Names of Samplers:	M. Matteson/K. Amidon/J. Telep				
Weather:	Sunny/Hot				
Comments:					
Composite Fillet Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**

Bottom Feeder Species 1 L-1809060019					
21	Common Carp	510	2020		9/6/2018
22	Common Carp	500	1600		9/6/2018
23	Common Carp	490	1640		9/6/2018
24	Common Carp	510	2200		9/6/2018
Bottom Feeder Species 2 L-1819160020					
25	Yellow Bullhead	290	390		9/6/2018
26	Yellow Bullhead	270	290		9/6/2018
27	Yellow Bullhead	270	240		9/6/2018

Sport Fish Species 1 L-1809060021					
14	Largemouth Bass	420	1300		9/6/2018
15	Largemouth Bass	450	1620		9/6/2018
16	Largemouth Bass	450	1360		9/6/2018

Sport Fish Species 2 L-1809060022					
17	Largemouth Bass	410	1060		9/6/2018
18	Largemouth Bass	400	1040		9/6/2018
19	Largemouth Bass	380	920		9/6/2018
20	Largemouth Bass	395	780		9/6/2018

Whole Body Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species					
L-1809060001	Largemouth Bass	340	610		9/6/2018
L-1809060002	Largemouth Bass	330	620		9/6/2018
L-1809060003	Largemouth Bass	340	658		9/6/2018
L-1809060004	Largemouth Bass	345	675		9/6/2018
L-1809060005	Largemouth Bass	325	590		9/6/2018
L-1809060006	Largemouth Bass	350	650		9/6/2018
L-1809060007	Largemouth Bass	340	580		9/6/2018
L-1809060008	Largemouth Bass	345	690		9/6/2018
L-1809060009	Largemouth Bass	340	562		9/6/2018
L-1809060010	Largemouth Bass	335	632		9/6/2018
L-1809060011	Largemouth Bass	325	562		9/6/2018
L-1809060012	Largemouth Bass	295	362		9/6/2018
Other Fish Collected					
L-1809060013	Bluegill	172	101		9/6/2018
L-1809060014	Walleye	470	800		9/6/2018
L-1809060015	Yellow Perch	180	72		9/6/2018
L-1809060016	Yellow Perch	181	60		9/6/2018
L-1809060017	Yellow Perch	185	90		9/6/2018

2018 Fish Tissue Study Sample Form					
Date:	9/12/2018				
Location:	Lake Erie East Harbor (FTCS-09)				
Collection Method:	Boat Electrofish				
Names of Samplers:	K. Amidon/J. Telep/S. Ampomah/K. Kallenborn				
Weather:	Overcast				
Comments:					
Composite Fillet Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**

Bottom Feeder Species 1 L-1809100013					
1	Common Carp	720	7257		
2	Common Carp	660	5443		
3	Common Carp	680	4990		
Bottom Feeder Species 2 L-1809100014					
1	Common Carp	610	4082		
2	Common Carp	610	3629		
3	Common Carp	650	4763		
4	Common Carp	600	5216		
Sport Fish Species 1 L-1809100015					
1	Largemouth	420	1090	1 - E	
2	Largemouth	420	1310		
3	Largemouth	380	1000		
4	Largemouth	390	1020		

Sport Fish Species 2 L-1809100016					
1	Smallmouth	420	1020	1 - E	
2	Smallmouth	410	1080		
3	Smallmouth	400	910		
4	Smallmouth	360	750		

Whole Body Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species					
L-1809100001	Freshwater Drum	480	1310		
L-1809100002	Freshwater Drum	460	1120		
L-1809100003	Freshwater Drum	510	1800		
L-1809100004	Freshwater Drum	510	1750		
L-1809100005	Freshwater Drum	450	1200		
L-1809100006	Freshwater Drum	470	1310		
L-1809100007	Freshwater Drum	530	2020		
L-1809100008	Freshwater Drum	480	1220		
L-1809100009	Freshwater Drum	490	1700		
L-1809100010	Freshwater Drum	470	1220		
L-1809100011	Freshwater Drum	510	1380	1 - L	
L-1809100012	Freshwater Drum	530	1810		
Other Fish Collected					
L-1809130001	Yellow Perch	200	98		
L-1809130002	Spotted Sucker	510	1610		
L-1809130003	Yellow Bullhead	260	280		
L-1809130004	Rainbow Trout	380	590		

2018 Fish Tissue Study Sample Form					
Date:	9/27/2018				
Location:	Lake Erie - Eastlake (FTCS-10)				
Collection Method:	Boat Electrofish				
Names of Samplers:	K. Amidon/J. Telep				
Weather:	Overcast				
Comments:	Difficult finding 12 whole body in same size class				
Composite Fillet Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species 1 L-1809270019					
19	Smallmouth	430	1410		9/28/2018
20	Smallmouth	440	1600		9/28/2018
21	Smallmouth	450	1510		9/28/2018

Sport Fish Species 2 L-1809270020					
22	Rockbass	210	20		9/28/2018
23	Rockbass	230	23		9/28/2018
24	Rockbass	200	20		9/28/2018
25	Rockbass	210	19		9/28/2018

Bottom Feeder Species 1 L-1809270017					
13	Common Carp	490	1650		9/28/2018
14	Common Carp	520	1900		9/28/2018
15	Common Carp	500	1650		9/28/2018
Bottom Feeder Species 2 L-1809270018					
16	Common Carp	570	2730		9/28/2018
17	Common Carp	580	2730		9/28/2018
18	Common Carp	590	2900		9/28/2018

Whole Body Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species					
L-1809270001	Freshwater Drum	590	1510		9/28/2018
L-1809270002	Freshwater Drum	470	1470		9/28/2018
L-1809270003	Freshwater Drum	480	1520		9/28/2018
L-1809270004	Freshwater Drum	460	1200		9/28/2018
L-1809270005	Freshwater Drum	420	800		9/28/2018
L-1809270006	Freshwater Drum	470	1480		9/28/2018
L-1809270007	Freshwater Drum	490	1250		9/28/2018
L-1809270008	Freshwater Drum	430	1000		9/28/2018
L-1809270009	Freshwater Drum	470	810		9/28/2018
L-1809270010	Freshwater Drum	470	1390		9/28/2018
L-1809270011	Freshwater Drum	440	980		9/28/2018
L-1809270012	Freshwater Drum	430	950		9/28/2018
Other Fish Collected					

2018 Fish Tissue Study Sample Form					
Date:	9/17/2018				
Location:	Wildwood (FTCS-11)				
Collection Method:	Boat Electrofish				
Names of Samplers:	M. Matteson/J. Telep/H. Boesinger/M. DeGarmo				
Weather:	Overcast				
Comments:					
Composite Fillet Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species 1 L-1809180015 Dup L-1809180019					
20	Walleye	520	1200		9/18/2018
21	Walleye	510	1290		9/18/2018
22	Walleye	500	1180		9/18/2018

Sport Fish Species 2 L-1809180016 Dup L-1809180020					
23	Largemouth Bass	370	970		9/18/2018
24	Largemouth Bass	390	1200		9/18/2018
25	Largemouth Bass	380	900		9/18/2018

Bottom Feeder Species 1 L1809180013 Dup L-1809180017					
13	Common Carp	630	3750		9/18/2018
14	Common Carp	660	3650		9/18/2018
15	Common Carp	690	4000		9/18/2018
Bottom Feeder Species 2 L-1809180014 Dup L-1809180018					
16	Brown Bullhead	350	648		9/18/2018
17	Brown Bullhead	350	575		9/18/2018
18	Brown Bullhead	360	538		9/18/2018
19	Brown Bullhead	350	710		9/18/2018

Whole Body Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species					
L-1809180001	Freshwater Drum	420	1040		9/18/2018
L-1809180002	Freshwater Drum	450	1340		9/18/2018
L-1809180003	Freshwater Drum	455	1190		9/18/2018
L-1809180004	Freshwater Drum	450	1310		9/18/2018
L-1809180005	Freshwater Drum	465	1550		9/18/2018
L-1809180006	Freshwater Drum	460	1250		9/18/2018
L-1809180007	Freshwater Drum	475	1600		9/18/2018
L-1809180008	Freshwater Drum	470	1475		9/18/2018
L-1809180009	Freshwater Drum	450	1200		9/18/2018
L-1809180010	Freshwater Drum	500	1600		9/18/2018
L-1809180011	Freshwater Drum	455	1500		9/18/2018
L-1809180012	Freshwater Drum	420	1000		9/18/2018
Other Fish Collected					

2018 Fish Tissue Study Sample Form

Date:	9/20/2018
Location:	Lake Erie - Lakewood (FTCS-12)
Collection Method:	Boat Electrofish
Names of Samplers:	M. Matteson/K. Amidon/M. Meany
Weather:	Overcast
Comments:	

Composite Fillet Samples

Sample #	Species	Length (mm)	Weight (g)	DELTs	Processed
Sport Fish Species 1 L-1809200065					
16	Smallmouth Bass	370	830		9/21/2018
17	Smallmouth Bass	370	725		9/21/2018
18	Smallmouth Bass	370	790		9/21/2018

Sport Fish Species 2 L1809200066					
13	Largemouth Bass	400	1050		9/21/2018
14	Largemouth Bass	430	1500		9/21/2018
15	Largemouth Bass	430	1475		9/21/2018

Bottom Feeder Species 1 L-1809200063					
22	Common Carp	490	1820		9/21/2018
23	Common Carp	500	1920		9/21/2018
24	Common Carp	490	1800		9/21/2018
Bottom Feeder Species 2 L-1809200064					
19	Channel Catfish	480	1000		9/21/2018
20	Channel Catfish	500	1680		9/21/2018
21	Channel Catfish	480	1400		9/21/2018

Whole Body Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species					
L-1809200001	Largemouth Bass	320	520		9/21/2018
L-1809200002	Largemouth Bass	320	580		9/21/2018
L-1809200003	Largemouth Bass	340	700		9/21/2018
L-1809200004	Largemouth Bass	340	665		9/21/2018
L-1809200005	Largemouth Bass	330	670		9/21/2018
L-1809200006	Largemouth Bass	325	635		9/21/2018
L-1809200007	Largemouth Bass	340	580		9/21/2018
L-1809200008	Largemouth Bass	340	735		9/21/2018
L-1809200009	Largemouth Bass	330	640		9/21/2018
L-1809200010	Largemouth Bass	320	565		9/21/2018
L-1809200011	Largemouth Bass	325	560		9/21/2018
L-1809200012	Largemouth Bass	330	580		9/21/2018
Other Fish Collected					

2018 Fish Tissue Study Sample Form					
Date:	9/24/2018				
Location:	Chagrin River - Daniels Park (FTCS-13) (502400)				
Collection Method:	Longline Ectrofish				
Names of Samplers:	M. Matteson/K. Amidon/H. Boesinger				
Weather:	Overcast/Windy				
Comments:					
Composite Fillet Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species 1 R-1809250021					
13	Smallmouth Bass	257	256		9/25/2018
14	Smallmouth Bass	241	183		9/25/2018
15	Smallmouth Bass	234	175		9/25/2018

Sport Fish Species 2 R-1809250022					
16	Rockbass	191	130		9/25/2018
17	Rockbass	175	100		9/25/2018
18	Rockbass	178	105		9/25/2018
19	Rockbass	173	90		9/25/2018

Bottom Feeder Species 1 R-1809250018					
20	Golden Redhorse	399	650		9/25/2018
21	Golden Redhorse	389	700		9/25/2018
22	Golden Redhorse	399	690		9/25/2018
23	Golden Redhorse	394	690		9/25/2018
Bottom Feeder Species 2 R-1809250019					
24	Golden Redhorse	434	920		9/25/2018
25	Golden Redhorse	422	890		9/25/2018

Whole Body Samples					
Sample #	**Species**	**Length (mm)**	**Weight (g)**	**DELTs**	**Processed**
Sport Fish Species					
R-1809250002	Walleye	127	27		9/25/2018
R-1809250003	Walleye	152	22		9/25/2018
R-1809250004	Walleye	147	23		9/25/2018
R-1809250005	Walleye	155	30		9/25/2018
R-1809250006	Walleye	142	19		9/25/2018
R-1809250007	Walleye	137	18		9/25/2018
R-1809250008	Walleye	142	16		9/25/2018
R-1809250009	Walleye	127	11		9/25/2018
R-1809250011	Walleye	155	20		9/25/2018
R-1809250012	Walleye	137	19		9/25/2018
R-1809250013	Walleye	132	21		9/25/2018
R-1809250014	Walleye	140	22		9/25/2018
Other Fish Collected					

Appendix B. QA/QC protocols

Approximately 10% of the composite fillet and whole-body samples were submitted as blind duplicates to both NEORSD Analytical Services and TestAmerica to run as duplicate samples. The duplicate samples were made by splitting the homogenized powder that was prepared by blending of the fish tissue samples. Relative percent difference (RPD) was used to determine the degree of discrepancy between the primary and duplicate sample (Formula 1) as outlined in the Ohio EPA *Surface Water Field Sampling Manual for water quality parameters and flows* (2018) QA/QC protocols.

Formula 1: $$RPD = \left(\frac{|X-Y|}{((X+Y)/2)} \right) * 100$$

X= is the concentration of the parameter in the primary sample
Y= is the concentration of the parameter in the duplicate sample

The acceptable percent RPD is based on the ratio of the sample concentration and detection limit (Formula 2) (Ohio EPA, 2018a).

Formula 2: $$\text{Acceptable \% RPD} = [(0.9465X^{-0.344})*100] + 5$$

X = sample/detection limit ratio

Those RPDs that were higher than acceptable may indicate potential problems with sample collection or analysis, and as a result, the data was rejected and not used for comparisons. Comparisons of duplicate samples, their relative percent differences, and their respective qualifiers are shown in Tables 1 and 2 below.

Table 1. Fillet sample duplicates

Sample location	Sample ID		Parameter	Unit	MDL	Result	Duplicate Result	X: Result/ MDL	Acceptable RPD %	Actual RPD %	Qualifier	Acceptable/ Fail
FTCS-11 Lake Erie Wildwood	L-1809180013	Common carp	Hg	mg/kg	0.001	0.147	0.137	147.00	22.004	7.042		Acceptable
	L-1809180014	Brown bullhead	Hg	mg/kg	0.001	0.092	0.1	92.00	24.979	8.333		Acceptable
	L-1809180015	Walleye	Hg	mg/kg	0.001	0.132	0.129	132.00	22.646	2.299		Acceptable
	L-1809180016	Largemouth bass	Hg	mg/kg	0.001	0.256	0.19	256.00	19.050	29.596	R	Fail
FTCS-11 Lake Erie Wildwood	L-1809180013	Common carp	Aldrin	ug/kg	0.5	*0.5*	*0.51*	1.00	99.650	1.980		Acceptable
	L-1809180013	Common carp	alpha-BHC	ug/kg	0.4	*0.4*	*0.41*	1.00	99.650	2.469		Acceptable
	L-1809180013	Common carp	beta-BHC	ug/kg	0.41	*0.41*	*0.43*	1.00	99.650	4.762		Acceptable
	L-1809180013	Common carp	delta-BHC	ug/kg	0.51	*0.51*	*0.52*	1.00	99.650	1.942		Acceptable
	L-1809180013	Common carp	gama-BHC(Lindane)	ug/kg	0.55	*0.55*	*0.57*	1.00	99.650	3.571		Acceptable
	L-1809180013	Common carp	alpha Chlordane	ug/kg	0.4	21	29	52.50	29.232	32.000	R	Fail
	L-1809180013	Common carp	gama Chlordane	ug/kg	0.38	*0.38*	23	1.00	99.650	193.499	R	Fail
	L-1809180013	Common carp	oxy-Chlordane	ug/kg	0.36	0.96	2.2	2.67	72.544	78.481	R	Fail
	L-1809180013	Common carp	4,4'-DDD	ug/kg	0.43	30	21	69.77	26.974	35.294	R	Fail
	L-1809180013	Common carp	4,4'-DDE	ug/kg	0.33	100	76	303.03	18.258	27.273	R	Fail
	L-1809180013	Common carp	4,4'-DDT	ug/kg	0.61	*0.61*	*0.63*	1.00	99.650	3.226		Acceptable
	L-1809180013	Common carp	Dieldrin	ug/kg	0.4	9.9	10	24.75	36.386	1.005		Acceptable
	L-1809180013	Common carp	Endosulfan I	ug/kg	0.44	*0.44*	*0.45*	1.00	99.650	2.247		Acceptable
	L-1809180013	Common carp	Endosulfan II	ug/kg	0.36	5.9	5	16.39	41.167	16.514		Acceptable
	L-1809180013	Common carp	Endrin	ug/kg	0.63	37	27	58.73	28.315	31.250	R	Fail

	L-1809180013	Common carp	Heptachlor	ug/kg	0.51	*0.51*	*0.52*	1.00	99.650	1.942		Acceptable
	L-1809180013	Common carp	Heptachlor epoxide	ug/kg	0.41	8.4	6.9	20.49	38.494	19.608		Acceptable
	L-1809180013	Common carp	Hexachlorobenzene	ug/kg	0.42	*0.42*	*0.43*	1.00	99.650	2.353		Acceptable
	L-1809180013	Common carp	Methoxychlor	ug/kg	0.63	*0.63*	*0.65*	1.00	99.650	3.125		Acceptable
	L-1809180013	Common carp	Mirex	ug/kg	0.3	*1*	0.76	3.33	67.553	27.273		Acceptable
	L-1809180014	Brown bullhead	Aldrin	ug/kg	0.026	*0.026*	0.026	1.00	99.650	0.000		Acceptable
	L-1809180014	Brown bullhead	alpha-BHC	ug/kg	0.02	*0.02*	0.02	1.00	99.650	0.000		Acceptable
	L-1809180014	Brown bullhead	beta-BHC	ug/kg	0.021	*0.021*	0.021	1.00	99.650	0.000		Acceptable
	L-1809180014	Brown bullhead	delta-BHC	ug/kg	0.026	*0.026*	0.026	1.00	99.650	0.000		Acceptable
	L-1809180014	Brown bullhead	gama-BHC(Lindane)	ug/kg	0.028	0.044	0.028	1.57	86.021	44.444		Acceptable
	L-1809180014	Brown bullhead	alpha Chlordane	ug/kg	0.021	6.4	5.3	304.76	18.232	18.803	R	Fail
	L-1809180014	Brown bullhead	gama Chlordane	ug/kg	0.019	*0.019*	0.019	1.00	99.650	0.000		Acceptable
	L-1809180014	Brown bullhead	oxy-Chlordane	ug/kg	0.018	0.54	0.34	30.00	34.376	45.455	R	Fail
	L-1809180014	Brown bullhead	4,4'-DDD	ug/kg	0.022	4.8	3.9	218.18	19.845	20.690	R	Fail
	L-1809180014	Brown bullhead	4,4'-DDE	ug/kg	0.017	13	10	764.71	14.643	26.087	R	Fail
	L-1809180014	Brown bullhead	4,4'-DDT	ug/kg	0.031	*0.031*	0.031	1.00	99.650	0.000		Acceptable
	L-1809180014	Brown bullhead	Dieldrin	ug/kg	0.021	2.5	2.2	119.05	23.284	12.766		Acceptable
	L-1809180014	Brown bullhead	Endosulfan I	ug/kg	0.022	*0.022*	0.022	1.00	99.650	0.000		Acceptable
	L-1809180014	Brown bullhead	Endosulfan II	ug/kg	0.018	*0.018*	0.018	1.00	99.650	0.000		Acceptable
	L-1809180014	Brown bullhead	Endrin	ug/kg	0.032	4.6	3.7	143.75	22.136	21.687		Acceptable

L-1809180014	Brown bullhead	Heptachlor	ug/kg	0.026	*0.026*	0.026	1.00	99.650	0.000		Acceptable
L-1809180014	Brown bullhead	Heptachlor epoxide	ug/kg	0.021	*0.021*	1	1.00	99.650	191.77	R	Fail
L-1809180014	Brown bullhead	Hexachlorobenzene	ug/kg	0.022	*0.022*	0.022	1.00	99.650	0.000		Acceptable
L-1809180014	Brown bullhead	Methoxychlor	ug/kg	0.032	*0.032*	0.032	1.00	99.650	0.000		Acceptable
L-1809180014	Brown bullhead	Mirex	ug/kg	0.015	*0.015*	0.015	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	Aldrin	ug/kg	0.025	*0.025*	*0.026*	1.00	99.650	3.922		Acceptable
L-1809180015	Walleye	alpha-BHC	ug/kg	0.02	*0.02*	*0.02*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	beta-BHC	ug/kg	0.021	*0.021*	*0.021*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	delta-BHC	ug/kg	0.026	*0.026*	*0.026*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	gama-BHC(Lindane)	ug/kg	0.028	*0.028*	*0.028*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	alpha Chlordane	ug/kg	0.02	0.91	1.1	45.50	30.455	18.905		Acceptable
L-1809180015	Walleye	gama Chlordane	ug/kg	0.019	*0.019*	*0.019*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	oxy-Chlordane	ug/kg	0.018	0.063	0.075	3.50	66.512	17.391		Acceptable
L-1809180015	Walleye	4,4'-DDD	ug/kg	0.022	0.07	0.77	3.18	68.562	166.66	R	Fail
L-1809180015	Walleye	4,4'-DDE	ug/kg	0.017	2.1	2.5	123.53	23.053	17.391		Acceptable
L-1809180015	Walleye	4,4'-DDT	ug/kg	0.031	*0.031*	*0.031*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	Dieldrin	ug/kg	0.02	0.67	0.84	33.50	33.282	22.517		Acceptable
L-1809180015	Walleye	Endosulfan I	ug/kg	0.022	*0.022*	*0.022*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	Endosulfan II	ug/kg	0.018	*0.018*	*0.018*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	Endrin	ug/kg	0.032	0.81	1.1	25.31	36.144	30.366		Acceptable
L-1809180015	Walleye	Heptachlor	ug/kg	0.026	*0.026*	*0.026*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	Heptachlor epoxide	ug/kg	0.021	0.22	0.22	10.48	47.186	0.000		Acceptable
L-1809180015	Walleye	Hexachlorobenzene	ug/kg	0.021	*0.021*	*0.022*	1.00	99.650	4.651		Acceptable
L-1809180015	Walleye	Methoxychlor	ug/kg	0.032	*0.032*	*0.032*	1.00	99.650	0.000		Acceptable
L-1809180015	Walleye	Mirex	ug/kg	0.015	*0.015*	*0.015*	1.00	99.650	0.000		Acceptable

	L-1809180016	Largemouth bass	Aldrin	ug/kg	0.026	*0.026*	0.025	1.00	99.650	3.922		Acceptable
	L-1809180016	Largemouth bass	alpha-BHC	ug/kg	0.02	*0.02*	0.02	1.00	99.650	0.000		Acceptable
	L-1809180016	Largemouth bass	beta-BHC	ug/kg	0.021	0.14	0.021	6.67	54.283	147.826	R	Fail
	L-1809180016	Largemouth bass	delta-BHC	ug/kg	0.026	*0.026*	0.026	1.00	99.650	0.000		Acceptable
	L-1809180016	Largemouth bass	gama-BHC(Lindane)	ug/kg	0.028	*0.028*	0.028	1.00	99.650	0.000		Acceptable
	L-1809180016	Largemouth bass	alpha Chlordane	ug/kg	0.021	1.7	2.7	80.95	25.878	45.455	R	Fail
	L-1809180016	Largemouth bass	gama Chlordane	ug/kg	0.019	*0.019*	0.019	1.00	99.650	0.000		Acceptable
	L-1809180016	Largemouth bass	oxy-Chlordane	ug/kg	0.018	0.2	0.28	11.11	46.341	33.333		Acceptable
	L-1809180016	Largemouth bass	4,4'-DDD	ug/kg	0.022	1.9	2.3	86.36	25.418	19.048		Acceptable
	L-1809180016	Largemouth bass	4,4'-DDE	ug/kg	0.017	7.2	9.6	423.53	16.816	28.571	R	Fail
	L-1809180016	Largemouth bass	4,4'-DDT	ug/kg	0.031	*0.031*	0.081	1.00	99.650	89.286		Acceptable
	L-1809180016	Largemouth bass	Dieldrin	ug/kg	0.021	1.5	2.1	71.43	26.797	33.333	R	Fail
	L-1809180016	Largemouth bass	Endosulfan I	ug/kg	0.022	*0.022*	0.022	1.00	99.650	0.000		Acceptable
	L-1809180016	Largemouth bass	Endosulfan II	ug/kg	0.018	*0.018*	0.018	1.00	99.650	0.000		Acceptable
	L-1809180016	Largemouth bass	Endrin	ug/kg	0.032	2	2.6	62.50	27.821	26.087		Acceptable
	L-1809180016	Largemouth bass	Heptachlor	ug/kg	0.026	*0.026*	0.025	1.00	99.650	3.922		Acceptable
	L-1809180016	Largemouth bass	Heptachlor epoxide	ug/kg	0.021	0.29	0.59	13.81	43.362	68.182	R	Fail
	L-1809180016	Largemouth bass	Hexachlorobenzene	ug/kg	0.021	0.028	0.07	1.33	90.732	85.714		Acceptable
	L-1809180016	Largemouth bass	Methoxychlor	ug/kg	0.032	*0.032*	0.032	1.00	99.650	0.000		Acceptable
	L-1809180016	Largemouth bass	Mirex	ug/kg	0.015	*0.015*	0.015	1.00	99.650	0.000		Acceptable

Italics: Estimated result

Table 2. Whole body fish duplicates

Sample location	Sample ID		Parameter	Unit	MDL	Result	Duplicate Result	X: Result/ MDL	Acceptable RPD %	Actual RPD %	Qualifier	Acceptable/ Fail
FTCS-06 Cuy RM 9.78	R-1810250005	Smallmouth bass	Hg	mg/kg	0.001	0.062	0.043	62.00	27.884	36.190	R	Fail
	R-1810250008	Smallmouth bass	Hg	mg/kg	0.001	0.039	0.04	39.00	31.841	2.532		Acceptable
												Acceptable
	R-1810250005	Smallmouth bass	Se	mg/kg	1.14	650.8	694.3	570.88	15.663	6.468		Acceptable
	R-1810250008	Smallmouth bass	Se	mg/kg	1.14	794.2	796.4	696.67	14.957	0.277		Acceptable
FTCS-07 Cuy RM 0.92	R-1810030005	Bluegill sunfish	Hg	mg/kg	0.001	0.028	0.029	28.00	35.081	3.509		Acceptable
	R-1810030008	Rock bass	Hg	mg/kg	0.001	0.069	0.062	69.00	27.058	10.687		Acceptable
	R-1810030015	Rock bass	Hg	mg/kg	0.001	0.09	0.087	90.00	25.131	3.390		Acceptable
FTCS-10 Lake Erie Eastlake	L-1809270002	Freshwater drum	Hg	mg/kg	0.001	0.127	0.172	127.00	22.882	30.100	R	Fail
	L-1809270003	Freshwater drum	Hg	mg/kg	0.001	0.349	0.343	349.00	17.630	1.734		Acceptable
	L-1809270005	Freshwater drum	Hg	mg/kg	0.001	0.108	0.081	108.00	23.907	28.571	R	Fail
	L-1809270008	Freshwater drum	Hg	mg/kg	0.001	0.092	0.096	92.00	24.979	4.255		Acceptable
FTCS-12 Lake Erie Lakewood	L-1809200005	Largemouth bass	Hg	mg/kg	0.001	0.094	0.09	94.00	24.832	4.348		Acceptable
	L-1809200032	Largemouth bass	Hg	mg/kg	0.001	0.087	0.108	87.00	25.367	21.538		Acceptable
FTCS-11 Lake Erie Wildwood	L-1809180004	Freshwater drum	Hg	mg/kg	0.001	0.097	0.107	97.00	24.619	9.804		Acceptable
	L-1809180009	Freshwater drum	Hg	mg/kg	0.001	0.136	0.121	136.00	22.466	11.673		Acceptable
	L-1809180011	Freshwater drum	Hg	mg/kg	0.001	0.178	0.182	178.00	20.921	2.222		Acceptable

Appendix C. Statistical Analysis Results

Total PCBs

Table 1. Summary: Kruskal-Wallis rank sum test; Total PCBs in River AOC sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
6.6934	3	0.08234
Significance value set at p=0.05		

Table 2. Summary: Kruskal-Wallis rank sum test; Total PCBs in River Reference sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
31.131	3	**7.978 E-07**
Significance value set at p=0.05 Lower p-value may be due to lower detection limits in more recent years.		

Table 3. Wilcoxon Rank Sum Test for Total PCBs in River Reference Sites by Year Assessed					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
1989-1992	2005	-5.08995	0.5921	-11.50	6.06
1989-1992	2008	-13.59003	0.1996	-24.00	-2.44
1989-1992	2018	11.93015	**4.10E-06**	4.99	22.54
2005	2008	-8.50009	**0.002**	-8.50	-8.50
2005	2018	16.48019	**4.74E-05**	16.48	16.49
2008	2018	24.98023	**3.56E-04**	24.98	24.99
Bold indicates a significant difference is observed					

Table 4. Summary: Kruskal-Wallis rank sum test; Total PCBs in Lake Erie AOC sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
31.458	3	**6.808 E-07**
Significance value set at p=0.05 Lower p-value may be due to lower detection limits in more recent years.		

Table 5. Wilcoxon Rank Sum Test for Total PCBs in Lake Erie AOC Sites by Year Assessed					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
1989-1992	2005	-51.22303	0.3012	-383.08	94.10
1989-1992	2008	-180.25	0.0706	-417.88	20.87
1989-1992	2018	139.6896	**1.468E-06**	51.72	345.45
2005	2008	-100.73265	0.3238	-405.00	362.00
2005	2018	242.9477	**2.493E-05**	89.94	919.95
2008	2018	503.71	**9.273E-06**	263.95	554.95
Bold indicates a significant difference is observed					

Table 6. Summary: Kruskal-Wallis rank sum test; Total PCBs in Lake Erie Reference sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
18.306	3	**3.803 E-04**
Significance value set at p=0.05 Lower p-value may be due to lower detection limits in more recent years.		

Table 7. Wilcoxon Rank Sum Test for Total PCBs in Lake Erie Reference Sites by Year Assessed					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
1989-1992	2005	232.499	**0.0291**	46.15	3694.39
1989-1992	2008	110.8043	0.6477	-537.68	3037.11
1989-1992	2018	272.6572	**3.283E-04**	220.37	489.44
2005	2008	-365.1255	0.359	-790.00	93.50
2005	2018	32.97727	0.1863	32.69	126.48
2008	2018	427.8415	**8.475E-03**	32.95	822.97
Bold indicates a significant difference is observed					

Table 8. Summary: Kruskal-Wallis rank sum test; 2018 Total PCBs by Group (River Reference, River AOC, Lake Reference, & Lake AOC)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
21.991	3	**6.55 E-05**
Significance value set at p=0.05 Lower p-value may be due to lower detection limits in more recent years.		

Table 9. Wilcoxon Rank Sum Test for 2018 Total PCBs by Group

2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
River Ref	River AOC	106.5956	**1.766E-05**	43.10	276.10
River Ref	Lake Ref	25.80413	**7.659E-03**	3.00	89.80
River Ref	Lake AOC	33.60001	**3.846E-03**	5.20	63.10
River AOC	Lake Ref	-57.48951	0.0832	-266.00	3.10
River AOC	Lake AOC	-61.77523	0.07544	-238.00	3.10
Lake Ref	Lake AOC	7.203	0.8471	-52.00	61.00

Bold indicates a significant difference is observed

Table 10. Summary: Wilcoxon Rank Sum Test for Cuyahoga River AOC sites Total PCB Concentrations by Fish Type (Bottom feeding species vs Sportfish)

Mean difference	Significance level (α=0.05)	95% Confidence Interval	
		Lower Bound	Upper Bound
274.4176	**8.201E-04**	100.7	1250.3

Bold indicates a significant difference is observed

Table 11. Summary: Wilcoxon Rank Sum Test for Lake Erie AOC Total PCB Concentrations by Fish Type (Bottom feeding species vs Sportfish)

Mean difference	Significance level (α=0.05)	95% Confidence Interval	
		Lower Bound	Upper Bound
47.51537	**0.02113**	10.50	228.00

Bold indicates a significant difference is observed

Table 12. Summary: Kruskal-Wallis rank sum test; Lipid Normalized Total PCBs in River AOC sites by year assessed (1989-1992, 2005, 2008, & 2018)

Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
14.898	3	**1.905-03**

Significance value set at p=0.05

Table 13. Wilcoxon Rank Sum Test for Lipid Normalized Total PCBs in River AOC Sites by Year Assessed

2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
1989-1992	2005	88.77684	**0.04099**	3.505	175.865
1989-1992	2008	70.39408	**0.04501**	1.887	141.760
1989-1992	2018	121.1973	**2.076E-03**	49.81059	201.08450
2005	2008	-21.44033	0.3265	-77.457	34.151
2005	2018	37.56941	0.1235	-11.331	100.122
2008	2018	60.5472	**4.826E-03**	23.058	104.526

Bold indicates a significant difference is observed

Table 14. Summary: Kruskal-Wallis rank sum test; Lipid Normalized Total PCBs in River Reference sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
18.291	3	**3.83E-04**
Significance value set at p=0.05 Lower p-value may be due to lower detection limits in more recent years.		

Table 15. Wilcoxon Rank Sum Test for Lipid Normalized Total PCBs in River Reference Sites by Year Assessed					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
1989-1992	2005	-26.96431	**1.725E-04**	-35.987	-18.911
1989-1992	2008	-13.38125	0.06434	-28.486	0.0560
1989-1992	2018	-0.8237869	0.8871	-8.237	9.138
2005	2008	12.84082	0.1478	-8.750	27.361
2005	2018	28.87368	**9.751E-04**	17.269	33.750
2008	2018	13.17197	**0.03839**	1.362	35.977
Bold indicates a significant difference is observed					

Table 16. Summary: Kruskal-Wallis rank sum test; Lipid Normalized Total PCBs in Lake Erie AOC sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
14.857	3	**1.943E-03**
Significance value set at p=0.05 Lower p-value may be due to lower detection limits in more recent years.		

Table 17. Wilcoxon Rank Sum Test for Lipid Normalized Total PCBs in Lake Erie AOC Sites by Year Assessed					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
1989-1992	2005	61.62373	0.1763	-19.172	171.009
1989-1992	2008	-16.3976	0.8205	-102.183	108.086
1989-1992	2018	111.5371	**3.321E-03**	32.360	223.697
2005	2008	-79.15106	**0.03478**	-182.431	-7.446
2005	2018	52.68367	**9.776E-03**	19.608	79.224
2008	2018	135.4488	**0.001306**	48.824	250.362
Bold indicates a significant difference is observed					

Table 18. Summary: Kruskal-Wallis rank sum test; Lipid Normalized Total PCBs in Lake Erie Reference sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
13.408	3	**3.833E-03**
Significance value set at p=0.05 Lower p-value may be due to lower detection limits in more recent years.		

Table 19. Wilcoxon Rank Sum Test for Lipid Normalized Total PCBs in Lake Erie Reference Sites by Year Assessed					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
1989-1992	2005	61.62372	0.1763	-19.172	171.009
1989-1992	2008	-16.3976	0.8205	-102.183	108.086
1989-1992	2018	111.5371	**3.3321E-03**	32.360	223.697
2005	2008	-79.15106	**0.03478**	-182.431	-7.446
2005	2018	52.68367	**9.9776E-03**	19.608	79.224
2008	2018	135.4488	**1.306E-03**	48.824	250.362
Bold indicates a significant difference is observed					

Table 20. Summary: Kruskal-Wallis rank sum test; 2018 Lipid Normalized Total PCBs by Group (River Reference, River AOC, Lake Reference, & Lake AOC)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
30.837	3	**9.199E-07**
*Significance value set at p=0.05		

Table 21. Wilcoxon Rank Sum Test for 2018 Lipid Normalized Total PCBs by Group					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
River Ref	River AOC	71.90007	**5.924E-06**	52.800	95.200
River Ref	Lake Ref	2.075357	0.8471	-14.3000	14.000
River Ref	Lake AOC	19.62197	**0.02623**	3.100	51.100
River AOC	Lake Ref	-71.23833	**1.046E-04**	-95.000	-47.900
River AOC	Lake AOC	-46.97246	**5.943E-03**	-77.500	-17.600
Lake Ref	Lake AOC	20.06938	**0.01509**	3.300	51.200
Bold indicates a significant difference is observed					

Table 22. Summary: Wilcoxon Rank Sum Test for Common Carp Fillet Lipid Normalized PCB Concentrations (Upstream of Akron sites vs Ship Channel site)			
Mean difference	Significance level (α=0.05)	95% Confidence Interval	
		Lower Bound	Upper Bound
0.00444	1.00	-0.518	0.105
Bold indicates a significant difference is observed			

Composite Fillet Mercury

Table 23. Summary: Kruskal-Wallis rank sum test; Composite Fillet Mercury Concentrations in River AOC sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
6.8385	3	0.07723
Significance value set at p=0.05		

Table 24. Summary: Kruskal-Wallis rank sum test; Composite Fillet Mercury Concentrations in River Reference sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
0.86801	3	0.8331
Significance value set at p=0.05		

Table 25. Summary: Kruskal-Wallis rank sum test; Composite Fillet Mercury Concentrations in Lake Erie AOC sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
27.884	3	**3.842E-06**
Significance value set at p=0.05		

Table 26. Wilcoxon Rank Sum Test for Composite Fillet Mercury Concentrations in Lake Erie AOC Sites by Year Assessed					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
1989-1992	2005	-0.3000	**1.176E-05**	-0.427	-0.200
1989-1992	2008	-0.02796	0.3392	-0.064	0.016
1989-1992	2018	-0.07199	**1.24E-3**	-0.127	-0.035
2005	2008	0.2735	**6.167E-03**	0.137	0.471
2005	2018	0.2233	**6.099E-03**	0.056	0.430
2008	2018	-0.0628	**0.04547**	-0.122	-0.002
Bold indicates a significant difference is observed					

Table 27. Summary: Kruskal-Wallis rank sum test; Composite Fillet Mercury Concentrations in Lake Erie Reference sites by year assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
2.2994	3	0.5126
*Significance value set at p=0.05		

Table 28. Summary: Kruskal-Wallis rank sum test; 2018 Composite Fillet Mercury Concentrations by Group (River Reference, River AOC, Lake Reference, & Lake AOC)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
2.6577	3	0.4475
*Significance value set at p=0.05		

Table 29. Summary: Wilcoxon Rank Sum Test for Lake Erie AOC sites Fillet Mercury Concentrations by Fish Type (Bottom feeding species vs Sportfish)			
Mean difference	Significance level (α=0.05)	95% Confidence Interval	
		Lower Bound	Upper Bound
-0.028	0.2123	-0.099	0.013
Bold indicates a significant difference is observed			

Table 30. Summary: Wilcoxon Rank Sum Test for Lake Erie AOC sites Fillet Mercury Concentrations by Fish Type (Bottom feeding species vs Sportfish)			
Mean difference	Significance level (p=0.05)	95% Confidence Interval	
		Lower Bound	Upper Bound
-0.101	**0.00729**	-0.158	-0.035
Bold indicates a significant difference is observed			

Whole Body Mercury

Table 31. Summary: Kruskal-Wallis rank sum test; Whole Body Mercury Concentrations in Cuyahoga River Reference Sites by Year Assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
39.116	2	**3.207E-09**
*Significance value set at p=0.05 May be due to lower detection limits in more recent years.		

Table 32. Wilcoxon Rank Sum Test for Whole Body Mercury Concentrations in Cuyahoga River Reference Sites by Year Assessed

2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2005	2008	0.03198	**0.04016**	9.95E-04	0.055
2005	2018	0.06301	**1.278E-07**	0.048	0.090
2008	2018	0.03198	**4.363E-07**	0.019	0.054
Bold indicates a significant difference is observed					

Table 33. Summary: Kruskal-Wallis rank sum test; Whole Body Mercury Concentrations in Cuyahoga River AOC Sites by Year Assessed (1989-1992, 2005, 2008, & 2018)

Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
17.712	2	**1.45E-04**
*Significance value set at p=0.05 May be due to lower detection limits in more recent years.		

Table 34. Wilcoxon Rank Sum Test for Whole Body Mercury Concentrations in Cuyahoga River AOC Sites by Year Assessed

2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2005	2008	0.02112	**2.269E-04**	0.011	0.032
2005	2018	0.02551	**4.211E-04**	0.012	0.039
2008	2018	0.00500	0.2631	-0.004	0.012
Bold indicates a significant difference is observed					

Table 35. Summary: Kruskal-Wallis rank sum test; Whole Body Mercury Concentrations in Lake Erie Reference Sites by Year Assessed (1989-1992, 2005, 2008, & 2018)

Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
33.64	2	**4.957E-08**
*Significance value set at p=0.05 May be due to lower detection limits in more recent years.		

Table 36. Wilcoxon Rank Sum Test for Whole Body Mercury Concentrations in Lake Erie Reference Sites by Year Assessed

2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval Lower Bound	95% Confidence Interval Upper Bound
2005	2008	0.07837	**2.969E-07**	0.052	0.102
2005	2018	0.02397	0.2142	-0.020	0.059
2008	2018	-0.0370	**4.271E-06**	-0.080	-0.02
Bold indicates a significant difference is observed					

Table 37. Summary: Kruskal-Wallis rank sum test; Whole Body Mercury Concentrations in Lake Erie AOC Sites by Year Assessed (1989-1992, 2005, 2008, & 2018)		
Kruskal-Wallis chi-squared	Degrees of Freedom	p-value*
22.455	2	**1.331E-05**
*Significance value set at p=0.05		

Table 38. Wilcoxon Rank Sum Test for Whole Body Mercury Concentrations in Lake Erie AOC Sites by Year Assessed					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
2005	2008	0.05899	**1.929E-05**	0.0321	0.096
2005	2018	0.02700	0.0649	2.52E-03	0.061
2008	2018	-0.02998	**2.65E-04**	-0.050	-0.014
Bold indicates a significant difference is observed					

Table 39. Wilcoxon Rank Sum Test for 2018 Whole Body Mercury Concentrations by Group					
2018 Study Comparison values		Mean difference	Significance level (p=0.05)	95% Confidence Interval	
				Lower Bound	Upper Bound
River Ref	River AOC	0.002994	0.5912	-0.005	0.012
River Ref	Lake Ref	0.059044	**4.997E-09**	0.048	0.103
River Ref	Lake AOC	0.041965	**5.469E-07**	0.025	0.581
River AOC	Lake Ref	0.06199	**1.044E-08**	0.046	0.096
River AOC	Lake AOC	0.03796	**5.359E-06**	0.023	0.056
Lake Ref	Lake AOC	-0.02992	**0.02077**	-0.058	-0.006
Bold indicates a significant difference is observed					

Table 40. Summary: Wilcoxon Rank Sum Test for Lake Erie AOC sites Whole Body Mercury Concentrations by species (Freshwater Drum vs Other Species)			
Mean difference	Significance level (α=0.05)	95% Confidence Interval	
		Lower Bound	Upper Bound
0.06497	**1.125E-05**	0.037	0.095
Bold indicates a significant difference is observed			

Table 41. Summary: Wilcoxon Rank Sum Test for Lake Erie Reference sites Whole Body Mercury Concentrations by species (Freshwater Drum vs Largemouth Bass)			
Mean difference	Significance level (α=0.05)	95% Confidence Interval	
		Lower Bound	Upper Bound
0.15178	**2.2516E-04**	0.058	0.202
Bold indicates a significant difference is observed			

Water Quality Standards for the Protection of Human Health (Fish Tissue) Comparison

Table 42. Water Quality Standards (Human Health) in HUC-12: 04110002 03 05 ***Fish Creek-Cuyahoga River*** **(RM 45.10 site)**					
Species	Trophic level	Number of samples	Geomean Total DDT (ug/kg)	Geomean Hg (mg/kg)	Geomean TPCB Fillet (mg/kg)
Smallmouth bass	4	1	5	0.337	0.053
Largemouth bass	4	2	5	0.221	0.040
Yellow perch	4	1	5	0.101	0.020
White perch	4	1	5	0.160	0.022
Black crappie	3	1	5	0.114	0.020
White sucker	3	1	5	0.133	0.123
Bluegill sunfish	3	1	5	0.090	0.288
Common carp	3	2	48.162	0.088	0.291
Cavg= ((8.0*C3)+(5.7*C4))/(8.0+5.7)			DDT	Hg	PCBs
	C3=		15.790	0.106	0.180
	C4=		5.000	0.205	0.034
	Cavg (mg/kg)=		N/A	0.81	0.069
	Cavg (ug/kg)=		7.590	181.092	**68.972**
WQS in Lake Erie Drainage basin: 140 ug/kg DDT; 350 ug/kg Hg; 23 ug/kg PCBs **Bold** indicates impaired for respective contaminant N/A = not analyzed					

Table 43. Water Quality Standards (Human Health) in HUC-12: 04110002 04 05 ***Boston Run-Cuyahoga River*** **(RM 41.70)**					
Species	Trophic level	Number of samples	Geomean Total DDT (ug/kg)	Geomean Hg (mg/kg)	Geomean TPCB (mg/kg)
Smallmouth bass	4	1	5	0.140	0.136
Common carp	3	2	39.900	0.132	1.602
Cavg= ((8.0*C3)+(5.7*C4))/(8.0+5.7)			DDT	Hg	PCBs
	C3=		39.900	0.132	1.602
	C4=		5.000	0.140	0.136
	Cavg (mg/kg)=		N/A	0.138	0.488
	Cavg (ug/kg)=		13.376	137.989	**487.551**
WQS in Lake Erie Drainage basin: 140 ug/kg DDT; 350 ug/kg Hg; 23 ug/kg PCBs **Bold** indicates impaired for respective contaminant N/A = not analyzed					

Table 44. Water Quality Standards (Human Health) in HUC-12: 04110002 06 05 *Cleveland-Cuyahoga River* (RM 0.92)

Species	Trophic level	Number of samples	Geomean Total DDT (ug/kg)	Geomean Hg (mg/kg)	Geomean TPCB (mg/kg)
Largemouth bass	4	2	5	0.142	0.074
Rock bass	4	4	5	0.109	0.043
Common carp	3	1	56.200	0.095	0.513
Brown bullhead	3	1	5	0.135	0.134
Cavg= ((8.0*C3)+(5.7*C4))/(8.0+5.7)			DDT	Hg	Total PCBs
	C3=		30.600	0.115	0.323
	C4=		5.000	0.126	0.058
	Cavg (mg/kg)=		N/A	0.123	0.122
	Cavg (ug/kg)=		11.144	123.043	**121.803**
WQS in Lake Erie Drainage basin: 140 ug/kg DDT; 350 ug/kg Hg; 23 ug/kg PCBs **Bold** indicates impaired for respective contaminant N/A = not analyzed					

Table 45. Water Quality Standards (Human Health) Lake Erie AOC sites

Species	Trophic level	Number of samples	Geomean Total DDT (ug/kg)	Geomean Hg (mg/kg)	Geomean TPCB (mg/kg)	Total Chlordane (ug/kg)
Largemouth bass	4	3	4.207	0.236	0.035	1.384
Smallmouth bass	4	1	8.3	0.276	0.052	0.288
Walleye	4	1	R	0.131	0.007	1.074
Common carp	3	3	59.0766	0.113	0.224	19.063
Yellow bullhead	3	1	2.96	0.188	0.018	1.650
Brown bullhead	3	1	R	0.096	0.054	R
Cavg= ((8.0*C3)+(5.7*C4))/(8.0+5.7)			DDT	Hg	PCBs	Chlordane
	C3=		31.018	0.132	0.098	10.356
	C4=		6.254	0.214	0.031	0.915
	Cavg (mg/kg)=		N/A	0.194	0.047	N/A
	Cavg (ug/kg)=		12.197	194.450	**47.361**	3.181
WQS in Lake Erie Drainage basin: 140 ug/kg DDT; 350 ug/kg Hg; 23 ug/kg PCBs; 130 ug/kg Chlordane **Bold** indicates impaired for respective contaminant N/A = not analyzed						

Table 46. Water Quality Standards (Human Health) in Lake Erie Reference sites

Species	Trophic level	Number of samples	Geomean Total DDT (ug/kg)	Geomean Hg (mg/kg)	Geomean TPCB (mg/kg)	Total Chlordane (ug/kg)
Common carp	3	3	21.473	0.115	0.085	3.538
Smallmouth bass	4	2	7.635	0.160	0.042	2.079
Rock bass	4	1	1.26	0.232	0.007	0.253
Channel catfish	4	1	46	0.118	0.310	7.190
Largemouth bass	4	1	4.89	0.325	0.022	1.330
Cavg= ((8.0*C3)+(5.7*C4))/(8.0+5.7)			DDT	Hg	PCBs	Chlordane
	C3=		21.473	0.115	0.085	3.538
	C4=		14.946	0.209	0.095	2.713
	Cavg (mg/kg)=		N/A	0.186	0.093	N/A
	Cavg (ug/kg)=		16.513	186.079	**92.967**	2.911

WQS in Lake Erie Drainage basin: 140 ug/kg DDT; 350 ug/kg Hg; 23 ug/kg PCBs; 130 ug/kg Chlordane
Bold indicates impaired for respective contaminant
N/A = not analyzed

Table 47. Water Quality Standards (Human Health) in HUC-12: 04110002 02 03 *Lake Rockwell-Cuyahoga River* (RM 64.30)

Species	Trophic level	Number of samples	Geomean Total DDT (ug/kg)	Geomean Hg (mg/kg)	Geomean TPCB (mg/kg)
Northern Pike	4	1	0	0.602	0.020
Smallmouth bass	4	2	0	0.298	0.020
Rock bass	4	1	0	0.088	0.020
White sucker	3	2	0	0.093	0.020
Common carp	3	1	0	0.267	0.042
Yellow Bullhead	3	1	0	0.185	0.020
Cavg= ((8.0*C3)+(5.7*C4))/(8.0+5.7)			DDT	Hg	PCBs
	C3=		0.000	0.182	0.027
	C4=		0.000	0.329	0.020
	Cavg (mg/kg)=		N/A	0.294	0.022
	Cavg (ug/kg)=		0.000	293.985	21.678

WQS in Lake Erie Drainage basin: 140 ug/kg DDT; 350 ug/kg Hg; 23 ug/kg PCBs
Bold indicates impaired for respective contaminant
N/A = not analyzed

Table 48. Water Quality Standards (Human Health) in HUC: 04110003 04 02 *Griswold Creek-Chagrin River* (RM 5.54)

Species	Trophic level	Number of samples	Geomean Total DDT (ug/kg)	Geomean Hg (mg/kg)	Geomean TPCB (mg/kg)	Geomean Chlordane (ug/kg)
Smallmouth bass	4	1	2.96	0.102	0.005	0.520
Rock bass	4	1	0.46	0.112	0.002	0.218
Golden redhorse	3	2	6.845436	0.204	0.012	1.224
Cavg= ((8.0*C3)+(5.7*C4))/(8.0+5.7)			DDT	Hg	PCBs	Chlordane
	C3=		6.845	0.204	0.012	1.224
	C4=		1.710	0.107	0.003	0.369
	Cavg (mg/kg)=		N/A	0.130	0.005	N/A
	Cavg (ug/kg)=		2.943	130.285	5.335	0.574

WQS in Lake Erie Drainage basin: 140 ug/kg DDT; 350 ug/kg Hg; 23 ug/kg PCBs; 130 ug/kg Chlordane
Bold indicates impaired for respective contaminant
N/A = not analyzed

Table 49. Comparison of Cuyahoga River AOC fish to BUI #1: Fish Consumption Delisting Guidance

Species	Known Contaminant*	Avg PCB (ug/kg)	Avg Hg (mg/kg)	PCB data based advisory	Hg data based advisory	Cuyahoga River BUI #1 removal criteria**	Comparison	Contaminant
Common carp	PCBs	965.25	0.1098	1/month	2/week	1/month	Same	PCBs
Smallmouth bass	Hg	94.45	0.2385	1/week	1/month	1/month	Same	Hg
White sucker	Hg	122.6	0.133	1/week	1/week	1/month	Less	
White perch	n/a	21.9	0.133	unrestricted	1/week	1/month	Less	
Bluegill sunfish	n/a	288	0.0898	1/month	2/week	1/month	Same	PCBs
Largemouth bass	n/a	44.3	0.2235	Unrestricted	1/month	1/month	Same	Hg
Yellow perch	n/a	101	0.101	1/week	2/week	1/month	Less	
Black crappie	n/a	19.9	0.114	Unrestricted	1/week	1/month	Less	

*Based off Ohio Sport Fish Consumption Advisory for Cuyahoga River *Ohio Edison Dam pool to mouth* (Ohio EPA et al., 2019)
**Based off Delisting Guidance and Restoration Targets for Areas of Concerns (Ohio EPA, 2017a)

Table 50. Comparison of Lake Erie AOC fish to Lake Erie based Fish Consumption Advisories and BUI #1: Fish Consumption Delisting Guidance

Species	Known contaminant*	Avg PCB (ug/kg)	Avg Hg (mg/kg)	PCB data based advisory	Hg data based advisory	Lake Erie Advisory**	Comparison	Contaminant
Common carp ≥ 27"	PCBs	664.07	0.118	1/month	1/week	1/2 months	Less	
Common carp <27"	PCBs	478.58	0.110	1/month	1/week	1/month	Same	PCBs
Smallmouth bass	PCBs, Hg	52.00	0.276	1/week	1/month	1/month	Same	Hg
Brown bullhead	Hg	93.50	0.116	1/week	1/week	1/month	Less	
Rock bass	*n/a*	*42.7*	*0.109*	*Unrestricted*	*2/week*	*1/week*	*Less*	
Largemouth bass	*n/a*	*50.90*	*0.206*	*1/week*	*1/week*	*1/week*	*Same*	*PCBs, Hg*
Yellow bullhead	*n/a*	*18.00*	*0.188*	*Unrestricted*	*1/week*	*1/week*	*Same*	*Hg*
Walleye	*n/a*	*6.90*	*0.131*	*Unrestricted*	*1/week*	*1/week*	*Same*	*Hg*

*Based off Ohio Sport Fish Consumption Advisory for *Lake Erie All Waters* (Ohio EPA et al., 2019)
**Based off Ohio Sport Fish Consumption Advisory (Ohio EPA, 2017a)
Italics are state fish consumption advice, and are not reflective of Lake Erie specific fish consumption advisories