NORTHEAST OHIO REGIONAL SEWER DISTRICT

2018 Sagamore Creek Environmental Monitoring
Biological, Water Quality and Habitat Survey Results

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Introduction

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 for the establishment of Total Maximum Daily Loads (TMDLs) for the Lower Cuyahoga River. The causes of impairment to the river were classified as organic enrichment, toxicity, low dissolved oxygen, nutrients, and flow alteration (Ohio EPA, 2003). Recent monitoring by the Northeast Ohio Regional Sewer District (NEORSD), however, has shown recovery of the biological community in some reaches of the river. Further assessments throughout the watershed, including tributaries of the Cuyahoga River, is necessary to determine what areas may be still impaired.

In 2018, NEORSD conducted environmental assessments including water chemistry sampling, habitat assessments, and fish and macroinvertebrate community surveys on Sagamore Creek, a tributary to the Cuyahoga River. The objective of this study was to conduct environmental monitoring on Sagamore Creek in addition to five other tributaries to the Cuyahoga River as part of NEORSD's general watershed monitoring program. Portions of the tributary data collected will provide additional information to support the continued monitoring of the lower Cuyahoga AOC and the potential delisting of some beneficial use impairments.

Sampling was conducted by the NEORSD Environmental Assessment group of the Water Quality and Industrial Surveillance (WQIS) Division and occurred from June 15 through September 30, 2018 (through October 15 for fish sampling assessments), as required in the Ohio Environmental Protection Agency (EPA) *Biological Criteria for the Protection of Aquatic Life Volume III* (1987b). Sampling was conducted by NEORSD Level 3 Qualified Data Collectors certified by the Ohio EPA in Fish Community and Benthic Macroinvertebrate Biology, and Chemical Water Quality and Stream Habitat Assessments as explained in the NEORSD study plan *2018 Cuyahoga River Tributaries Environmental Monitoring* approved by Ohio EPA on April 18, 2018. The results obtained from these assessments were evaluated using the Ohio EPA's Qualitative Habitat Evaluation Index (QHEI), Index of Biotic Integrity (IBI), and Invertebrate Community Index (ICI). Water chemistry data was validated per the methods outlined by the Ohio EPA (2018b) and compared to the Ohio Water Quality Standards (Ohio EPA, 2018a) to determine attainment of applicable uses. An examination of the biological information was used in conjunction with the water quality data and QHEI results in order to assess the health of the stream and to show any temporal as well as spatial trends.

Figure 1 is a study area map, noting the location of the sampling location evaluated during the 2018 study. Table 1 indicates the sampling location for the study site on Sagamore Creek with respect to river mile, latitude/longitude, description, and the types of

surveys conducted. A digital photo catalog of the sampling locations is available upon request by contacting the NEORSD WQIS Division.

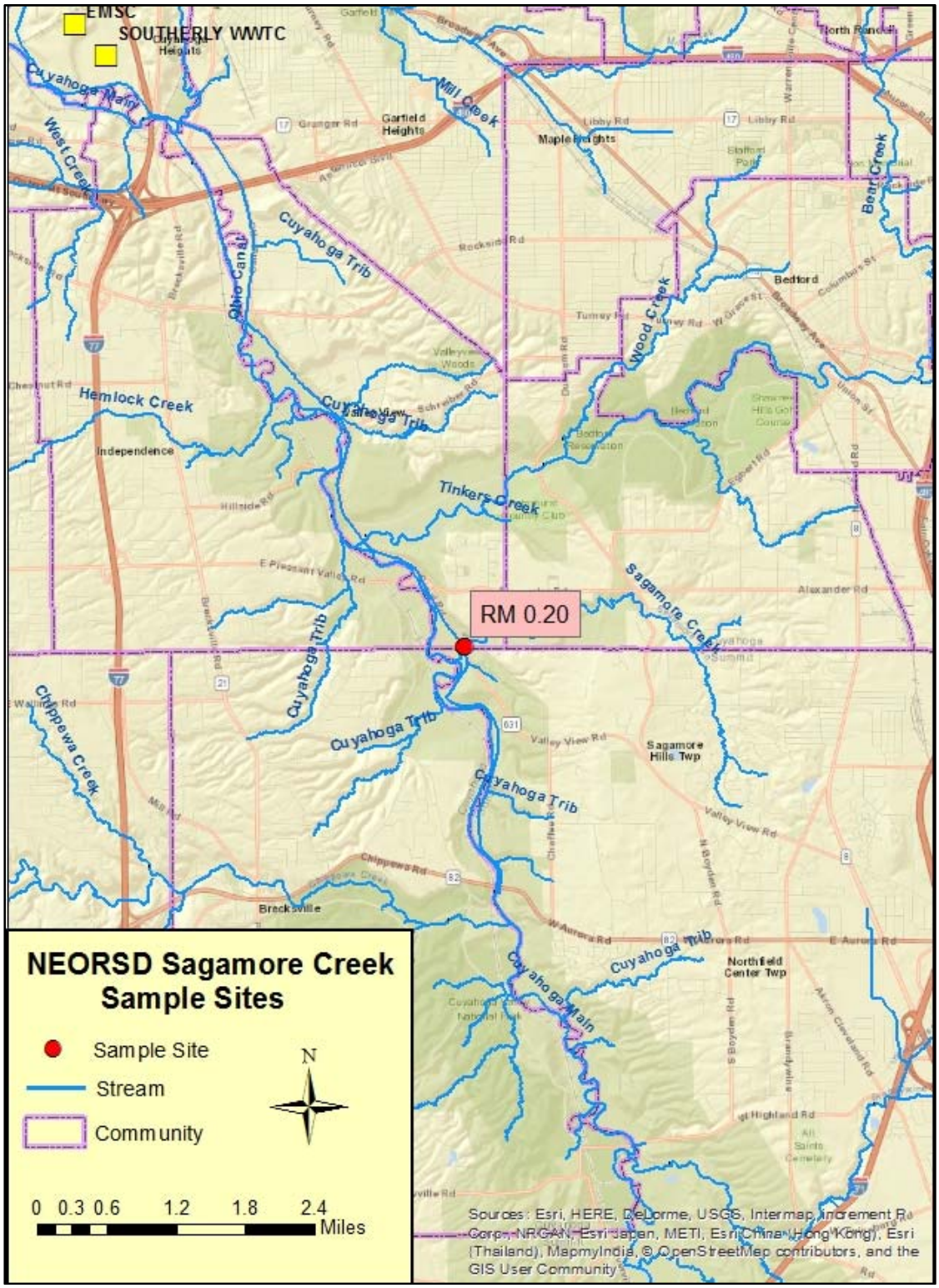

Figure 1. 2018 Sagamore Creek Monitoring Site

Table 1. Sagamore Creek Evaluated Site						
Site Location	Latitude	Longitude	River Mile	Description	HUC 8	Purpose
Sagamore Creek	41.3514	-81.5923	0.20	Upstream of Canal Road	04110002 - Cuyahoga	General watershed monitoring.

Water Chemistry Sampling

Methods

Five separate water chemistry and bacteriological sampling events were conducted between June 15th and September 30th, 2018. Techniques used for sampling and analyses were conducted according to methods found in *Surface Water Field Sampling Manual for water quality parameters and flows* (Ohio EPA, 2018b). 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 one 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 sonde or YSI EXO1 sonde. Duplicate samples and field blanks were each collected 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, 2015b).

Formula 2: Acceptable % RPD = $[(0.9465x^{-0.344})*100] + 5$
x = sample/detection limit ratio

Those RPDs that are 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 completed 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 Average (OMZA), it generally cannot be determined if Sagamore Creek 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 stream.

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

Results and Discussion

Sagamore Creek is designated Coldwater Habitat (CWH), Agricultural Water Supply, Industrial Water Supply, and Primary Contact Recreation. For the 2018 study, one duplicate sample and one field blank were collected for quality assurance and quality control (QA/QC) purposes. The duplicate and field blank samples were collected at RM 0.20 on July 18, 2018. For the duplicate sample, there were no parameters rejected based on RPD values. For the field blank, there were two parameters that showed possible contamination. It is unclear how the field blank became contaminated and may be due to inappropriate sample collection, handling, and/or contaminated blank water. Water quality parameters that were listed as estimated based on Ohio EPA data validation protocol can be seen on Table 2.

Table 2. Parameters Affected by Possible Blank Contamination

Cu
TKN

Paired parameters for all samples collected from RM 0.20 were evaluated for QA/QC purposes. The comparisons revealed no rejected data for the sampling site. Two instances occurred in which the data for the paired parameters needed to be qualified because the sub-parameter was greater than the parent one (Table 3). Because there were no exceedances associated with these parameters, qualification of these results did not significantly change the overall water chemistry assessment of Sagamore Creek.

Table 3. Paired Data Parameter Analysis						
Date	Site	Parameter	Data Pair	Acceptable RPD (%)	Actual RPD (%)	Qualifier
7/5/2018	RM 0.20	*TP*	*DRP*	73.6	19.4	Estimated
7/18/2018	RM 0.20	*TP*	*DRP*	72.0	6.5	Estimated

The water chemistry samples collected at each site were compared to the applicable Ohio Water Quality Standards for the designated uses to determine attainment (Ohio EPA, 2018). Water chemistry sampling at RM 0.20 in 2018, resulted in mercury concentrations that were below the method detection limit for EPA Method 245.1. 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. Mercury may be introduced into Sagamore Creek from urban runoff and atmospheric deposition within the watershed. Apart from the probable mercury exceedances, Sagamore Creek RM 0.20 met all other water quality criteria for the 2018 sampling season.

The Primary Contact Recreation criteria for Sagamore Creek include an *E. coli* criterion not to exceed a Statistical Threshold Value (STV) of 410 colony counts/100mL in more than ten percent of the samples taken during any 90-day period, and a 90-day geometric mean criterion of 126 colony counts/100mL (Ohio EPA, 2015a). Based on all sampling events, RM 0.20 met the geomean and STV criteria in 2018 (Table 4).

Table 4. 2018 Sagamore Creek *E. coli* Densities (most-probable number/100mL)	
Date	RM 0.20
6/20/2018*	251
6/27/2018	212
7/05/2018*	29
7/11/2018	18
7/18/2018*	9.5
90-day Geomean	48.3
*Wet-Weather Event: 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.	

In 2015, the Ohio EPA Nutrients Technical Advisory Group released a proposed Stream Nutrient Assessment Procedure (SNAP) designed to determine the degree of impairment in a stream due to nutrient enrichment. SNAP assigns designations for quality of surface waters based on factors including dissolved oxygen (DO) swings, benthic chlorophyll *a*, total phosphorous, and dissolved inorganic nitrogen (Ohio EPA, 2015c). NEORSD did not assess DO swings or benthic chlorophyll *a* in 2018; however, nutrients were assessed.

Table 5 shows the nutrient concentrations for the Sagamore Creek site in 2018. The results of dissolved inorganic nitrogen and total phosphorous were compared to Table 2 listed in the SNAP document. According to this section of SNAP, the site analyzed on Sagamore Creek exhibit "background levels typical of least disturbed conditions," (Ohio EPA, 2015c). This indicates that neither phosphorous or nitrogen are of a significant concern as a primary source of impairment at this site.

Table 5. 2018 Sagamore Creek Nutrient Concentrations

Site	Total Phosphorus Geometric Mean (mg/L)	Dissolved Inorganic Nitrogen Geometric Mean (mg/L)
RM 0.20	0.030	0.275

Habitat Assessment

Methods

An instream habitat assessment was conducted once at RM 0.20 in 2018 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 55 or more in headwater streams 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.

Results and Discussion

The stream segment at RM 0.20 was assessed on June 22, 2018. A QHEI score of 88 was calculated, correlating to a narrative rating of *Excellent* (Table 6), exceeding the warmwater habitat (WWH) target score of 55 for a headwater stream. The dominant substrate found within the reach was cobble and gravel. There was a moderate amount of instream cover, including a small amount of undercut banks, overhanging vegetation, rootmats, rootwads, boulders, oxbows, and woody debris. There was also a moderate amount of shallows and high quality pools greater than 70 centimeters, which serve as quality fish refuge areas. Lack of channelization of the reach, high stability, and little to

no erosion of the steam banks all positively contributed to the overall score at this site. The pool/glide quality in the reach received the highest possible score, which also positively contributed to the QHEI score. Based on the overall habitat characteristics of this stream segment, RM 0.20 should be able to support a healthy fish population.

In 2017, a QHEI score of 77 (*Good*) was calculated for the stream segment at Sagamore Creek RM 0.20. The increase in QHEI score from 2017 to 2018 was largely attributed to the increase in instream cover. Overhanging vegetation and shallows were not observed in 2017, but were in 2018. Additionally, the total amount of instream cover increased from sparse to moderate.

Table 6. 2018 Sagamore Creek QHEI Results

River Mile	Date	QHEI Score	Narrative
0.20	6/22/2018	88	*Excellent*

Fish Community Assessment

Methods

Two quantitative electrofishing passes were conducted at RM 0.20 on Sagamore Creek in the 2018 sampling season. Sampling was conducted using longline electrofishing techniques and consisted of shocking all habitat types within a sampling zone while moving from downstream to upstream. The sampling zone was 0.15 kilometers for this 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.

The electrofishing results for each pass were compiled and utilized to evaluate fish community health through the application of the Ohio EPA Index of Biotic Integrity (IBI). 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 (Table 7). The summation of the twelve 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*. The twelve metrics utilized for headwater sites are listed in Table 8.

Table 7. Fish Community Biology Scores in the EOLP Ecoregion							
Ohio EPA Narrative	Very Poor	Poor	Fair	Marginally Good	Good	Very Good	Exceptional
IBI Score	12-15	16-27	28-33	34-37	38-45	46-49	50-60
Ohio EPA Status	Non-Attainment			NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment							

Table 8. Index of Biotic Integrity (IBI) Metrics (Headwater)
Total Number of Native Species
Number of Darters & Sculpins
Number of Headwater Species
Number of Minnow Species
Number of Sensitive Species
Percent Tolerant Species
Percent Pioneering Species
Percent Omnivores
Percent Insectivores
Number of Simple Lithophils
Percent DELT Anomalies
Number of Fish

According to *Biological Criteria for the Protection of Aquatic Life, Volume II* (1987a), there is presently no IBI criterion for the CWH use. A stream may be designated Coldwater Habitat (CWH) by the predominance, not necessarily just presence, of designated CWH non-salmonid species in the fish community found within the reach. WWH IBI scores are used for comparative purposes only and do not indicate attainment status of the stream.

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

Results and Discussion

For the 2018 electrofishing events, the fish community within the Sagamore Creek RM 0.20 sampling reach averaged an IBI score of 45, correlating to a narrative rating of *Good* (Table 9). In 2017, the fish community at RM 0.20 also received an IBI score of 45 (*Good*). The first electrofishing pass, completed on July 22, 2018, resulted in an IBI score of 42 (*Good*). Apart from *Oncorynchus mykiss* (rainbow trout), 12 of 13 total species collected were considered native fish. Rainbow trout are considered a designated CWH taxa and comprised about 29% of the total sample population during this assessment. Because this was the only CWH designated taxa found, the reach does not meet the requirements for fish species for CWH. Three native darter species were present in the reach including the *Etheostoma blenniodes* (greenside darter), *Etheostoma caeruleum* (rainbow darter), and *Etheostoma flabellare* (barred fantail darter). The greenside darter and the rainbow darter are both considered to be sensitive species, and approximately 15.6% of the total fish were tolerant of pollution.

The second pass of RM 0.20, completed on August 31, 2018, resulted in an IBI score of 48, correlating to a narrative rating of *Very Good*. There were several differences in overall sample population composition in comparison to the first pass sample. *Pimephales promelas* (Northern fathead minnow) and *Lepomis cyanellus* (green sunfish) were collected during the first pass, but not during the second. Four species were collected during the second pass that were not collected during the first, including *Micropterus salmoides* (largemouth bass), *Ethestoma nigrum* (Johnny darter), *Lepomis gibbosus* (pumpkinseed sunfish), and *Pimephales notatus* (bluntnose minnow). The only CWH-applicable taxa present was the rainbow trout, comprising 6.4% of the total sample. The increase in the IBI score on the second pass can be explained by the increase in the number of native species (14) and the addition of another darter species (Johnny darter). Additionally, the total sample population collected increased from 602 individuals in the first pass to 1179 in the second. This increase in overall sample size may be attributed to weather-related causes or seasonal population drifts.

Table 9. 2018 Sagamore Creek IBI Results

	1st Pass		2nd Pass		Average
River Mile	Date	IBI (*Narrative Rating*)	Date	IBI (*Narrative Rating*)	IBI (*Narrative Rating*)
0.20	6/22/2018	42 (*Good*)	8/31/2018	48 (*Very Good*)	45 (*Good*)

Macroinvertebrate Community Assessment

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 the Sagamore Creek sampling location listed in Table 1. Methods for sampling followed the Ohio EPA's Biological Criteria for the Protection of Aquatic Life, Volume III (1987b). 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 are available upon request from the NEORSD WQIS Division.

The overall aquatic macroinvertebrate community in the stream was evaluated using Ohio EPA's Invertebrate Community Index (ICI) (Ohio EPA 1987b, DeShon 1995). The ICI consists of ten community metrics (Table 10), 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 (Table 11). This scoring evaluates the community against Ohio EPA's reference sites for each specific eco-region.

Table 10. ICI Metrics	
Total Number of Taxa	Percent Caddisflies
Number of Mayfly Taxa	Percent Tanytarsini Midges
Number of Caddisfly Taxa	Percent Other Diptera and Non-insects
Number of Dipteran Taxa	Percent Tolerant Organisms (As Defined)
Percent Mayflies	Number of Qualitative EPT Taxa

Table 11. Macroinvertebrate Community Biology Scores in the EOLP Ecoregion							
Ohio EPA Narrative	Very Poor	Poor	Fair	Marginally Good	Good	Very Good	Exceptional
IBI Score	0	2-12	14-28	30-32	34-40	42-44	46-60
Ohio EPA Status	Non-Attainment			NSD	Attainment		
NSD – Non-Significant Departure of WWH attainment							

According to *Biological Criteria for the Protection of Aquatic Life, Volume II* (1987a), there is presently no ICI criterion for the CWH use. However, according to the Volume II text, Ohio EPA does list macroinvertebrate taxa that are indicative of CWH.

Results and Discussion

In 2018, the ICI score on Sagamore Creek at RM 0.20 was calculated at 40 with a narrative rating of *Good*. Of the 30 total taxa found within the sample, two taxa collected during qualitative sampling, *Baetis tricaudatus* and *Diamesa sp*, were indicative of CWH. Because only two cold water taxa were collected, the sample population does not meet attainment of the CWH use. Two metrics that had a significant contribution to the total ICI score were "Number of Caddisfly Taxa" and "Percent Caddisflies". Caddisfly taxa obtained from the sample include *Chimarra aterrima*, *Polycentropus sp*, *Cheumatopsyche sp*, and *Hydroptila sp*. Other metrics positively contributing to the overall ICI score were "Percent Tanytarsini Midges" and "Qualitative EPT Taxa". There were 14 EPT taxa obtained, consisting of six mayfly taxa, eight caddisfly taxa, and zero stonefly taxa. Eight taxa were considered to be moderately intolerant to pollution, while 14.97 percent of all organisms were tolerant to pollution. The dominant proportion of the sample population collected classified as facultative or better, which supports the high ICI score. The presence of quality riffle habitat, along with substrate stability within the sample reach, may have been a positive influence on the macroinvertebrate community, which supports that Sagamore Creek RM 0.20 is able to support a diverse and healthy macroinvertebrate population.

An ICI score of 48 (*Exceptional*) was calculated at RM 0.20 in 2017. The metrics that contributed to the lower score in 2018 were "Percent Mayflies" and "Percent Diptera and Non-Insects". One possible reason for the lower ICI score in 2018 was yearly variability. Additionally, the total precipitation during the 2017 sampling season was 11.41 inches, compared to the total precipitation during the 2018 sampling season of 17.53 inches. The increase in flow in Sagamore Creek due to increased precipitation may have caused a population drift that impacted the macroinvertebrate population at RM 0.20.

Conclusions

In 2018, Sagamore Creek RM 0.20 was not in CWH attainment based on indicator species as listed in Biological Criteria for the Protection of Aquatic Life, Volume II. Only one fish species and two macroinvertebrate taxa were indicative of a CWH. The stream was in full attainment for water quality, as there were no *E. coli* or water quality standards exceedances in 2018 (Table 12).

Table 12. 2018 Sagamore Creek Survey Results

River Mile	Aquatic Life Use Attainment Status	Average IBI Score (*Narrative Rating*)	ICI Score (*Narrative Rating*)	QHEI Score (*Narrative Rating*)	Water Quality Exceedances
0.20	NON*+	*45* *Good*	*40* *Good*	88 *Excellent*	None

* - CWH Attainment Based on Indicator Species as Listed in *Biological Criteria for the Protection of Aquatic Life, Volume II*

\+ - WWH biocriterion attainment: IBI score of 40; ICI score of 34 (Non-significant departure: ≤4 IBI units; ≤4 ICI units)

While no IBI criteria has been established for use determination of CWH, the IBI score was used to help assess the overall health of the fish population. An IBI score of 45 (*Good*) was calculated for RM 0.20, which would have exceeded the minimum WWH score required and contributed to the attainment of the biocriterion for aquatic life use. Quality riffle and pool habitats allowed Sagamore Creek to support a healthy fish population that would have surpassed WWH standards. Similar to the absence of a criterion for IBI, there is also no established criterion for macroinvertebrates and ICI for use determination of CWH. The overall ICI score of 40 (*Good*) would have surpassed the minimum score required for WWH aquatic life use attainment if this location was assessed based on WWH standards. Higher water temperatures may have been a contributing factor to the lack of coldwater fish and macroinvertebrate species inhabiting the stream. CWH taxa primarily inhabit streams with summer water temperatures below 20° C (Ohio EPA, 1987b). At Sagamore Creek RM 0.20, the average summer water temperature during the 2018 sampling season at this reach was 20.6° C. It is uncertain whether the higher water temperatures were caused by human activity or occurred naturally.

Sagamore Creek, upstream of RM 2.30, has a WWH aquatic life use designation. This upstream influence may be one significant reason that the lower reach is not able to achieve CWH attainment. Migration of fish and macroinvertebrates through natural or weather-related methods downstream may cause population shifts and not allow CWH indicator taxa to dominate the reach (Holomuzki, 2000). Sagamore Creek RM 0.20 may not be in attainment of CWH use standards; however, it is evident that this reach is healthy and able to sustain diverse macroinvertebrate and fish communities.

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References

DeShon, J. E. (1995). Development and Application of the Invertebrate Community Index (ICI). In W. Davis and T. Simon (Ed.), *Biological assessment and criteria, tools for water resource planning and decision making* (pp. 217-243). Boca Raton, FL: Lewis Publishers.

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. (2018a). *State of Ohio Water Quality Standards Ohio Administrative Code Chapter 3745-1* (Revision: February 8, 2018). 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* C*riteria 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. (2018b). *Surface Water Field Sampling Manual for water quality parameters and flow.* Columbus, Ohio: Division of Surface Water.

Ohio Environmental Protection Agency. (2015). *Proposed Stream Nutrient Assessment Procedure*. Columbus, OH: Division of Surface Water, Ohio EPA Nutrients Technical Advisory Group.

Ohio Environmental Protection Agency. (2015a). *Proposed Stream Nutrient Assessment Procedure*. Columbus, OH: Division of Surface Water, Ohio EPA Nutrients Technical Advisory Group.