NORTHEAST OHIO REGIONAL SEWER DISTRICT

2014 Cuyahoga River Environmental Monitoring

Prepared by
Water Quality and Industrial Surveillance Division

Introduction

In 2014, the Northeast Ohio Regional Sewer District (NEORSD) conducted water chemistry sampling, habitat assessments, and fish and benthic macroinvertebrate community surveys in the lower Cuyahoga River. Sampling was conducted by NEORSD Level 3 Qualified Data Collectors certified by Ohio Environmental Protection Agency (EPA) in Fish Community and Benthic Macroinvertebrate Biology, and Chemical Water Quality and Stream Habitat Assessments as explained in the NEORSD study plan *2014 Cuyahoga River Environmental Monitoring* approved by Ohio EPA on April 14, 2014.

One of the purposes of this study was to determine the attainment status of the river in relation to point and nonpoint sources of pollution. The lower Cuyahoga River has been designated as one of 42 Great Lakes Areas of Concern (AOC) by the International Joint Commission. Past monitoring indicated impairment of aquatic biota in the river and was the basis of a Total Maximum Daily Load (TMDL) for the Lower Cuyahoga River (Ohio EPA, 2003). The causes of impairment to the river were classified as organic enrichment, toxicity, low dissolved oxygen, nutrients and flow alteration. Some of the sites in the river, however, have been in full attainment of the biological criteria in recent years. This study was completed to determine current conditions in the river, identify any spatial and temporal trends in present and historic data, and measure the magnitude of any impacts.

The fish and macroinvertebrate community in the Cuyahoga River navigation channel was also monitored in support of three grants related to habitat restoration as part of the Great Lakes Restoration Initiative. These grants include the *Cuyahoga River Larval Fish Study* funded by the U.S. Army Corps of Engineers that is being implemented by the Cuyahoga County Planning Commission, the Cuyahoga County Engineer's Office project *Cuyahoga AOC Urban Riparian Habitat Restoration*, and the Ohio Department of Natural Resource's *Cuyahoga AOC Urban Riparian Habitat Restoration Opportunities*. Completion of the Scranton Peninsula Habitat Restoration Project as part of these grants occurred in 2013. Monitoring in 2014 was completed to determine the effectiveness of this project on improving the fish community.

Figure 1 is a map of the sampling locations evaluated, and Table 1 indicates the sampling locations with respect to river mile (RM), latitude/longitude, description and surveys conducted. A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD's Water Quality and Industrial Surveillance (WQIS) Division.

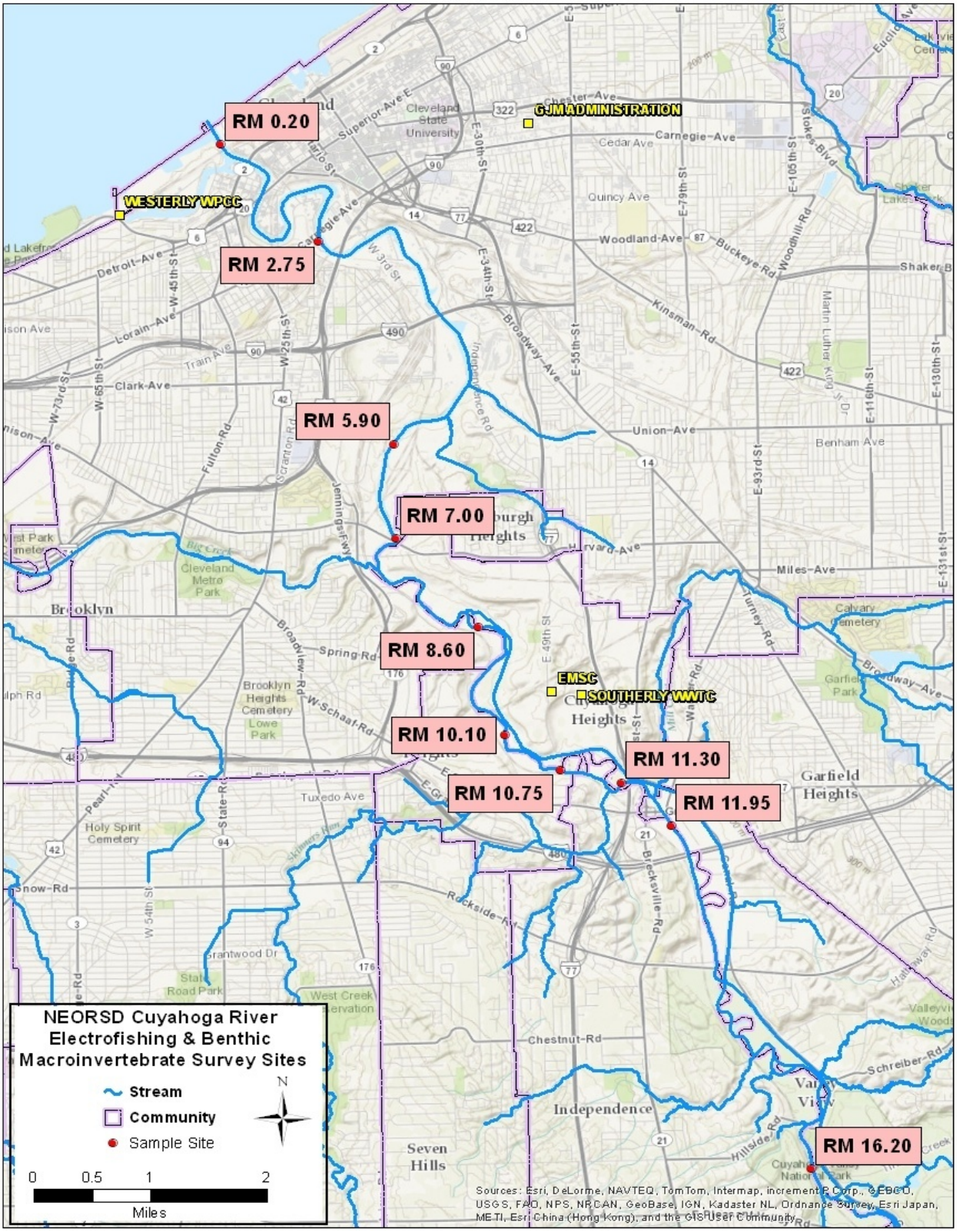


Figure 1. Sampling Locations

Table 1. Sample Locations					
Location	Latitude	Longitude	River Mile	Description	Purpose
Downstream of Tinkers Creek	41.3678	-81.6139	16.20	Downstream of the confluence with Tinkers Creek near Old Riverview Road	Background data for fish, habitat, macroinvertebrates, and chlorophyll *a*
Upstream of Mill Creek	41.4123 41.4101	-81.6364 -81.6346	12.10[a] 11.95	Upstream of the confluence with Mill Creek (I-480)	Evaluate Mill Creek discharge on fish, habitat and macroinvertebrates
Downstream of Mill Creek	41.4179	-81.6446	11.30	Downstream of the confluence with Mill Creek	Evaluate Mill and West Creek discharges on fish, habitat and macroinvertebrates
Upstream of Southerly WWTC	41.4196	-81.6547	10.75	Upstream of Southerly WWTC effluent discharge	Evaluate West Creek and Southerly WWTC discharges on fish, habitat and macroinvertebrates, and Southerly WWTC discharge on chlorophyll *a* levels.
Downstream of Southerly WWTC	41.4242	-81.6638	10.10	Downstream of Southerly WWTC effluent discharge	Evaluate Southerly WWTC discharge on fish, habitat, macroinvertebrates, and chlorophyll *a* levels.
Upstream of Big Creek	41.4381	-81.6680	8.60	Upstream of the confluence with Big Creek	Evaluate Big Creek discharge on fish, habitat and macroinvertebrates
Downstream of Big Creek	41.4497	-81.6815	7.00	Downstream of the confluence with Big Creek/ Upstream of habitat restoration project	Evaluate Big Creek discharge on fish, habitat and macroinvertebrates; Southerly WWTC discharge on chlorophyll *a* levels; and effectiveness of habitat restoration in

[a] HD and Water Chemistry Collection Site

Table 1. Sample Locations					
Location	Latitude	Longitude	River Mile	Description	Purpose
					navigation channel on fish.
Head of Navigation Channel	41.4619	-81.6816	5.90	Head of navigation channel/Upstream of restoration site	Evaluate effectiveness of habitat restoration in navigation channel on fish.
Restoration Site (formerly Scaravelli's Marina)	41.4881	-81.6938	2.75	Mid-navigation channel/Site of GLRI habitat restoration project	Evaluate effectiveness of habitat restoration in navigation channel on fish.
Cuyahoga River Mouth	41.5008	-81.7098	0.20	Near mouth of river in navigation channel	Evaluate effectiveness of habitat restoration in navigation channel on fish.

Water Chemistry Sampling

Methods

Water chemistry and bacteriological sampling was conducted five times between July 23 and August 19, 2014, on the Cuyahoga River between RMs 16.20 and 0.20. Techniques used for sampling and analyses followed the Ohio EPA *Surface Water Field Sampling Manual* (2013). Chemical water quality samples from each site were collected with a 4-liter disposable polyethylene cubitainer with a disposable polypropylene lid, three 473-mL plastic bottles and a 125-mL plastic bottle. The first 473-mL plastic bottle was field preserved with trace nitric acid, the second was field preserved with trace sulfuric acid and the third bottle received no preservative. The sample collected in the 125-mL plastic bottle (Dissolved Reactive Phosphorus) was filtered using a 0.45-µm PVDF syringe filter. All water quality samples were collected as grab samples. Bacteriological samples were collected in sterilized plastic bottles preserved with sodium thiosulfate. At the time of sampling, measurements for dissolved oxygen, pH, temperature, and conductivity were collected using either a YSI 600XL or EXO1 sonde. Duplicate samples and field blanks were each collected at randomly selected sites, at a frequency not less than 5% of the total samples collected. Relative percent difference

(RPD) was used to determine the degree of discrepancy between the primary and duplicate sample (Formula 1).

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, 2013).

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 and, as a result, the data was not used for comparison to the water quality standards.

Mercury analysis for all of the sampling events was done using EPA Method 245.1. Because the detection limit for this method is above the criteria for the Human Health Nondrinking and Protection of Wildlife Outside Mixing Zone Averages (OMZA), it generally cannot be determined if the Cuyahoga River was in attainment of those criteria. Instead, this type of mercury sampling was used as a screening tool to determine whether contamination was present above those levels typically found in the river.

Water chemistry analysis sheets for each site are available upon request from the NEORSD WQIS Division.

Results and Discussion

Three field blanks and three duplicate samples were collected as part of this study in 2014. For the field blanks, there were four parameters that showed possible contamination. It is unclear how the field blanks became contaminated and may be due to inappropriate sample collection, handling, contaminated blank water and/or interference during turbidity analysis. Table 2 lists water quality parameters that were listed as estimated or downgraded from Level 3 to Level 2 data based on Ohio EPA data validation protocol.

Table 2. Parameters affected by possible blank contamination
COD
Cr
NH_3
Zn

For the duplicate samples, six instances occurred in which the acceptable RPD was exceeded (Table 3). Two of the dates in which these samples were collected were considered wet weather[1]. The increased flow during these sampling events may have resulted in less homogenization of the river than during dry weather, due to runoff, and therefore could have resulted in the differences observed between the two samples. The final date in which there was an RPD high enough to result in data being rejected did not occur during wet weather sampling and the reason for the unacceptable difference between the samples remains unknown.

Table 3. Duplicate samples with RPDs greater than acceptable				
Site	Date	Parameter	Acceptable RPD	Actual RPD
16.20	7/23/14	*E. coli*	133.3	141.0
16.20	7/23/14	Na	9.8	11.4
10.75	7/29/14	Al	12.6	27.0
10.75	7/29/14	Sn	99.7	160.1
10.75	7/29/14	Ti	20.6	94.6
10.75	7/29/14	TP	23.6	24.6
8.60	8/5/14	Al	17.5	17.6
8.60	8/5/14	Fe	16.9	18.0

The final QA/QC check for the samples that were collected was for paired parameters, or those parameters in which one is a subset of the other. There was one instance in which a set of parameters had to be qualified as estimated because of this and occurred for total solids and total dissolved solids at RM 16.20 on July 23rd.

The sites upstream of the navigation channel are all designated warmwater habitat, agricultural water supply, industrial water supply, and Class A primary contact recreation. Those in the navigation channel are designated limited resource water-navigation maintenance from June through January and whenever the river flow is less than 703 ft^3/s during the rest of the year and fish passage during the months of February

[1] Wet weather sampling events: greater than 0.10 inches of rain but less than 0.25 inches, samples collected that day and the following day are considered wet weather samples; greater than 0.25 inches, the samples collected that day and the following two days are considered wet weather samples.

through May when flow is equal to or greater than 703 ft^3/s. They are also designated industrial water supply and Class A primary contact recreation.

Exceedances of the recreation use bacteriological criteria occurred at all of the sites during 2014. The criteria for *Escherichia coli (E. coli)* consist of two components: a seasonal geometric mean and a value not to be exceeded in more than 10% of the samples collected during a 30-day period (single sample maximum). For those streams designated Class A primary contact recreation, these criteria are 126 colony counts/100mL and 298 colony counts/100mL, respectively. The seasonal geometric mean criterion was exceeded at all of the sites (Table 4) and was higher than in 2013. The single-sample maximum criterion was exceeded at all of the sites for a majority of the 30-day periods during the study. These exceedances could be due to all but one of the sampling dates taking place during or following wet-weather events. Potential sources of bacteria to the river could include stormwater runoff and CSOs.

Table 4. 2014 Cuyahoga River *E. coli* Densities (most-probable number/100mL)

Date	RM 16.20	RM 12.10	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00	RM 5.90	RM 2.75	RM 0.20
7/23/2014	---	166	92	149	92	96	146	224	218	81
7/29/2014*	931	1,937	1,361	2,002	1,884	2,075	1,406	1,894	2,314	967
8/5/2014*	308	250	232	203	2,667	335	126	359	106	126
8/12/2014*	57,650	15,450	6,237	5,096	5,926	4,797	6,569	7,456	5,142	4,502
8/19/2014*	86	118	286	312	220	110	134	348	526	120
Seasonal Geomean	1,092	681	553	626	904	512	469	831	679	351

* Wet weather event

Exceeds single sample maximum criteria for 30-day period starting on that date

Mercury was a second parameter that failed to meet the applicable criteria during the sampling that was conducted at these sites. Exceedances of the aquatic life and wildlife outside mixing zone averages (OMZA) occurred at most of the sites during the sampling (Table 5). The exception to this was the sites within the navigation channel, as all measurements were below the detection limit. It is expected that the use of EPA Method 1631E, a low level method, instead of EPA Method 245.1 would have resulted in exceedances of the criteria throughout the sampling period at all of the sites.

Table 5. 2014 Cuyahoga River Mercury Concentrations (ug/L)										
	RM 16.20	RM 12.10	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00	RM 5.90	RM 2.75	RM 0.20
7/23/2014	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
7/29/2014	<0.01	j0.01	<0.01	j0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
8/5/2014	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01	<0.01
8/12/2014	0.105	0.052	j0.047	j0.031	j0.017	j0.032	j0.031	<0.01	<0.01	<0.01
8/19/2014	<0.01	<0.01	j0.01	<0.01	<0.01	j0.01	<0.01	<0.01	<0.01	<0.01

Exceedance of Wildlife (0.0013 ug/L) and Aquatic Life (0.0031 ug/L) OMZAs for 30-day period beginning with that date, assuming "j" values are actual concentrations and concentrations below the MDL are zero.

For the rest of the parameters that were measured, there were exceedances of the aquatic life, human health nondrinking and agricultural criteria for some of the metals at the five upstream sites (Tables 6 to 8). These exceedances were all due to high concentrations in the samples collected on August 12th. Approximately 0.5 inches of rain, as measured at the NEORSD Southerly rain gauge, fell in the area just prior to the sampling and could have been the cause of these elevated levels. There typically have not been any exceedances of these parameters in recent years.

Table 6. 2014 Aquatic Life & Tier I Exceedances					
Site	Date/ 30-Day Period	Parameter	Measurement/ 30-Day Average	Criterion	Type
RM 16.20	7/29 - 8/26	Cu	16.1	15.0	OMZA
RM 16.20	8/5 - 9/22	Cu	19.5	15.2	OMZA
RM 16.20	8/12 - 9/09	Cu	27.3	16.1	OMZA
RM 16.20	8/12	Cu	51.1	23.7	OMZM
RM 16.20	7/23 - 8/20	Pb	16.6	14.2	OMZA
RM 16.20	7/29 - 8/26	Pb	20.5	13.1	OMZA
RM 16.20	8/5 - 9/2	Pb	26.2	13.3	OMZA
RM 16.20	8/12 - 9/9	Pb	37.9	14.5	OMZA
RM 16.20	8/12	Zn	202.6	192.5	OMZM
RM 12.10	8/12	Cu	25.3	25.1	OMZM
RM 12.10	8/12 - 9/9	Pb	16.7	15.3	OMZA
OMZA = Outside Mixing Zone Average OMZM = Outside Mixing Zone Maximum					

Table 7. 2014 Human Health NonDrinking Tier II Outside Mixing Zone Average Exceedances				
Site	30-Day Period	Parameter	30-Day Average	Criterion
RM 16.20	7/29 - 8/26	Al	5,422	4,500
RM 16.20	8/5 - 9/2	Al	6,864	4,500
RM 16.20	8/12 - 9/9	Al	10,048	4,500

Table 8. 2014 Agricultural Outside Mixing Zone Average Exceedances				
Site	30-Day Period	Parameter	30-Day Average	Criterion
RM 16.20	7/23 - 8/20	Fe	12,322	5,000
RM 16.20	7/29 - 8/26	Fe	19,380	5,000
RM 16.20	8/5 - 9/2	Fe	28,259	5,000
RM 12.10	7/23 - 8/20	Fe	5,338	5,000
RM 12.10	7/29 - 8/26	Fe	6,531	5,000
RM 12.10	8/5 - 9/1	Fe	7,603	5,000
RM 12.10	8/12 - 9/9	Fe	10,630	5,000
RM 11.30	7/29 - 8/26	Fe	5,561	5,000
RM 11.30	8/5 - 9/2	Fe	6,220	5,000
RM 11.30	8/12 - 9/9	Fe	8,368	5,000
RM 10.75	8/5 - 9/2	Fe	5,202	5,000
RM 10.75	8/12 - 9/9	Fe	6,873	5,000
RM 10.10	8/12 - 9/9	Fe	5,585	5,000

In 2013, the Ohio EPA released a draft Trophic Index Criterion designed to determine the degree of nutrient enrichment in a stream. Under the draft document, nutrient target values are based on designated use and Qualitative Habitat Evaluation Index scores. For warmwater habitat sites with QHEI scores between 12 and 64, the targets are 0.13 mg/L for total phosphorus (TP) and 3.0 mg/L for dissolved inorganic nitrogen (DIN), which includes ammonia, nitrate and nitrite. For all other aquatic life uses and QHEI scores, the targets for TP and DIN are 0.30 mg/L and 3.0 mg/L, respectively; the sites in the Cuyahoga River all fall under this category. Based on the average concentrations that were measured in 2014, the TP target was met at all of the sites, while the DIN target was only met at the sites upstream of Southerly WWTC. This was the same as in 2013.

Table 9. 2014 Cuyahoga River Average Nutrient Concentrations (mg/L)										
	RM 16.20	RM 12.10	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00	RM 5.90	RM 2.75	RM 0.20
TP	0.20	0.18	0.20	0.18	0.20	0.19	0.18	0.13	0.12	0.11
DRP	0.03	0.04	0.04	0.04	0.06	0.06	0.06	0.06	0.05	0.04
DIN	2.12	2.10	2.48	2.50	3.49	3.16	3.30	3.50	3.11	3.10

Habitat Assessment

Methods

Instream habitat assessments were conducted once at each site upstream of the Cuyahoga River navigation channel in 2014 using the Qualitative Habitat Evaluation Index (QHEI). The QHEI was developed by the Ohio EPA to assess aquatic habitat conditions that may influence the presence or absence of fish species by evaluating the physical attributes of a stream. The index is based on six metrics: stream substrate, instream cover, channel morphology, riparian zone and bank condition, pool and riffle quality, and stream gradient. The QHEI has a maximum score of 100, and a score of 60 or more suggests that sufficient habitat exists to support a fish community that attains the warmwater habitat criterion (Ohio EPA, 2003). A more detailed description of the QHEI can be found in Ohio EPA's *Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (QHEI)* (2006). QHEI field sheets for each site are available upon request from the NEORSD WQIS Division.

The habitat at the sites in the navigation channel were evaluated one time each in 2014 using the lacustuary QHEI (L-QHEI). Similar to the QHEI, the L-QHEI was developed by the Ohio EPA to assess aquatic habitat conditions that may influence the presence or absence of fish species, but in lacustuary zones or along the lake shoreline. The index is based on the metrics of substrate, cover types, shoreline morphology, riparian zone/bank erosion, and aquatic vegetation quality. The L-QHEI also has a maximum score of 100. More information can be found in Ohio EPA's *Methods for Assessing Habitat in Lake Erie Shoreline Waters Using the Qualitative Habitat Evaluation Index (QHEI) Approach (Version 2.1)* (2010). L-QHEI field sheets are also available upon request from the NEORSD WQIS Division.

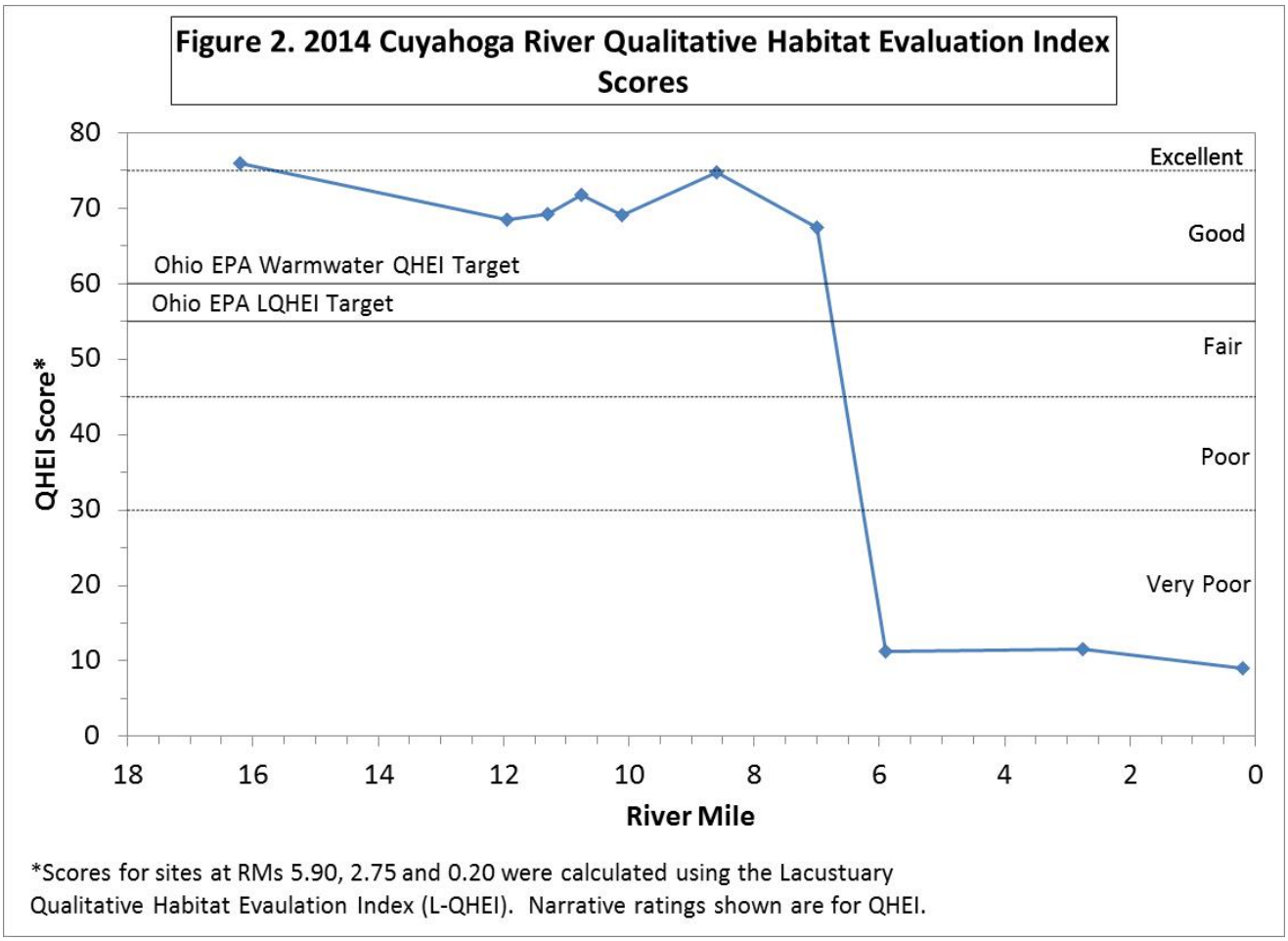
Results and Discussion

All of the sites upstream of the navigation channel had QHEI scores that met Ohio EPA's target of 60 and, therefore, should be capable of supporting warmwater habitat fish communities (Figure 2). The highest score was found at the site immediately

downstream of Tinkers Creek, which was the only site to score in the *Excellent* range. No significant differences were found when comparing scores from 2014 to those obtained in recent years.

Individual components of the QHEI can also be used to evaluate whether a site is capable of meeting the WWH designated use. This is done by categorizing specific attributes as indicative of either a WWH or modified warmwater habitat (MWH) (Rankin, 1995). Attributes that are considered characteristic of MWH are further classified as being of moderate or high influence to fish communities. The presence of one high or four moderate influence characteristics has been found to result in lower IBI scores, with a greater prevalence of these characteristics usually preventing a site from meeting WWH attainment (Ohio EPA, 1999).

Upstream of the navigation channel, the sites all had the WWH characteristics of fast currents and eddies, maximum depths greater than 40 cm, and either had never been channelized or had recovered from it (Table 6). All of the sites except for the one at RM 8.60 had sparse instream color, a high-influence MWH characteristics. Additionally, the site at RM 11.95 also had no sinuosity. The total number of moderate influence MWH attributes at each site ranged from three to six; common characteristics shared by most or all of the sites included a sand substrate, moderate-to-high embeddedness, moderate-to-heavy silt cover, and low sinuosity. Based on the number of the MWH attributes at these sites, it would be more difficult for most of them to meet the WWH fish criteria, even though they are higher than the overall target score of 60.



The sites in the navigation channel were evaluated using the L-QHEI and all failed to meet Ohio EPA's target score of 55 (Figure 2). The site characteristics that contributed heavily to the low scores included muck substrates, a general lack of instream cover, poor development, and a highly modified shoreline. Based on these attributes, it would not be expected that these sites would be able to support warmwater habitat fish communities. Some changes at RM 2.75 had occurred since the previous year due to the restoration project there. Although aquatic plants were introduced into a section of the electrofishing zone in 2013, none of them were still living when the habitat assessment was completed in 2014. No significant changes were found at the other two sites.

Table 10. Qualitative Habitat Evaluation Index scores and physical attributes

			MWH Attributes																													
			WWH Attributes										High Influence						Moderate Influence													
River Mile	QHEI Score	Habitat Rating	No Channelization or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinousity	Extensive/Moderate Cover	Fast Current/Eddies	Low-Normal Overall Embeddedness	Max. Depth >40 cm	Low-Normal Riffle Embeddedness	**Total WWH Attributes**	Channelized or no Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max. Dept <40 cm (WD, HW sites)	**Total High Influence Attributes**	Recovering Channel	Heavy/Moderate Silt Cover	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1-2 Cover Types	Intermittent & Poor Pools	No Fast current	High/Mod. Overall Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Total Moderate Influence Attribute**
16.20	76.00	Excellent	x			x			x		x		4				x		1			x			x				x	x		4
11.95	68.50	Good	x						x		x		3			x	x		2		x	x		x					x	x		5
11.30	69.25	Good	x						x		x		3				x		1		x	x		x	x				x	x		6
10.75	71.75	Good	x			x			x		x		4				x		1		x	x			x				x	x		5
10.10	69.00	Good	x						x		x		3				x		1		x	x		x	x				x	x		6
8.60	74.75	Good	x					x	x	x	x	x	6						0			x		x	x							3
7.00	67.50	Good	x						x		x		3				x		1		x	x		x	x				x	x		6

Fish Community Assessment

Methods

One quantitative electrofishing passes was conducted at each site upstream of the navigation channel in 2014, except at RM 16.20. No surveys were conducted at RM 16.20 due to flow conditions in the river that prevented boat launching. Within the navigation channel, two electrofishing surveys were conducted at RMs 5.90 and 0.20, and one was conducted at RM 2.75. A list of the dates when the surveys were completed, along with flow as measured at the United States Geological Survey gage station in either Independence or Newburgh Heights, is given in Table 11. Sampling was conducted using boat electrofishing techniques and consisted of shocking all habitat types within a sampling zone while moving from upstream to downstream by slowly and steadily maneuvering the boat as close to shore and submergent objects as possible. The sampling zone was 0.5 kilometers for each site. The methods that were used followed Ohio EPA protocol methods as detailed in *Biological Criteria for the Protection of Aquatic Life, Volumes II* (1987a) and *III* (1987b). Fish collected during the surveys were identified, weighed and examined for the presence of anomalies, including DELTs (deformities, eroded fins, lesions, and tumors). All fish were then released to the waters from which they were collected, except for vouchers and those that could not be easily identified in the field.

Table 11. Sampling Dates and River Flows

Date	Sites sampled (RMs)	Daily Mean Flow (CFS*)
7/18/14	5.90, 0.20	729**
9/25/14	10.75, 10.10, 8.60	372
9/29/14	11.95, 11.30, 7.00	365
10/6/14	5.90	587**
10/10/14	2.75, 0.20	514**

*Provisional data
**Measured at Newburgh Heights gage station; all other flows measured at Independence.

The electrofishing results for each pass were compiled and utilized to evaluate fish community health through the application of two Ohio EPA indices, the Index of Biotic Integrity (IBI) and the Modified Index of Well-Being (MIwb). The IBI incorporates 12 community metrics representing structural and functional attributes. The structural attributes are based upon fish community aspects such as fish numbers and diversity. Functional attributes are based upon fish community aspects such as feeding strategies, environmental tolerances, and disease symptoms. These metrics are individually scored

by comparing the data collected at the survey site with values expected at reference sites located in a similar geographical region. The maximum possible IBI score is 60 and the minimum possible score is 12. The summation of the 12 individual metrics scores provides a single-value IBI score, which corresponds to a narrative rating of *Exceptional, Good, Marginally Good, Fair, Poor* or *Very Poor*. Sites at River Miles 5.90, 2.75, and 0.20 were evaluated using the lacustuary IBI (LIBI). The LIBI is intended to be used in those areas near the mouths of rivers that may be affected by lake levels. The 12 metrics utilized for boat and lacustuary sites are listed in Table 12.

The second fish index utilized by Ohio EPA is the Modified Index of Well-being (MIwb). The MIwb, Formula 1 below, incorporates four fish community measures: numbers of individuals, biomass, and the Shannon Diversity Index (H) (Formula 2 below) based on numbers and weight of fish. The MIwb is a result of a mathematical calculation based upon the formula.

Formula 1: $$MIwb = 0.5\ lnN + 0.5\ lnB + \overline{H}(No.) + \overline{H}(Wt.)$$

N = Relative numbers of all species excluding species designated as highly tolerant, hybrids, or exotics

B = Relative weights of all species excluding species designated as highly tolerant, hybrids, or exotics

$\overline{H}(No.)$ = Shannon Diversity Index based on numbers

$\overline{H}(Wt.)$ = Shannon Diversity Index based on weight

Formula 2: $$\overline{H} = -\sum\left[\left(\frac{n_i}{N}\right)log_e\left(\frac{n_i}{N}\right)\right]$$

n_i = Relative numbers or weight of species

N = Total number or weight of the sample

Table 12. Index of Biotic Integrity Metrics

Boat	Lacustuary
Number of native species	Number of native species
Percent round-bodied suckers	Number of sunfish species
Number of sunfish species	Number of cyprinid species
Number of sucker species	Number of benthic species
Number of intolerant species	Percent phytophilic
Percent tolerant	Percent top carnivores
Percent omnivores	Number of intolerant species
Percent insectivores	Percent omnivores
Percent top carnivores	Percent non-indigenous
Number of individuals	Percent tolerant

Table 12. Index of Biotic Integrity Metrics	
Boat	Lacustuary
Percent simple lithophils	Percent DELTs
Percent DELTs	Number of individuals

Lists of the species, numbers, weights, pollution tolerances and incidence of DELT anomalies for fish collected during the electrofishing passes at each site are available upon request from the NEORSD WQIS Division.

Results and Discussion

The sites upstream of the navigation channel all had MIwb scores that met or were within non-significant departure from the warmwater habitat criterion, except for the site at RM 7.00 (Table 13 and Figure 3). This was the first time since 2006 that this site did not meet the criterion (Table 14). The decline in score was due to a large decrease in the number of fish collected there. The cause for this decline is unknown as no significant water quality differences were found between the site at RM 7.00 and the next upstream one at RM 8.60.

Table 13. 2014 Cuyahoga River IBI and MIwb Results							
		1st Pass		2nd Pass		Average	
Location	River Mile	IBI	MIwb	IBI	MIwb	IBI	MIwb
Upstream from Mill Creek	11.95	**44**	**9.1**	---	---	**44**	**9.1**
Downstream from Mill Creek	11.30	**42**	**9.3**	---	---	**42**	**9.3**
Upstream from Southerly WWTC	10.75	*38*	**9.0**	---	---	*38*	**9.0**
Downstream from Southerly WWTC	10.10	**40**	**9.5**	---	---	**40**	**9.5**
Upstream from Big Creek	8.60	34	*8.2*	---	---	34	*8.2*
Downstream from Big Creek	7.00	32	7.6	---	---	32	7.6
Upstream of Newburgh SS RR Bridge*	5.90	11	6.3	11	6.2	11	6.3
Scranton Road Restoration Site*	2.75	29	*8.4*	---	---	29	*8.4*
Upstream of Confluence w/ Lake Erie*	0.20	20	5.9	26	5.1	23	5.5
Bold = meets WWH criterion [IBI ≥40; MIwb ≥8.7] *Italics = non-significant departure from WWH criterion [IBI ≥36; MIwb ≥8.2]* * WWH criteria do not apply; LIBI used instead of IBI							

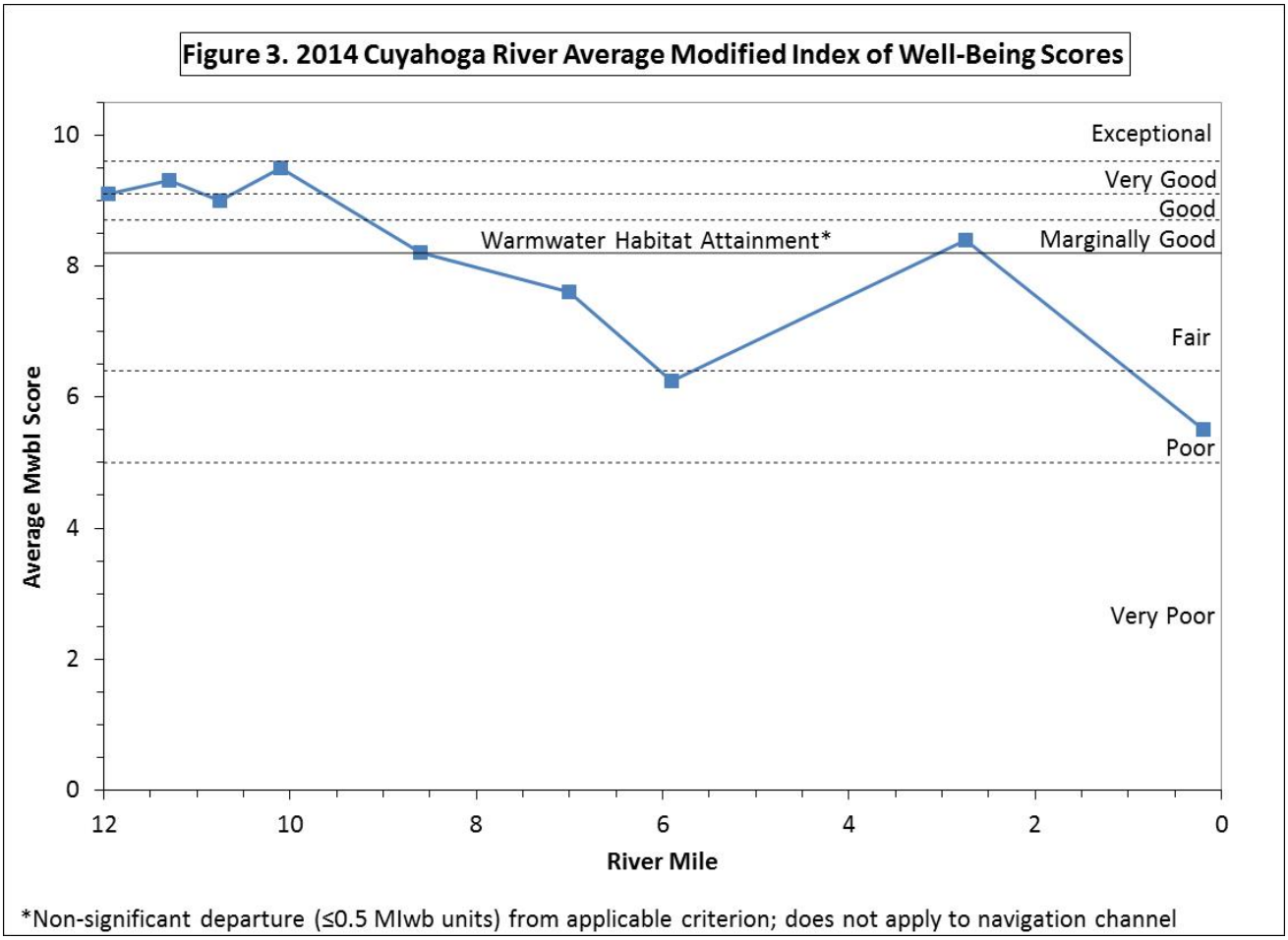


Table 14. Cuyahoga River Historic MIwb Scores (1990-2014)										
	RM 16.20	RM 11.95	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00	RM 5.90*	RM 2.75*	RM 0.20*
1990	-	-	-	4.5	4.6	-	-	-	-	-
1991	-	-	-	5.5	5.6	-	6.1	-	-	-
1992	-	-	-	5.6	6.6	-	5.8	-	-	-
1997	-	-	-	7.5	6.1	-	6.1	-	-	-
1998	-	-	-	7.8	7.6	-	5.5	-	-	-
1999	-	-	-	8.2	*8.6*	-	7.0	-	-	-
2001	-	-	-	7.4	*8.2*	-	6.1	-	-	-
2003	-	-	-	7.6	7.8	-	7.0	-	-	-
2004	-	-	-	8.0	*8.4*	-	-	-	-	-
2006	-	-	-	**8.8**	*8.5*	-	7.8	-	-	-
2007	*8.6*	*8.5*	*8.3*	**9.4**	**9.7**	-	*8.3*	-	-	-
2008	**9.9**	*8.2*	**9.1**	**8.9**	**9.4**	-	*8.5*	-	-	-
2009	**9.9**	**8.8**	**9.5**	**9.1**	**9.2**	**9.0**	*8.5*	-	-	-
2010	**9.5**	**9.0**	**9.7**	**9.7**	**9.5**	**9.2**	**8.8**	6.2	7.2	6.3

Table 14. Cuyahoga River Historic MIwb Scores (1990-2014)										
	RM 16.20	RM 11.95	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00	RM 5.90*	RM 2.75*	RM 0.20*
2011	**9.6**	**8.7**	**8.9**	**9.5**	**9.1**	**8.8**	*8.4*	7.3	8.1	6.8
2012	-	**9.2**	**9.5**	**9.6**	**10.1**	**9.6**	*8.6*	8.1	6.9	7.4
2013	-	8.3	**9.2**	**9.2**	**9.1**	**8.8**	8.3	6.3	-	5.9
2014	-	**9.1**	**9.3**	**9.0**	**9.5**	*8.2*	7.6	6.8	8.8	5.5

Bold = meets WWH criterion [≥8.7]
Italics = non-significant departure from WWH criterion [≥8.2]
Underline = meets proposed interim biological criteria for lacustuary habitats
*WWH criterion does not apply

Within the navigation channel, the biological criteria do not apply. However, based on the sampling that was conducted, the MIwb score at the restoration site would have met proposed interim biological criteria for lacustuary habitats of 8.6, while the scores at the other two sites would not have. The score at the restoration site in 2014 was the highest that has ever been measured there, which indicates that the changes to the habitat may be beneficial to the fish community. Monitoring at that site over the next few years will help to further determine any benefits from the project.

For the IBI, four of the sites upstream of the navigation channel had scores that met the warmwater habitat criterion or were within non-significant departure from it (Table 13 and Figure 4). The two sites that failed to meet the criterion were the ones immediately upstream and downstream of Big Creek. For the site at RM 8.60, problems with the electrofishing boat were encountered when completing the survey. As a result, one section of the electrofishing zone was not sampled. It is expected that completion of the entire zone would have resulted in an IBI score in attainment of the criterion, as it has done so each of the other years that it has been assessed (Table 15). For the other sites, scores from 2014 were comparable to those from 2013. The exception was the site at RM 10.10, which had an increase of 7 IBI units. During past years, some individual electrofishing passes at that site have met or exceeded this score, even though average scores have always been lower.

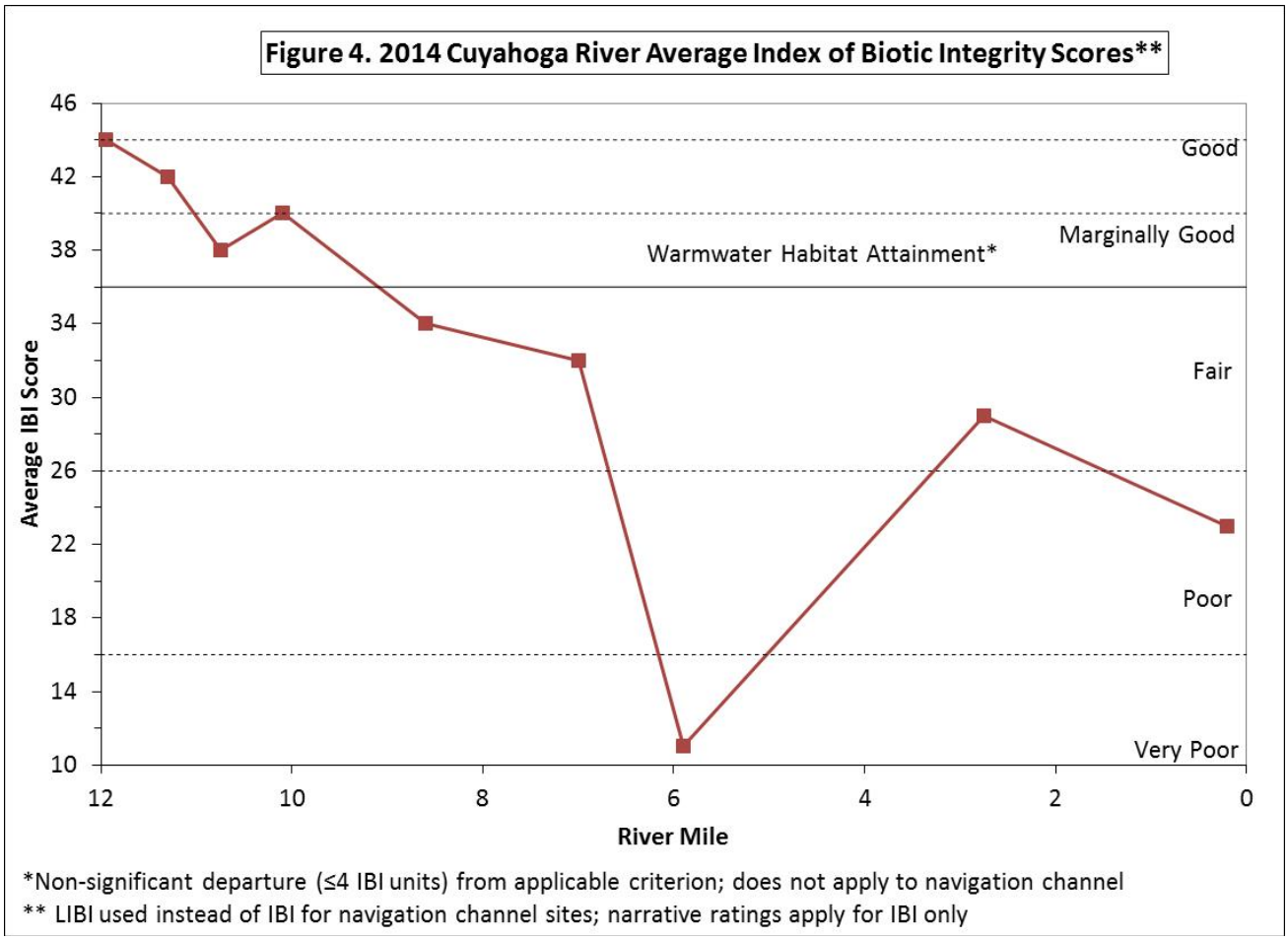
Table 15. Cuyahoga River Historic IBI Scores (1990-2014)										
	RM 16.20	RM 11.95	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00	RM 5.90*	RM 2.75*	RM 0.20*
1990	-	-	-	15	15	-	-	-	-	-
1991	-	-	-	17	16	-	18	-	-	-
1992	-	-	-	20	19	-	21	-	-	-
1997	-	-	-	25	17	-	18	-	-	-
1998	-	-	-	26	27	-	21	-	-	-

Table 15. Cuyahoga River Historic IBI Scores (1990-2014)										
	RM 16.20	RM 11.95	RM 11.30	RM 10.75	RM 10.10	RM 8.60	RM 7.00	RM 5.90*	RM 2.75*	RM 0.20*
1999	-	-	-	31	31	-	24	-	-	-
2001	-	-	-	30	29	-	22	-	-	-
2003	-	-	-	34	28	-	23	-	-	-
2004	-	-	-	35	35	-	-	-	-	-
2006	-	-	-	*39*	*36*	-	31	-	-	-
2007	*39*	30	*38*	34	35	-	33	-	-	-
2008	**44**	34	*38*	*37*	*36*	-	34	-	-	-
2009	**45**	*38*	**44**	*36*	31	**40**	31	-	-	-
2010	**43**	*39*	*39*	33	*37*	**41**	31	18	27	25
2011	**47**	*39*	35	**44**	*36*	**40**	32	28	25	27
2012	-	*36*	35	*38*	34	*38*	29	24	20	27
2013	-	**41**	**42**	*36*	33	**41**	34	21	-	23
2014	-	**44**	**42**	*38*	**40**	34	32	11	29	23

Bold = meets WWH criterion [≥40]
Italics = non-significant departure from WWH criterion [≥36]
*Lacustuary IBI; WWH criterion does not apply

An examination of the individual IBI metrics showed that generally, the proportion of round-bodied suckers scored poorly (metric score of 1) at most of the sites in 2014; the exception to this was the site at RM 8.60. This is the same as was found in 2013. Habitat may be the main contributing factor for why more of this type of species was not collected. The site at RM 8.60 has an extended riffle/run sequence where the majority of the round-bodied suckers were collected. While the other sites also had riffles, the quality of the riffles was not as high and could have resulted in the lower number of round-bodied suckers collected there.

Similar to past years, the metric for number of pollution-intolerant fish scored poorly at all of the sites; only one intolerant fish, a stonecat madtom, was collected in 2014. Water quality conditions continue to be one reason for why these fish may be absent. Exceedances of the bacteriological criteria indicate that there may be some sanitary sewage present in the river. The stress to fish associated with such pollutants could therefore be a hindrance to the establishment of those species.



The sites within the navigation channel were evaluated using the lacustuary IBI (LIBI). The site at RM 2.75 had the best score and rated *Fair*. This was also the best score at that site since sampling began by NEORSD in 2010 and was mainly due to a larger number of both species and fish collected there, along with a lower proportion of tolerant individuals. The reason for the improvements may be due to the restoration project, although further assessments in upcoming years will help determine if this is true. In 2014, the site at RM 5.90 scored in the *Very Poor* category, which was a significant decrease from previous years. All of the metrics at this site scored either a 0 or 1 for at least one of the passes. The site at RM 0.20 was rated *Poor*, with a score that was similar to past years. A lack of suitable habitat, specifically due to the highly modified nature of the navigation channel, continues to be the main cause for the generally poor fish community at these locations.

Macroinvertebrate Sampling

Methods

Macroinvertebrates were sampled quantitatively using modified Hester-Dendy (HD) samplers in conjunction with a qualitative assessment of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly), also referred to as EPT taxa, inhabiting available habitats at the time of HD retrieval. Sampling was conducted at all of the locations listed in Table 1. Methods for sampling followed the Ohio EPA's Biological Criteria for the Protection of Aquatic Life, Volume III (1987b). HDs within the navigation channel were floated at a depth of approximately two feet below the surface. The recommended period for HDs to be installed is six weeks.

The macroinvertebrate samples were sent to Third Rock Consulting of Lexington, Kentucky, for identification and enumeration. Specimens were identified to the lowest practical taxonomic level as defined by the Ohio EPA (1987b). Lists of the species collected during the quantitative and qualitative sampling at each site are available upon request from WQIS.

The overall aquatic macroinvertebrate community in the stream was evaluated using either Ohio EPA's Invertebrate Community Index (ICI) (OEPA 1987a, Ohio EPA undated) or Lacustuary Invertebrate Community Index (LICI) (OEPA 1987a, Ohio EPA undated). The ICI and LICI both consist of ten community metrics (Table 16), each with four scoring categories. Metrics 1-9 are based on the quantitative sample, while Metric 10 is based on the qualitative EPT taxa. The total of the individual metric scores result in the overall score. This scoring evaluates the community against Ohio EPA's reference sites for each specific eco-region.

Table 16. Metrics

ICI	LICI
Total number of taxa	Total number of taxa
Number of mayfly taxa	Number of dipteran taxa
Number of caddisfly taxa	Number of sensitive taxa
Number of dipteran taxa	Percent predominant taxon
Percent mayflies	Percent other diptera and non-insects
Percent caddisflies	Percent mayflies and caddisflies
Percent Tanytarsini midges	Percent sensitive taxa (excluding Dreissinids)
Percent other diptera and non-insects	Percent collector-gatherers
Percent tolerant organisms (as defined)	Dipteran abundance
Number of qualitative EPT taxa	Number of qualitative EPT taxa

Results and Discussion

Four out of the five sites upstream of the navigation channel in which Hester-Dendy samplers were collected had ICI scores that met the warmwater habitat criterion (Table 17 and Figure 5). The only site that did not meet the criterion was the one at RM 7.00. That site and the one immediately upstream of it had significantly lower scores compared to the previous year (Table 18). The sites at RMs 162.0 and 11.30, on the other hand, had scores that were significantly higher than 2013 and were the highest ever received at those sites from NEORSD assessments.

Table 17. Macroinvertebrate Results

Location	River Mile	ICI Score	LICI Score	Density (Organisms per square foot)	Total Number of Taxa	Number of Qualitative EPT Taxa	% Tolerant (as defined)	Narrative Rating
Downstream of Tinkers Creek	16.20	**44**	---	793	46	13	1.9	Very Good
Upstream of Mill Creek	12.10	**---**	---	---	55	14	---	Good
Downstream of Mill Creek	11.30	**48**	---	596	53	12	1.7	Excellent
Upstream of Southerly WWTC	10.75	**---**	---	---	39	13	---	Marginally Good
Downstream of Southerly WWTC	10.10	**34**	---	1025	57	11	21.9	Good
Upstream of Big Creek	8.60	*30*	---	529	44	9	28.1	Marginally Good
Downstream of Big Creek	7.00	28	---	563	46	8	11.1	Fair
Head of Navigation Channel	5.90	---	28	312	32	0	39.8	Fair
Restoration Site	2.75	---	36	474	26	0	44.4	Fair

Table 17. Macroinvertebrate Results								
Location	River Mile	ICI Score	LICI Score	Density (Organisms per square foot)	Total Number of Taxa	Number of Qualitative EPT Taxa	% Tolerant (as defined)	Narrative Rating
Cuyahoga River Mouth	0.20	---	26	268	15	0	10.2	Fair

Bold indicates attainment of WWH criterion

Italics indicates non-significant departure (≤4 ICI units) from criterion

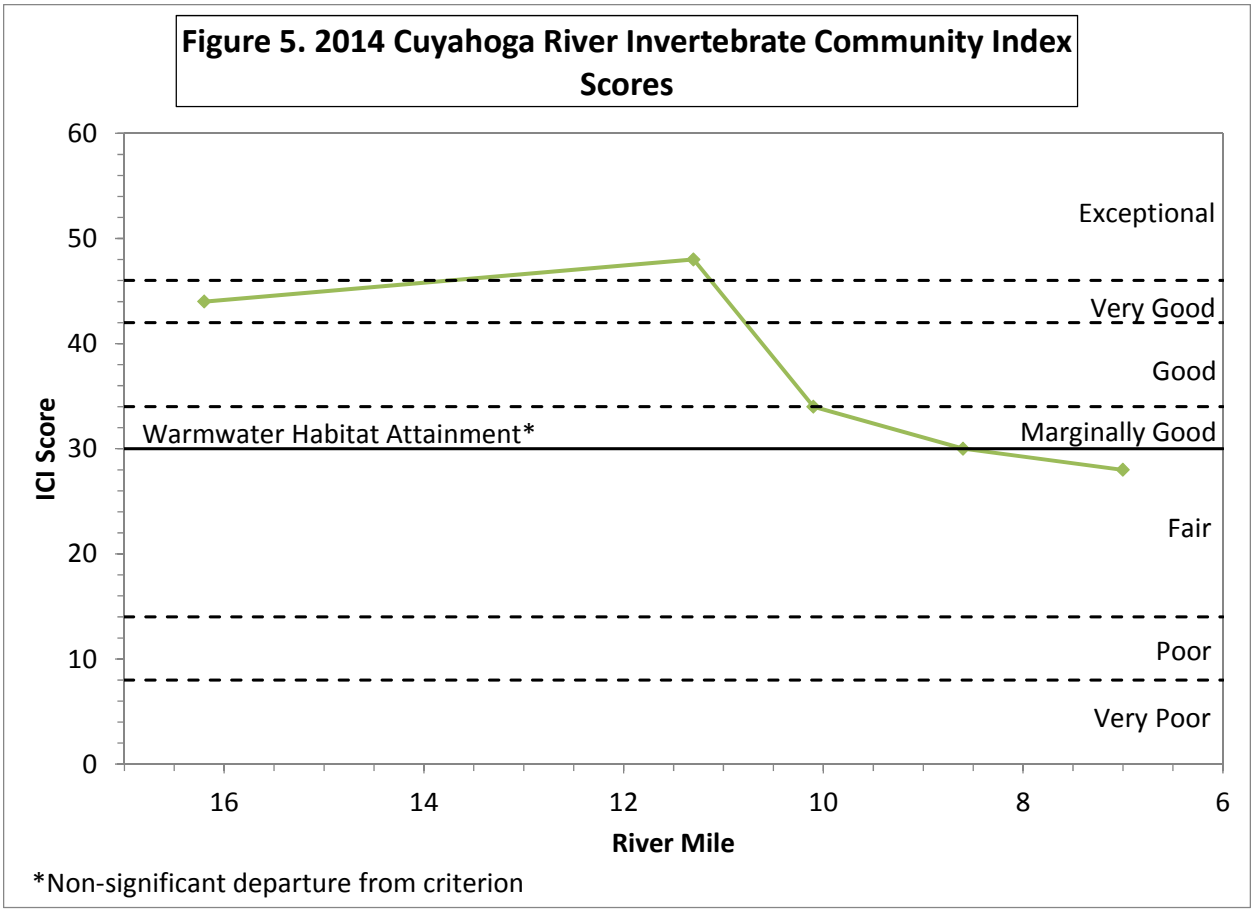
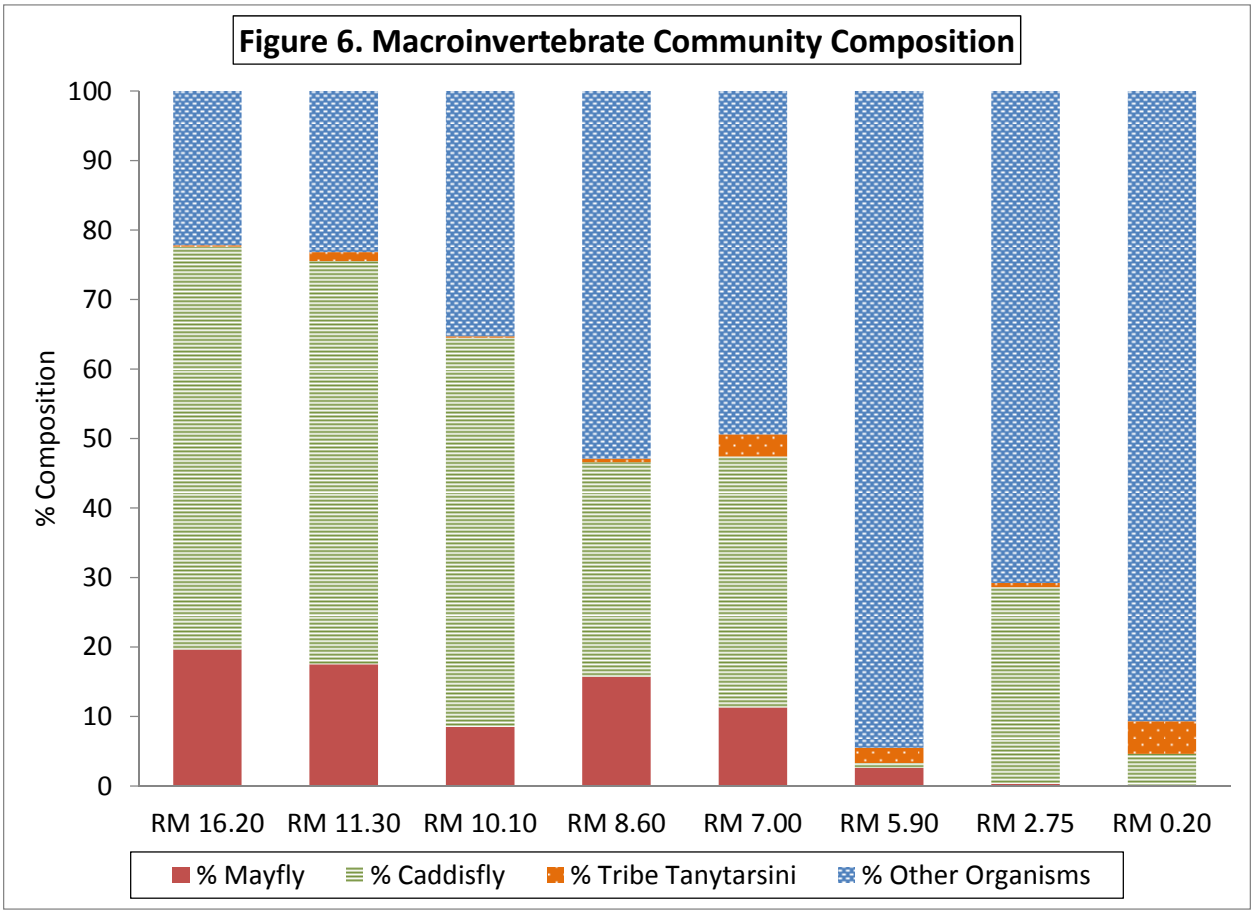


Table 18. Cuyahoga River Historic ICI Scores (2006-2014)										
Year	16.20	12.10	11.30	10.75	10.10	8.60	7.00	5.90*	2.75*	0.20*
2006	30	---	---	**38**	**34**	---	---	---	---	---
2007	**34**	**35**	**34**	*32*	**36**	---	**38**	---	---	---
2008	**40**	**40**	**40**	**40**	**40**	---	**38**	---	---	---
2009	**36**	**38**	**36**	**42**	**38**	**36**	**42**	---	---	---
2010	**36**	**40**	**40**	**36**	32	**44**	**34**	---	---	---
2011	**40**	**36**	**36**	*30*	---	---	26	46	---	36
2012	**40**	**44**	**38**	**40**	**34**	**40**	*30*	28	---	16
2013	**36**	**40**	**34**	**46**	**34**	**42**	**38**	36	---	---
2014	**44**	**---**	**48**	**---**	**34**	*30*	28	28	36	26

Bold indicates attainment of WWH criterion
Italics indicates non-significant departure (≤4 ICI units) from criterion
**LICI instead of ICI*

The changes in scores at RMs 8.60 and 7.00 could be due to the time of year in which the Hester-Dendy samplers and qualitative samples were collected. Ohio EPA recommends that macroinvertebrate sampling be completed no later than September 30th. After this date, which is when the samples from the Cuyahoga River were collected in 2014, the macroinvertebrate community starts to shift in composition to different organisms than for what the ICI is calibrated. In 2013, organisms belonging to the pollution-sensitive taxa groups (mayflies, caddisflies, and tribe Tanytarsini midges, also known as EPT taxa) comprised between 72 and 86% of the macroinvertebrates collected at the locations upstream of the navigation channel. In 2014, however, this was only true at the two most upstream locations (Figure 6). For the rest of the sites, the percentages were much lower, with a greater percentage of those macroinvertebrates considered to be pollution-tolerant present.

No Hester-Dendy samplers were collected from the sites at RM 12.10 and 10.75 in 2014. Instead, a narrative rating was assigned based on the qualitative sample. Both of these sites were expected to meet or be within non-significant departure of the ICI criterion, with the site at RM 12.10 being assigned a rating of *Good* and the site at RM 10.75 a *Marginally Good*. Both of these sites had numbers of EPT taxa that exceeded Ohio EPA's recommendation for warmwater habitat communities (Ohio EPA 1987b). Although the number of sensitive taxa was below the recommendations, other characteristics of the qualitative sample, such as the total number of taxa and the predominant organisms, were indicative of sites that would be expected to meet the warmwater habitat criterion.



The three sites within the navigation channel were evaluated using the LICI; all had scores that fell into the *Fair* category. During the time period that NEORSD has assessed the macroinvertebrate community in the navigation channel, LICI scores have been highly variable. The scores from 2014 at RMs 5.90 and 0.20 fell within the middle of all scores obtained over the last four years. For RM 2.75, this was the first year that a Hester-Dendy sampler was successfully collected from that site, so no comparison could be made to past years. No EPT taxa were collected in the qualitative samples at any these sites, with a much lower percentage, compared to the sites upstream of the navigation channel, present on the Hester-Dendy samplers. At RMs 5.90 and 2.75, there was also a much greater percentage of organisms present that are considered to be pollution tolerant. Similar to the fish, a lack of suitable habitat could be one reason for why a healthier macroinvertebrate community was not present.

Conclusions

In 2014, the sampling that was conducted indicated that five out of the seven sites sampled upstream of the navigation channel were in full attainment of the biological

criteria (Table 19). The site at RM 16.20 met the criterion for the ICI; it is expected that it would have met the fish criteria as well if sampling could have been conducted there. The sites at RMs 12.10 and 10.75 met the fish criteria and were expected to meet the ICI criterion if a Hester-Dendy sampler would have been collected from them. The sites immediately upstream and downstream of Big Creek did not score as well; the site at RM 8.60 was in partial attainment of the criteria, while the one at RM 7.00 was in non-attainment. Equipment problems during the electrofishing survey at RM 8.60 most likely resulted in the fish score not meeting the WWH criterion, as it has been in full attainment of the biocriteria for every other year that NEORSD has conducted sampling there. The reasons for the site at RM 7.00 not being in attainment were unclear; water chemistry sampling did not indicate any differing water quality conditions than the sites upstream of it.

Exceedances of water quality criteria did occur for some metals at the five most upstream sites. For most of these, this may have been the result of wet weather occurring prior to one of the sampling events, as these parameters have typically met the criteria in recent years. At all of the sites upstream of the navigation channel, there were exceedances of the mercury wildlife and aquatic life criteria. These exceedances, however, did not indicate any contamination above those levels normally found in streams in northeast Ohio.

Table 19. 2014 Cuyahoga River Survey Results

River Mile	Aquatic Life Use Attainment Status	IBI Score (Narrative Rating)	MIwb Score (Narrative Rating)	ICI Score (Narrative Rating)	QHEI Score (Narrative Rating)	Water Quality Exceedances
16.20	(FULL[1])			44 *(Very Good)*	76.00 *(Excellent)*	Aluminum, Copper, *E. coli,* Iron, Lead, Mercury
11.95	(FULL[2])	44 *(Very Good)*	9.1 *(Good)*	*(Good[3])*	68.5 *(Good)*	Copper, *E. coli,* Lead, Iron, Mercury
11.30	FULL	42 *(Good)*	9.3 *(Very Good)*	48 *(Exceptional)*	69.25 *(Good)*	*E. coli,* Iron, Mercury
10.75	(FULL[2])	38 *(Marginally Good)*	9.0 *(Good)*	*(Marginally Good)*	71.75 *(Good)*	*E. coli,* Iron, Mercury
10.10	FULL	40 *(Good)*	9.5 *(Very Good)*	34 *(Good)*	69.00 *(Good)*	*E. coli,* Iron, Mercury
8.60	PARTIAL	34 *(Fair)*	8.2 *(Fair)*	30 *(Marginally Good)*	74.75 *(Good)*	*E. coli,* Mercury
7.00	NON	32 *(Fair)*	7.6 *(Fair)*	28 *(Fair)*	67.50 *(Good)*	*E. coli,* Mercury

Table 19. 2014 Cuyahoga River Survey Results						
River Mile	Aquatic Life Use Attainment Status	IBI Score (Narrative Rating)	MIwb Score (Narrative Rating)	ICI Score (Narrative Rating)	QHEI Score (Narrative Rating)	Water Quality Exceedances
5.90[4]	N/A	11 *(Very Poor)*	6.8 *(Fair)*	28 *(Fair)*	11.25 *(Very Poor)*	*E. coli*
2.75[4]	N/A	29 *(Poor)*	8.8 *(Good)*	36 *(Fair)*	11.50 *(Very Poor)*	*E. coli*
0.20[4]	N/A	23 *(Poor)*	5.5 *(Fair)*	26 *(Fair)*	9.00 *(Very Poor)*	*E. coli*

WWH biocriterion attainment: IBI score of 40; MIwb score of 8.2; ICI score of 34
Non-significant departure: ≤4 IBI units; ≤0.5 MIwb units; ≤4 ICI units
--HD not collected; qualitative assessment only
[1]Based on ICI score and best professional judgment
[2]Based on IBI and MIwb scores and best professional judgment
[3]Narrative rating based on best professional judgment and habitat evaluation
[4]Lacustuary scoring

As in years past, assessments in 2014 showed that for all of the sites, some water quality impairments may be preventing establishment of healthier biological communities. Exceedances of the water quality standards occurred for *E. coli*, indicating the presence of some sanitary sewage in the river. Potential sources of pollution include illicit discharges, CSOs, stormwater runoff, and flow from upstream tributaries. Effluent from Southerly WWTC did not appear to significantly contribute to these exceedances.

Although the biological criteria do not apply to sites with the navigation channel, assessments completed there generally indicated the presence of impacted biological communities. Habitat evaluations at those sites resulted in scores that fell into the *Very Poor* category. Some improvements to the fish community, as indicated by a *Good* MIwb score, did occur at RM 2.75 when compared to sampling from past years. This improvement may have been a result of the restoration project that was completed there in 2013. The remaining biological scores for that site and all of the ones for the other two sites showed the need for improved habitat in order for healthier fish and macroinvertebrate communities to be present.

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References

Holomuzki, J.R., & and Biggs, B.J.F. (2000). Taxon-specific responses to high-flow disturbance in streams: implications for population persistence. *Journal of the North American Benthological Society*, 19, 670-679.

Ohio Environmental Protection Agency. (1987a). *Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters* (Updated January 1988; September 1989; November 2006; August 2008). Columbus, OH: Division of Water Quality Monitoring and Assessment.

Ohio Environmental Protection Agency. (1987b). *Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities* (Updated September 1989; March 2001; November 2006; and August 2008). Columbus, OH: Division of Water Quality Monitoring and Assessment.

Ohio Environmental Protection Agency. (1999). *Association Between Nutrients, Habitat, and the Aquatic Biota in Ohio Rivers and Streams* (MAS/1999-1-1). Columbus, OH: Division of Surface Water.

Ohio Environmental Protection Agency. (2003). Total Maximum Daily Loads for the Lower Cuyahoga River. Ohio EPA, Division of Surface Water. Water Standards and Technical Support Section.

Ohio Environmental Protection Agency. (2006a). *Methods for assessing habitat in flowing waters: using the Qualitative Habitat Evaluation Index (QHEI)*. (Ohio EPA Technical Bulletin EAS/2006-06-1). Columbus, OH: Division of Surface Water; Division of Ecological Assessment Section.

Ohio Environmental Protection Agency. (2009). *State of Ohio Water Quality Standards Ohio Administrative Code Chapter 3745-1* (Revision: Adopted July 9, 2009; Effective October 9, 2009). Columbus, OH: Division of Surface Water, Standards and Technical Support Section.

Ohio Environmental Protection Agency. (2010). *Draft State of Ohio Water Quality Standards Ohio Administrative Code Chapter 3745-1-44 Criteria for the control of nutrient enrichment in streams.* Columbus, OH: Division of Surface Water, Standards and Technical Support Section.

Ohio Environmental Protection Agency. (2010). *Methods of Assessing Habitat in Lake Erie Shoreline Waters Using the Qualitative Habitat Evaluation Index (QHEI) Approach (Version 2.1).* Twinsburg, OH: Division of Surface Water, Northeast District Office.

Ohio Environmental Protection Agency. (2012). *Manual of Ohio EPA Surveillance Methods and Quality Assurance Practice.* Columbus, OH: Division of Surface Water; Division of Environmental Services.

Ohio Environmental Protection Agency. (2013). *Surface Water Field Sampling Manual for water column chemistry, bacteria and flows*. Columbus, Ohio: Division of Surface Water.

Ohio Environmental Protection Agency. (Undated). *Biological criteria for the protection of aquatic life: Volume IV: Fish and macroinvertebrate indices for Ohio's Lake Erie nearshore waters, harbors, and lacustuaries.* Columbus, OH: Northeast District Office and Ecological Assessment Unit.

Rankin, E.T. (1995). Habitat indices in water resource quality assessments. In W.S. Davis and T. Simon (eds.). *Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making* (pp. 181-208). Boca Raton, FL: Lewis Publishers.

Trautman, M. B. (1981). *The Fishes of Ohio*. Columbus, Ohio: The Ohio State University Press.

Yoder, C.O., & E.T. Rankin. (1995). Biological response signatures and the area of degradation value: new tools for interpreting multimetric data, pp. 263-286 (Chapter 17). *in* W.S. Davis and T. Simon (eds.). *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making.* Lewis Publishers, Boca Raton, FL.