Biological and Water Quality Study of Symmes Creek, Indian Guyan Creek and Direct Ohio River Tributaries, 2016

Jackson, Gallia and Lawrence Counties, Ohio

Symmes Creek at Symmes Creek Road CR 56 (RM 56.8)

Ohio EPA Technical Report AMS/2016-SYMME-2

Division of Surface Water
Assessment and Modeling Section

June 2020
(Revised July 28, 2020)

Biological and Water Quality Study of Symmes Creek, Indian Guyan Creek and Direct Ohio River Tributaries, 2016

Jackson, Gallia and Lawrence counties, Ohio

June 2020
Ohio EPA Report DSW/AMS 2016-SYMME-2

Prepared by:

State of Ohio Environmental Protection Agency
Division of Surface Water
Lazarus Government Center
50 West Town Street, Suite 700
P.O. Box 1049
Columbus, Ohio 43216-1049

Division of Surface Water
Southeast District Office
2195 East Front Street
Logan, Ohio 43138

Ecological Assessment Section
Groveport Field Office
4675 Homer Ohio Lane
Groveport, Ohio 43125

Mike DeWine, Governor State of Ohio
Laurie A. Stevenson, Director Ohio Environmental Protection Agency

Table of Contents

Tables

Figures

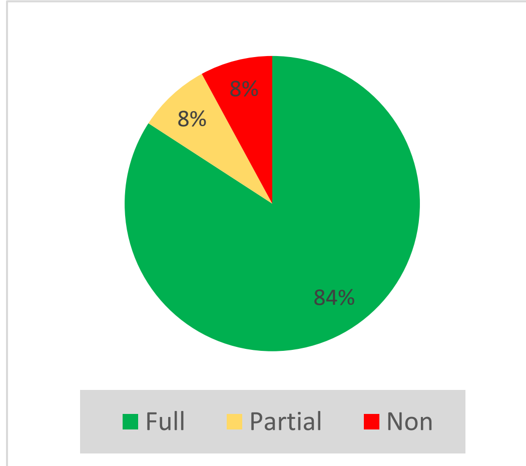
List of Acronyms

ALU	aquatic life use
AWS	agricultural water supply
BMP	Best management practices
CFR	Code of Federal Regulations
cfs	cubic feet per second
cfu	colony forming units
CSO	combined sewer overflow
CWA	Clean Water Act
CWH	coldwater habitat
DC	direct current
DELT	deformities, erosions, lesions, tumors
DIN	disolved inorganic nitrogen
DO	dissolved oxygen
EPT	Ephemeroptera, Plecoptera, Trichoptera
ESL	ecological screening level
EWH	exceptional warmwater habitat
GIS	geographic information system
GPS	Global Positioning System
HHEI	headwater habitat evaluation index
HSTS	household sewage treatment system
HUC	hydrologic unit code
IBI	index of biotic integrity
I/I	inflow and infiltration
ICI	invertebrate community index
IP	Interior Plateau
IPS	Integrated Prioritization System
IR	Integrated Report
IWS	industrial water supply
LRAU	large river assessment unit
LRW	limited resource water
MGD	million gallons per day
MIwb	Modified Index of well-being
MS4	municipal separate storm sewer system
MWH	modified warmwater habitat
NPDES	National Pollutant Discharge Elimination System
NRCS	Natural Resources Conservation Service

OAC	Ohio Administrative Code
ODH	Ohio Department of Health
ODNR	Ohio Department of Natural Resources
ORC	Ohio Revised Code
PAH	polycyclic aromatic hydrocarbon
PCB	polychlorinated biphenyls
PCR	primary contact recreation
PEC	probable effects concentration
PWS	public water supply
QHEI	Qualitative Habitat Evaluation Index
RT & E	rare, threatened and endangered species
RM	river mile
SCR	secondary contact recreation
SMCRA	Surface Mining Control and Reclamation Act
SQG	sediment quality guidelines
SRV	sediment reference value
SSO	sanitary sewer overflow
STP	sewage treatment plant
STV	statistical threshold value
TALU	tiered aquatic life use
TDS	total dissolved solids
TEC	threshold effects concentration
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TSD	technical support document
TSS	total suspended solids
UAA	use attainability analysis
VOC	volatile organic compound
WAP	Western Allegheny Plateau
WAU	watershed assessment unit
WET	whole effluent toxicity
WLA	waste load allocation
WQPSD	water quality permit support document
WQS	water quality standards
WWH	warmwater habitat
WWTP	wastewater treatment plant

Executive Summary

Rivers and streams in Ohio sustain aquatic life populations and support a variety of beneficial uses such as recreation and water supply (public, industrial and agricultural). Ohio EPA evaluates waterways to determine the appropriate beneficial use designations and determine if the assigned uses are appropriate and are meeting the goals of the federal Clean Water Act. In 2016 and 2017, Ohio EPA evaluated 101 sampling locations within the Symmes Creek watershed in Jackson, Gallia and Lawrence counties, Indian Guyan Creek watershed in Gallia and Lawrence counties, and other direct Ohio River tributaries in Gallia and Lawrence counties. There were nine total locations that were selected for additional biological sampling efforts in 2017. Ohio EPA felt it was necessary to collect additional information from these select locations to help determine appropriate aquatic life uses or to help identify appropriate causes/sources of biological impairment. These waters were evaluated to determine if they were supporting beneficial uses and meeting goals of the federal Clean Water Act.



Of the 101 sites assessed for aquatic life use (ALU), 85 sites (84 percent) were fully meeting their assigned or recommended ALU, eight (eight percent) were in partial attainment and eight (eight percent) were in non-attainment (**Error! Reference source not found.**, Figure 1). Of the 70 streams assessed, 53 streams were recommended or verified for the Warmwater Habitat (WWH) ALU, twenty streams or stream segments were recommended the Exceptional Warmwater Habitat (EWH) ALU, three streams were recommended for the Coldwater Habitat (CWH) ALU and one location was recommended for the dual EWH and CWH aquatic life use (Table 1). A complete listing of stream beneficial uses (aquatic life, water supply, recreation) and any recommended changes are discussed in the ***Beneficial Use Recommendations*** section and are listed in Table 24.

Instream habitat for the Symmes Creek mainstem was good to excellent and capable of supporting exceptional biological communities (average QHEI = 71.5). Instream habitat for 40 of the 49 Symmes Creek tributary locations were good to excellent (average QHEI = 69). Ten locations, mostly in the Black Fork sub-watershed, had fair to poor habitat (QHEI average = 46.7). The Indian Guyan Creek mainstem also had good to excellent habitat (average QHEI = 73.9) as did 17 of 19 tributary locations (QHEI average = 67). Two tributaries to Indian Guyan Creek were in the fair to poor range (average QHEI =43.5). Instream habitat for the 15 direct Ohio River tributaries was in the good to excellent range (average QHEI = 64.2).

Symmes Creek ALU impairment

Six of the 11 impaired stream reaches in the Symmes Creek watershed occurred within the Black Fork sub-basin. Streams in this portion of the watershed tended to have more limited habitat features and lower dissolved oxygen (DO) associated with wetland and lentic habitats compared to other traditional, free-flowing (lotic) streams in this ecoregion. In addition to limited habitat features, Huntingcamp Creek was impacted by municipal and industrial wastewater discharges as well as channelization and urbanization from the village of Oak Hill. Black Fork Creek at river mile (RM) 11.0 (station 303576) was impaired due to flow regime alteration and low DO related to the Jackson Lake spillway with average DO levels of 3.1 mg/L and minimum levels of 1.74 mg/L. Dicks Creek had influences from mine drainage and was also limited by poor instream habitat and very low flows. Peters Cave Creek was impaired due to a heavy sand and sediment bedload from farming activities (channelization, riparian removal, livestock with free access to the creek) and unreclaimed abandoned mines in the headwaters possibly contributing an additional sand bedload.

Indian Guyan Creek and Direct Ohio River tributaries ALU impairment

One location in the Indian Guyan Creek watershed and three direct Ohio River tributaries were not meeting the requisite ALU goals. Slate Run in the Indian Guyan Creek sub-watershed had a poor macroinvertebrate community due to low flows and possible organic enrichment from failing home septic treatment systems. Three direct Ohio River tributaries were impaired. Paddy's Creek was limited by natural low flow conditions. The Little Chickamauga Creek and Twomile Creek sub-watersheds are more densely populated and impacted by organic enrichment from failing home septic treatment systems or poorly treated effluent from regional wastewater treatment plants.

Figure 1—Symmes Creek, Indian Guyan Creek and direct Ohio River Tributaries sampling locations and ALU attainment status, 2016-2017.

Table 1—Aquatic life use attainment status for stations sampled in the Symmes Creek, Indian Guyan Creek and direct Ohio River tributaries based on data collected June - October 2016. Follow up samples were collected in 2017 and are noted with brackets around the Index of Biotic Integrity (IBI), Invertebrate Community Index (ICI) or Qualitative Habitat Evaluation Index (QHEI) score or narrative.

The IBI, Modified Index of well-being (MIwb) and ICI are scores based on the performance of the biotic community. The QHEI is a measure of the ability of the physical habitat of the stream to support a biotic community. The table is organized by assessment unit (12-digit hydrologic unit code (HUC-12)). Sites with ALU changes recommended are evaluated using the biocriteria for the recommended use, not the current use. For an explanation regarding recommended Aquatic Life Use designations, please refer to Beneficial Use Designations and Recommendations within this report. Symmes Creek, Indian Guyan Creek and direct Ohio River tributaries are in the Western Allegheny Plateau (WAP) ecoregion in Gallia, Jackson and Lawrence counties. If biological impairment has occurred, the causes and sources of the impairment are noted.

Station	Location	Aquatic Life Use (ALU)[a]	River Mile (RM)[b]	Drain. Area (mi^2)	IBI	MIwb[c]	ICI[d]	QHEI	Attain. Status[e]	Causes	Sources
05090101 01 01 — Chickamauga Creek											
300742	Chickamauga Creek at St. Rt. 160	WWH (V)	5.0	12.1[H]	42[NS]	-	MG[NS]	65.0	FULL		
W03S19	Little Chickamauga Creek N. of Gallipolis at St. Rt. 160	WWH (V)	0.16	5.9[H]	44	-	F*	64.75	**PARTIAL**	Organic Enrichment	Unsewered areas
05090101 07 03 – Swan Creek											
303641	Swan Creek adj. Swan Creek Rd.	EWH (R)	4.25	8.3[H]	54	-	VG[NS]	74.5	FULL		
303527	Swan Creek N.E. of Crown City at Swan Creek Rd., dst. Little Swan Creek	EWH (R)	2.35	14.7[H]	52	-	VG[NS]	63.75	FULL		
303638	Tributary to Swan Creek (5.95) at Hamilton Rd.	WWH (R)	0.50	2.2[H]	50	-	MG[NS]	70.0	FULL		
303587	Little Swan Creek at private bridge off Swan Creek Rd.	EWH (R)	0.05	4.2[H]	56	-	VG[NS]	70.75	FULL		
05090101 07 04 – Flatfoot Creek – Ohio River											
303586	Teens Run at Barcus Hollow Rd.	EWH (R)	1.20	2.5[H]	50	-	E	48.5	FULL		

Station	Location	Aquatic Life Use (ALU)[a]	River Mile (RM)[b]	Drain. Area (mi²)	IBI	MIwb[c]	ICI[d]	QHEI	Attain. Status[e]	Causes	Sources
05090101 07 06 – Little Indian Guyan Creek											
303652	Little Indian Guyan Creek at Twp. Rd. 122 S	EWH (R)	2.70	5.90[H]	52	-	[VG[NS]]	67.75	FULL		
303596	Little Indian Guyan Creek at Big Spring Rd.	EWH (R)	1.65	8.50[H]	52	-	E	57.25	FULL		
303532	Little Indian Guyan Creek at Scottown at St. Rt. 217	EWH (R)	0.13	14.90[H]	50	-	56	74.0	FULL		
303650	Watson Creek at Long Creek Rd.	WWH (R)	0.05	1.9[H]	50	-	G	76.25	FULL		
303648	Trace Creek adj. St. Rt. 775 near mouth	EWH (R)	0.10	3.7[H]	46[ns]	-	E	68.75	FULL		
05090101 07 07 – Johns Creek – Indian Guyan Creek											
303663	Indian Guyan Creek at Mercerville Rd.	EWH (R)	29.05	5.20[H]	50	-	E	72.25	FULL		
W02K05	Indian Guyan Creek N. of Crown City adj. St. Rt. 218	EWH (R)	26.4	16.00[H]	52	-	46	70.75	FULL		
303539	Indian Guyan Creek at Shoal Creek Rd.	EWH (R)	21.7	25.40[W]	47[NS]	9.10[NS]	[48]	77.5	FULL		
W02K04	Indian Guyan Creek at Co. Rd. 67 (Scottown covered bridge)	EWH (R)	15.3	33.50[W]	50	9.42	E	68.75	FULL		
303664	Perigen Creek at Mercerville Rd.	CWH (R)	0.10	2.1[H]	46	-	G	70.5	FULL		
303669	Drake Fork at Rocky Fork Rd.	WWH (V)	0.30	2.5[H]	52	-	G	73.25	FULL		
303670	Tributary to Drake Fork (0.55) at St. Rt. 218	WWH (R)	0.05	0.9[H]	50	-	G	64.5	FULL		
303668	Johns Creek at Rocky Fork Rd.	WWH (V)	0.10	1.9[H]	42[NS]	-	-	59.0	FULL		
303667	Rocky Fork at Cecil Rd.	WWH (V)	0.10	3.4[H]	54	-	MG[NS]	62.5	FULL		
303662	Lanes Branch adj. St. Rt. 218	WWH (V)	0.10	1.6[H]	42[NS]	-	-	38.0	FULL		
303659	Georges Creek at St. Rt. 218	EWH (R)	0.05	1.9[H]	52	-	[VG[NS]]	62.0	FULL		

Station	Location	Aquatic Life Use (ALU)[a]	River Mile (RM)[b]	Drain. Area (mi^2)	IBI	MIwb[c]	ICI[d]	QHEI	Attain. Status[e]	Causes	Sources
303657	Williams Creek at Berry Rd.	WWH (R)	1.55	0.90[H]	49	-	G	66.0	FULL		
303656	Williams Creek at St. Rt. 216	WWH (R)	0.05	3.20[H]	50	-	G	64.25	FULL		
05090101 07 08 – Wolf Creek – Indian Guyan Creek											
303675	Indian Guyan Creek at old St. Rt. 775	EWH (R)	10.60	54.10[W]	54	9.81	E	73.6	FULL		
W02S08	Indian Guyan Creek at Co. Rd. 69	EWH (R)	5.76	64.00[W]	52	9.90	54	81.0	FULL		
609150	Indian Guyan Creek adj. Indian Guyan Rd. dst. Bear Creek.	EWH (R)	2.95	73.30[W]	53	9.11[NS]	48	73.0	FULL		
303676	Wolf Creek at St. Rt. 775	EWH (R)	0.35	4.7[H]	54	-	VG[NS]	74.75	FULL		
303647	Slate Run at Twp. Rd. 192 N	WWH (V)	0.40	1.1[H]	48	-	P*	49.0	**NON**	Organic enrichment Natural conditions (flow)	HSTS Natural sources
303594	Fivemile Creek at Seneca Trail	EWH (R)	0.30	3.3[H]	54	-	VG[NS]	60.75	FULL		
303593	Bear Creek at Indian Guyan Rd.	WWH (V)	0.05	2.9[H]	48	-	G	74.5	FULL		
303592	Bent Creek at Greasy Ridge Rd.	WWH (V)	0.05	1.9[H]	46	-	G	62.75	FULL		
05090101 07 09 – Paddy Creek – Ohio River											
303591	Paddy Creek at Private Rd. 21501	WWH (V)	1.65	4.9[H]	34*	-	G	56.0	**PARTIAL**	Natural conditions (flow)	Natural sources (low flow)
303590	Little Paddy Creek at service road off Walnut St.	WWH (R)	0.40	2.0[H]	48	-	MG[NS]	68.5	FULL		
303645	Twomile Creek at Wylie St.	WWH (V)	1.45	3.0[H]	42[NS]	-	F*	54.0	**PARTIAL**	Organic enrichment	Unsewered areas
303589	Federal Creek at Federal Creek Rd.	WWH (V)	0.85	4.0[H]	52	-	G	66.25	FULL		
303588	Clean Fork adj. Clean Fork Rd. upst. Federal Creek	WWH (V)	0.10	1.7[H]	56	-	MG[NS]	67.5	FULL		

Station	Location	Aquatic Life Use (ALU)[a]	River Mile (RM)[b]	Drain. Area (mi^2)	IBI	MIwb[c]	ICI[d]	QHEI	Attain. Status[e]	Causes	Sources
303643	Big Creek adj. Big Creek Rd.	CWH (R)	0.68	1.6[H]	48	-	G	65.5	FULL		
05090101 08 01 – Dirtyface Creek											
303571	Dirtyface Creek adj. C-H-D Rd. near pipeline crossing	EWH (R)	4.70	3.0[H]	50	-	VG[NS]	60.5	FULL		
300156	Dirtyface Creek at C-H-D Rd.	WWH (V)	1.82	12.0[H]	52	-	G	70.75	FULL		
05090101 08 02 – Black Fork Symmes Creek											
303576	Black Fork Symmes Creek DST Jackson Lake Spillway	WWH (V)	11.0	18.7[H]	36*	-	F*	72.0	**NON**	Flow alteration Low dissolved oxygen	Impacts from hydrostructure flow regulation
W02S02	Black Fork Symmes Creek at BlackFork Rd	WWH (V)	5.77	28.3[W]	49	9.07	G	70.75	FULL		
303501	Black Fork Symmes Creek N. of Gallia at St. Rt. 233	WWH (V)	2.40	47.6[W]	52	9.23	G	70.0	FULL		
303575	Black Fork Symmes Creek Canoe launch off Gallia Rd.	EWH (R)	0.10	62.6[W]	48[NS]	9.22[NS]	52	70.0	FULL		
303636	Hewitt Run at Franklin Valley Rd.	WWH (V)	0.75	4.6[H]	28*	-	F*	58.25	**NON**	Manganese Natural conditions (wetland habitat)	Historic mining Natural sources
W02S06	Huntingcamp Creek upst. Oak Hill WWTP	WWH (V)	1.71	1.8[H]	[40[NS]]	-	26*	[61.5]	**PARTIAL**	Specific conductance Sedimentation/siltation	Abandoned mine lands Channelization
W02S03	Huntingcamp Creek dst. Oak Hill WWTP	WWH (V)	1.20	2.4[H]	30*	-	P*	38.25	**NON**	Organic enrichment Ammonia Sedimentation/siltation	Municipal point source discharges Channelization Upstream land disturbance
303574	Cambria Creek (A.K.A. Lefthand Fork) At Potts Rd.	WWH (V)	1.65	7.2[H]	52	-	G	69.0	FULL		

Station	Location	Aquatic Life Use (ALU)[a]	River Mile (RM)[b]	Drain. Area (mi²)	IBI	MIwb[c]	ICI[d]	QHEI	Attain. Status[e]	Causes	Sources
303573	Dicks Creek at Sardis Rd.	WWH (V)	0.30	3.0[H]	24*	-	P*	46.0	**NON**	pH Metals Natural conditions (flow)	Historic mining Natural sources (low flow)
303572	Clear Fork at Shafer Rd	WWH (V)	0.70	3.1[H]	34*	-	F*	61.25	**NON**	Natural conditions (habitat)	Natural sources (low flow)
05090101 08 03 – Headwaters Symmes Creek											
303584	Symmes Creek at Vega and C-H-D Rd.	WWH (V)	70.0	14.8[H]	52	-	42	81.0	FULL		
300158	Symmes Creek at Jenkins Alben Rd (Twp. Rd. 102)	WWH (V)	62.7	45.8[W]	46	9.14	G	59.8	FULL		
303577	Tributary to Symmes Creek (73.03) at C-H-D Rd.	WWH (R)	0.10	5.7[H]	40[NS]	-	F*	38.25	**PARTIAL**	Natural conditions (flow and habitat)	Natural sources
200756	Sugar Run N.E. of Oak Hill at mouth Adj. Co. Rd. 2	WWH (V)	0.10	4.7[H]	42[NS]	-	-	64.5	(FULL)		
303705	Cherry Fork at Cherry Fork Rd.	WWH (V)	0.40	2.5[H]	40[NS]	-	F*	60.5	**PARTIAL**	Natural conditions (flow)	Natural sources (low flow)
05090101 09 01 – Sand Fork											
303569	Sand Fork at Palestine-Okey Church Rd. (Twp. Rd. 217)	WWH (V)	15.1	3.0[H]	40[NS]	-	MG[NS]	65.0	FULL		
303568	Sand Fork at drive to Timber Ridge Lake	WWH (V)	14.8	8.9[H]	44	-	G	62.25	FULL		
301798	Sand Fork at Lecta at St. Rt. 775	WWH (V)	13.40	13.8[H]	52	-	48	65.0	FULL		
303567	Sand Fork at Peters Cave Rd.	WWH (V)	10.25	28.3[W]	42[NS]	8.47	VG	66.0	FULL		
300154	Sand Fork at Patriot-Cadmus Rd.	EWH (R)	2.70	40.4[W]	51	9.70	E	70.5	FULL		

Station	Location	Aquatic Life Use (ALU)[a]	River Mile (RM)[b]	Drain. Area (mi²)	IBI	MIwb[c]	ICI[d]	QHEI	Attain. Status[e]	Causes	Sources
303565	Peters Cave Creek adj. Peters Cave Rd.	WWH (V)	0.20	5.2[H]	38*	-	VG	51.25	**PARTIAL**	Habitat alterations	Agricultural activities
											Channelization
										Sedimentation/siltation	Historic mining
05090101 09 02 – Buffalo Creek											
200752	Buffalo Creek adj. Buffalo-Olive Rd., dst. Indian Creek	WWH (V)	5.00	3.1[H]	[42[NS]]	-	G	[72.75]	FULL		
W02S09	Buffalo Creek at Co. Rd. 14	EWH (R)	1.91	8.5[H]	46[ns]	-	E	68.0	FULL		
303560	Indian Creek near mouth of Buffalo-Olive Rd.	WWH (V)	0.10	0.8[H]	22*	-	-	66.0	(**NON**)	Natural conditions (flow)	Natural sources (low flow)
W02S01	Caulley Creek near mouth at Co. Rd. 14	EWH (R)	0.15	4.9[H]	52	-	E	73.5	FULL		
303559	Miller Creek at Caulley Creek Rd.	CWH (R)	0.05	1.0[H]	48	-	[G]	71.5	FULL		
05090101 09 03 – Camp Creek – Symmes Creek											
303500	Symmes Creek at Waterloo-Mt Vernon Rd.	EWH (R)	38.7	201.9[W]	54	10.05	50	71.0	FULL		
200753	Symmes Creek at Cadmus at St. Rt. 141	EWH (R)	47.1	182.0[W]	52	9.95	[42[NS]]	70.0	FULL		
200754	Symmes Creek dst. Coal Branch @ Symmes Creek Rd.	EWH (R)	56.7	125.0[W]	49[NS]	9.90	50	83.25	FULL		
303637	Sweetbit Creek at Pumpkintown Rd.	WWH (R)	0.30	2.0[H]	38*	-	G	44.5	**PARTIAL**	Natural conditions (habitat)	Natural sources
303564	Trace Creek at private drive off St. Rt. 141	WWH (V)	0.55	2.7[H]	44	-	MG[NS]	51.0	FULL		
303570	Wolf Run at Symmes Creek Rd.	WWH (V)	0.10	0.9[H]	24*	-	F*	50.0	**NON**	Natural conditions (Flow)	Natural sources (low flow)
303563	Camp Creek at Peniel Rd.	WWH (V)	0.65	4.5[H]	48	-	VG	46.75	FULL		

Station	Location	Aquatic Life Use (ALU)[a]	River Mile (RM)[b]	Drain. Area (mi²)	IBI	MIwb[c]	ICI[d]	QHEI	Attain. Status[e]	Causes	Sources
303562	Little Buffalo Creek at Carpenter Rd. (Twp. Rd. 182)	EWH/ CWH (R)	1.20	2.6[H]	50	-	[VG][ns]	67.3	FULL		
05090101 10 01 – Johns Creek											
303557	Johns Creek at Etna-Waterloo Rd.	WWH (V)	5.35	9.4[H]	56	-	G	79.25	FULL		
300153	Johns Creek S. of Waterloo at St. Rt. 141	WWH (V)	0.07	22.7[W]	51	8.39[NS]	VG	72.5	FULL		
303556	Slab Fork at Etna-Waterloo Rd.	EWH (R)	0.10	2.6[H]	50	-	VG[NS]	73.0	FULL		
303554	Brushy Buckeye Creek at Buckeye Rd.	WWH (V)	0.10	1.9[H]	54	-	G	77.25	FULL		
303553	Handley Branch near mouth off Handley Branch Rd.	WWH (R)	0.10	1.7[H]	40[NS]	-	G	50.5	FULL		
303555	Buckeye Creek at Buckeye Rd. (Trib to Johns Creek)	WWH (V)	1.40	3.4[H]	46	-	G	76.75	FULL		
05090101 10 02 – Long Creek											
303550	Buckeye Creek at St. Rt. 775 (Trib. to Long Creek)	EWH (R)	0.90	3.8[H]	52	-	VG[NS]	74.5	FULL		
303551	Long Creek at St. Rt. 775	WWH (V)	4.30	5.3[H]	52	-	G	67.5	FULL		
303536	Long Creek S.E. of Arabia at Zalmon Rd.	WWH (V)	0.86	14.7[H]	48	-	42	65.25	FULL		
05090101 10 03 – Pigeon Creek – Symmes Creek											
303533	Symmes Creek at Arabia at St. Rt. 141	EWH (R)	31.7	255.3[W]	57	10.01	50	64.5	FULL		
303558	Pigeon Creek at Webster Rd.	WWH (V)	0.55	3.2[H]	46	-	G	50.0	FULL		
303552	Buck Creek at St. Rt. 141	EWH (R)	0.35	5.0[H]	48[ns]	-	E	60.0	FULL		

Station	Location	Aquatic Life Use (ALU)[a]	River Mile (RM)[b]	Drain. Area (mi^2)	IBI	MIwb[c]	ICI[d]	QHEI	Attain. Status[e]	Causes	Sources
05090101 10 04 – Aaron Creek – Symmes Creek											
303534	Symmes Creek at Linnville adj. St. Rt. 217	EWH (R)	17.5	313.2[B]	49	10.32	-	62.0	FULL		
300151	Symmes Creek at Aid at St. Rt. 141	EWH (R)	22.6	300.0[B]	50	10.77	52	67.75	FULL		
303549	Aaron Creek at Elkins Creek Rd.	WWH (V)	0.65	8.3[H]	48	-	G	64.25	FULL		
303548	Elkins Creek at National Forest pull-off adj. Elkins Creek Rd.	WWH (V)	1.80	3.3[H]	50	-	G	78.25	FULL		
303547	Sharps Creek near mouth	EWH (R)	0.20	4.6[H]	52	-	VG[NS]	69.5	FULL		
303546	Venisonham Creek at St. Rt. 217	WWH(V)	0.95	3.9[H]	52	-	G	72.25	FULL		
200747	Leatherwood Creek N.W. of Getaway at St. Rt. 243	WWH (V)	0.80	4.0[H]	46	-	VG	67.75	FULL		
05090101 10 05 – McKinney Creek – Symmes Creek											
303768	Symmes Creek adj. Eaton Rd. (Co. Rd. 32)	EWH (R)	3.90	349.5[B]	46[NS]	10.23	48	77.0	FULL		
200746	Symmes Creek adj. St. Rt. 243, Dst. McKinney Creek	EWH (R)	8.40	346.0[B]	54	10.50	46	79.0	FULL		
303545	Rankin Creek at private drive adj. Rankin Creek Rd.	EWH (R)	0.55	3.9[H]	52	-	VG[NS]	78.0	FULL		
303544	McKinney Creek at St. Rt. 243	WWH (V)	0.35	5.0[H]	48	-	MG[NS]	69.75	FULL		
303540	Big Branch Creek t Henson Hollow Rd. (Co. Rd. 158)	WWH (V)	0.55	3.0[H]	50	-	MG[NS]	75.5	FULL		

Station	Location	Aquatic Life Use (ALU)[a]	River Mile (RM)[b]	Drain. Area (mi^2)	IBI	MIwb[c]	ICI[d]	QHEI	Attain. Status[e]	Causes	Sources
05090101 10 02 – Buffalo Creek – Ohio River											
303531	Buffalo Creek at Buffalo Creek Rd.	WWH (V)	1.10	6.7[H]	46	-	MG[NS]	73.0	FULL		
303583	Scarey Creek at Lick Creek Rd. (Co. Rd. 15)	WWH (R)	0.05	2.1[H]	52	-	MG[NS]	55.0	FULL		

a (V) is verified and (R) is recommended. Verified ALUs are unchanged from the current WQS and recommended ALUs are either different than the current WQS ALU or the stream is not listed in the WQS and is undesignated. The current use designations are listed in OAC 3745-1-16 in Table 16-1.
b River Mile (RM) represents the Point of Record (POR) for the station, not the actual sampling RM.
c MIwb is not applicable to headwater streams with drainage areas ≤ 20 mi^2.
d A narrative evaluation of the qualitative sample based on attributes such as EPT taxa richness, number of sensitive taxa, and community composition was used when quantitative data was not available or considered unreliable. VP=Very Poor, P=Poor, LF=Low Fair, F=Fair, MG=Marginally Good, G=Good, VG=Very Good, E=Exceptional
e Attainment is given for the proposed status when a change is recommended.
NS Nonsignificant departure from biocriteria (≤4 IBI or ICI units, or ≤0.5 MIwb units).
* Indicates significant departure from applicable biocriteria (>4 IBI or ICI units, or >0.5 MIwb units). Underlined scores are in the Poor or Very Poor range and would automatically place a site into non-attainment.
B Boat site (large or deep waters, necessitating the use of boat sampling methods)
H Headwater site (draining ≤20 $miles^2$)
W Wading site (non-boat site draining >20 $miles^2$)

Biological Criteria[1] – WAP Ecoregion		
Index – Site Type	**EWH**	**WWH**
IBI – Headwaters	50	44
IBI – Wading	50	44
IBI – Boat	48	40
MIwb – Wading	9.4	8.4
MIwb – Boat	9.6	8.6
ICI	46	36

1 Biological criteria for the WAP ecoregion presented in OAC 3745-1-07, Table 7-1

Components of an Ohio EPA Biological and Water Quality Survey

What is a Biological and Water Quality Survey?

A biological and water quality survey (biosurvey) evaluates the biological, physical and chemical condition of waters within a specified sampling frame. The sampling frame may range from a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites; or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and numerous sites.

Ohio EPA employs biological, chemical and physical monitoring to meet three major objectives:

1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained;
2) determine if use designations assigned to a given water body are appropriate and attainable; and
3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices (BMP).

The data gathered by a biosurvey is processed, evaluated and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs or other actions that may be needed to resolve existing impairment of recommended or designated uses. While the principal focus of a biosurvey is the ALU status, the status of other uses such as recreation and water supply, as well as human health concerns are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (for example, National Pollutant Discharge Elimination System (NPDES) permits, Director's Orders, the Ohio WQS [OAC 3745-1] and Water Quality Permit Support Documents [WQPSDs]), and are eventually incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] also known as the Integrated Report [IR]).

Hierarchy of Indicators

A carefully conceived ambient monitoring approach, using cost-effective indicators consisting of ecological, chemical and toxicological measures, helps ensure that all relevant pollution sources are judged objectively based on environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach includes a hierarchical continuum from administrative to true environmental indicators (Figure 2). The six levels of indicators include:

1) actions taken by regulatory agencies (permitting, enforcement, grants);
2) responses by the regulated community (treatment works, pollution prevention);
3) changes in discharged quantities (pollutant loadings);
4) changes in ambient conditions (water quality, habitat);
5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and,
6) changes in health, ecology, or other effects (ecological condition, pathogens).

The results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4 and 5) which should translate into the environmental results (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. Stressor indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. Exposure indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. Response indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages (rare, threatened, endangered, special status and declining species) or bacterial levels which serve as surrogates for the recreational uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators within the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and patterns within the biological data itself. Thus, the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or sub-basin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the IR, the Ohio Nonpoint Source Assessment and other technical bulletins.

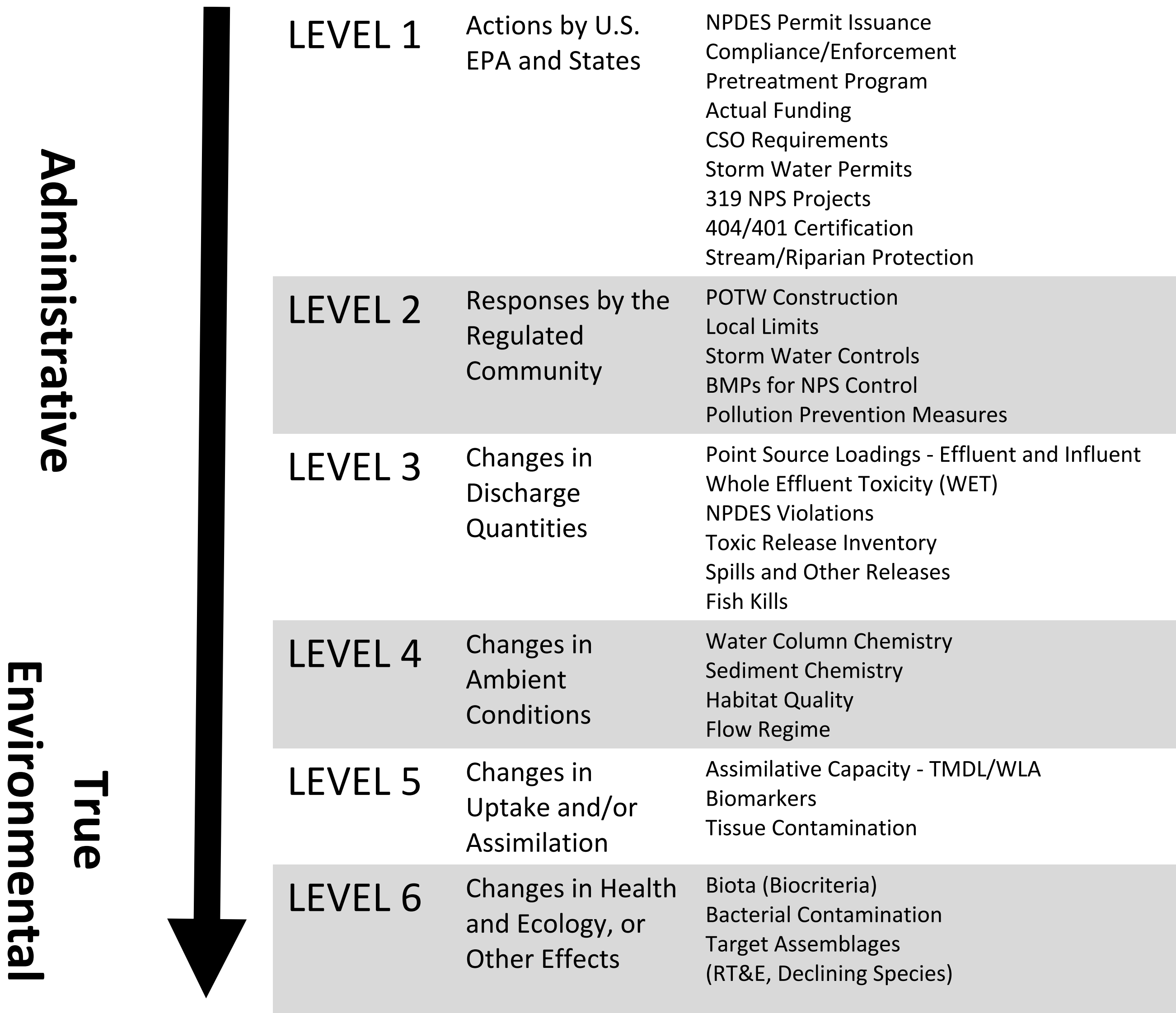


Figure 2—Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by U.S. EPA.

Ohio Water Quality Standards: Designated Aquatic Life Use

The Ohio Water Quality Standards (WQS; OAC 3745-1) consist of designated uses and chemical, physical, and biological criteria designed to represent measurable properties of the environment that are consistent with the goals specified by each use designation. Use designations consist of two broad groups — aquatic life and non-aquatic life uses. In applications of the Ohio WQS to the management of water resource issues in Ohio's rivers and streams, the aquatic life use criteria frequently result in the most stringent protection and restoration requirements, hence their emphasis in biological and water quality reports. Also, an emphasis on protection for aquatic life generally results in water quality suitable for all uses. The five aquatic life uses currently defined in the Ohio WQS are:

1) **Warmwater Habitat (WWH)** — this use designation defines the typical warmwater assemblage of aquatic organisms for Ohio rivers and streams; this use represents the principal restoration target for the majority of water resource management efforts in Ohio.

2) **Exceptional Warmwater Habitat (EWH)** — this use designation is reserved for waters which support unusual and exceptional assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered or special status (declining species); this designation represents a protection goal for water resource management efforts dealing with Ohio's best water resources.
3) **Coldwater Habitat (CWH)** — this use is intended for waters that support assemblages of coldwater organisms or those which are sanctioned by the Ohio Department of Natural Resources (ODNR), Division of Wildlife and stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis. This use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to Lake Erie tributaries that support periodic runs of salmonids during the spring, summer, and/or fall.
4) **Modified Warmwater Habitat (MWH)** — this use applies to streams and rivers which have been subjected to extensive, maintained and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable and where the activities have been sanctioned by state or federal law; the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment and poor quality habitat.
5) **Limited Resource Water (LRW)** — this use applies to small streams (usually less than three mi^2 drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported.

Chemical, physical and/or biological criteria are generally assigned to each use designation in accordance with the broad goals defined by each. As such, the system of use designations employed in the Ohio WQS constitutes a tiered approach in that varying and graduated levels of protection are provided by each. This hierarchy is especially apparent for parameters such as dissolved oxygen, ammonia-nitrogen, temperature and the biological criteria. For other parameters such as heavy metals, the technology to construct an equally graduated set of criteria has been lacking, thus the same water quality criteria may apply to two or three different aquatic life use designations.

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. All surface waters of the state are designated as primary contact recreation unless otherwise designated as bathing waters or secondary contact recreation. Primary contact waters are surface waters that, during the recreation season, are suitable for one or more full body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking and scuba diving. Secondary contact waters are surface waters that result in minimal exposure potential to water-borne pathogens because the waters are: rarely used for water-based recreation such as, but not limited to, wading; situated in remote, sparsely populated areas; have restricted access points; and have insufficient depth to provide full body immersion, thereby greatly limiting the potential for water-based recreation activities. The SCR designation applies only to water bodies specifically designated as such in the WQS. Recreational use designations only apply seasonally from May 1 through October 31. Recreational use designation attainment status is determined using bacterial indicators (*E. coli*) and the criteria associated with each recreation use is specified in the

Ohio WQS. The presence of indicator bacteria such as *E. coli* indicates that the water body is contaminated with fecal matter of warm-blooded origin, which could include birds and mammals, including humans.

Attainment of recreation uses are evaluated based on a comparison of measured bacteria levels in the water body to the applicable criterion as reflected in OAC 3745-1-37, which are intended to minimize potential exposure to pathogenic organisms and thereby protect the health of recreational uses of the water.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS) and Industrial Water Supply (IWS). The PWS designation applies within 500 yards of a potable (drinking) water supply or food processing industry intake. The AWS and IWS use designations are usually applied to all waters unless it can be clearly shown that they are not applicable. A hypothetical example of this might be within an urban area where livestock watering or pasturing does not take place or could not be supported, thus a recommendation may be made that the AWS use not be applied to a particular water body. The limited number of applicable chemical criteria associated with these uses are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Ohio EPA also measures chemical concentrations in fish tissue to support Ohio's sport fish consumption advisory program and to assess whether water quality is sufficient to support human health water quality goals intended by Ohio's WQS.

Mechanisms for Water Quality Impairment

The following present the varied causes of impairment that affect the resource quality of lotic (free flowing) systems in Ohio. While the various issues are presented under separate headings, it is important to remember that they are often interrelated and cumulative in terms of the detrimental impact that can result.

Habitat and Flow Alterations

Habitat alteration, such as channelization, negatively impacts biological communities directly by limiting the complexity of living spaces available to aquatic organisms. Consequently, fish and macroinvertebrate communities are not as diverse compared to unimpacted systems. Indirect impacts may include the removal of riparian trees and field tiling to facilitate drainage. Following a rain event, most of the water is quickly removed from tiled fields rather than filtering through the soil, recharging ground water, and reaching the stream at a lower volume and more sustained rate. As a result, baseflow of small streams can be reduced, causing them to go dry more frequently or to become intermittent. Urbanization impacts include removal of riparian trees, influx of storm water runoff by increasing the area of impervious surfaces, straightening and piping of stream channels and riparian vegetation removal.

Tree shade is important because it limits the energy input from the sun, moderates water temperature and limits evaporation. Removal of the tree canopy further degrades conditions because it eliminates an important source of coarse organic matter essential for a balanced ecosystem. Riparian vegetation aids in nutrient uptake, may decrease runoff rate into streams and helps keep soil in place. Erosion impacts channelized streams more severely due to the lack of a riparian buffer zone to slow runoff, trap sediment and stabilize banks. Additionally, deep trapezoidal channels lack a functioning flood plain and therefore cannot expel sediment as would normally occur during flood events along natural watercourses. The confinement of flow within an artificially deep channel accelerates the movement of water downstream, exacerbating flooding of downstream properties.

Siltation and Sedimentation

Whenever the natural flow regime is altered to facilitate drainage, increased amounts of sediment are likely to enter streams either by overland transport or increased bank erosion. The removal of wooded riparian areas accelerates the erosion process. Channelization excludes all but the highest flow events to confinement within the artificially high banks. As a result, former flood plain areas that allowed for the removal of sediment from the primary stream channel no longer serve this function. As water levels fall following a rain event, interstitial spaces between larger rocks fill with sand and silt and the diversity and quality of available habitat to support aquatic life such as fish, aquatic insects, bivalves and salamanders is reduced. Excessive siltation can exclude sensitive filter feeders such as bivalves, fish (i.e. lamprey and paddlefish), and aquatic insects. Silt can also clog the gills of aquatic organisms, reduce visibility thereby excluding site feeding fish and salamander species and smother the eggs of simple lithophilic spawning fish. Lithophilic spawning fish require clean substrates with interstitial voids in which to deposit eggs. Conversely, pioneering species benefit. They are generalists and best suited for exploiting disturbed and less heterogeneous habitats. The net result is a lower diversity of aquatic species compared with a typical warmwater stream with natural habitats.

Excessive sedimentation can also adversely impact water quality, recreational value, aesthetic quality and drinking water. Nutrients absorbed to soil particles remain trapped in the watercourse. Likewise, bacteria, pathogens and pesticides which also attach to suspended or bedload sediments become concentrated in waterways where the channel is functionally isolated from the landscape. Community drinking water systems must address these issues with more expensive advanced treatment technologies.

Nutrient Enrichment

The assessment of the impact of nutrients on aquatic life uses a weight-of-evidence approach. The objective of the weight-of-evidence approach is to evaluate the trophic state of the stream. Similar to lakes, trophic status in streams can be described by position along the familiar oligotrophic-eutrophic continuum; however, trophic status in streams is additionally described by a continuum defined at one end by heterotrophy, and at the other by autotrophy (Dodds W. , 2007). In general, oligotrophic systems are described as having low nutrients, low algal biomass and high clarity. Conversely, eutrophic systems are rich in nutrients, have high algal biomass and have large D.O. swings. Mesotrophic systems have intermediate characteristics between oligotrophic and eutrophic systems. The transition from oligotrophy to eutrophy is often accompanied by a shift from a heterotrophic status to an autotrophic status; and the process is commonly referred to as eutrophication. The amount of dissolved oxygen produced during the day by autotrophs relative to the amount of oxygen consumed at night by the entire microbial community, informs position along both continuums. For the purposes of this evaluation, eutrophication will be defined as the process by which a stream becomes enriched with nutrients, resulting in high chlorophyll-a concentrations or wide diel D.O. swings (USGS, 2014). Therefore, the focus for identifying eutrophication requires effective monitoring of the trophic state, which is dictated by primary production and respiration. Ohio EPA considers the performance of the biology relative to the available habitat, diel (24-hour) range of dissolved oxygen, algal biomass and finally nutrient concentrations to perform this assessment.

Ohio and other states have been developing nutrient reduction strategies in recent years to address cultural eutrophication (U.S. EPA, State Development of Numeric Criteria for Nitrogen and Phosphorus Pollution, 2015); (Ohio EPA, 2014); (Miltner, 2010); (Heiskary & Markus, 2003). Wide diel D.O. ranges associated with eutrophication are caused by excessive photosynthesis (O_2 production) during daylight hours and respiration at night. The most recent investigations by Ohio EPA have identified a diel D.O. range of 6.5 mg/L as a threshold generally protective of biological and stream quality; diel D.O. ranges greater than 6.5 mg/L are indicative of eutrophication in Ohio streams and are likely over-enriched (Ohio EPA, 2014).

Chlorophyll concentrations from benthic algae (attached to bottom substrates) are measured as a proxy for algal community biomass in wadeable streams and small rivers, while chlorophyll concentrations measured from sestonic algae (suspended in the water column) serve as a proxy for algal abundance in large rivers. Physical factors such as width-depth ratio, time of travel and longitudinal gradient may largely determine whether sestonic or benthic algae drive production and respiration. However, sestonic algae typically dominate streams defined as large rivers, and benthic algae typically dominate small streams. Miltner identified benthic chlorophyll levels that broadly demarcate enrichment status relative to Ohio (Miltner, 2010). Streams with less than ~90 mg/m^2 can be considered least disturbed for Ohio. Benthic chlorophyll levels between 90 ~ 183 mg/m^2 are typical for Ohio streams with modest amounts of agriculture or wastewater loadings. Levels between 183-320 mg/m^2 are typical of streams draining agricultural landscapes or that are effluent dominated. Chlorophyll levels exceeding 320 mg/m^2 characterize over-enrichment or nuisance conditions. A review of studies on sestonic chlorophyll-a by Dodds (2006), which included some midwestern streams, suggest that concentrations of 40-100 µg/L sestonic chlorophyll-a identify eutrophic conditions while concentrations >100 µg/L indicate hypertrophic conditions. Miltner (2018) identified essentially identical boundaries based on associations between chlorophyll concentrations and various water quality and biological indicators.

Organic Enrichment and Low Dissolved Oxygen

Relative to atmospheric oxygen, the amount of oxygen soluble in water is low and it decreases as temperature increases. This is one reason why tree shade is so important. The two main sources of oxygen in water are diffusion from the atmosphere and plant photosynthesis. Turbulence at the water surface is critical because it increases surface area and promotes diffusion. Drainage practices such as channelization eliminate turbulence produced by riffles, meanders and debris snags. Although plant photosynthesis produces oxygen by day, it is consumed by the reverse process of respiration at night. Oxygen is also consumed by bacteria that decay organic matter, so it can be easily depleted unless it is replenished from the air. Sources of organic matter include poorly treated wastewater, sewage bypasses and dead plants and algae. Dissolved oxygen criteria are established in the Ohio WQS to protect aquatic life. The minimum and average limits are tiered values related to the applicable aquatic life use designation of the stream (OAC 3745 -1-35, Table 35-1).

Ammonia

Ammonia enters streams as a component of fertilizer and manure run-off and wastewater effluent. Ammonia gas (NH_3) readily dissolves in water to form the compound ammonium hydroxide (NH4OH). In aquatic ecosystems, equilibrium is established as ammonia shifts from a gas to undissociated ammonium hydroxide to the dissociated ammonium ion (NH4+). Under normal conditions (neutral pH 7.0 and temperature 25° C), almost none of the total ammonia is present as gas, only 0.55 percent is present as ammonium hydroxide, and the rest is ammonium ion. Alkaline pH shifts the equation toward gaseous ammonia production, so the amount of ammonium hydroxide increases. This is important because while the ammonium ion is almost harmless to aquatic life, ammonium hydroxide is very toxic and can reduce growth and reproduction or cause mortality.

Ammonia criteria are established in the Ohio WQS to protect aquatic life. The maximum and average limits are tiered values based on sample pH and temperature and vary based upon the aquatic life use designation that applies to the water body (OAC 3745-1-35, Tables 35-2 through 35-8).

Metals

Metals can be toxic to aquatic life and hazardous to human health. Although they are naturally occurring elements, many are extensively used in manufacturing and are byproducts of human activity. Certain metals like copper and zinc are essential in the human diet, but excessive levels are usually detrimental. Lead and mercury are of particular concern because they can trigger fish consumption advisories. Mercury is used in the production of chlorine gas and caustic soda and in the manufacturing of batteries and fluorescent light bulbs. The burning of coal for electricity generation and for steel production can release mercury into the environment through air deposition and from wastewater discharges. In the environment, mercury forms inorganic salts, but bacteria convert these to methyl-mercury and this organic form builds up in the tissues of fish. Extended exposure can damage the brain, kidneys, and developing fetus. The Ohio Department of Health (ODH) issued a statewide mercury advisory in 1997 primarily for women of child-bearing age and children age 15 and under. They are advised to eat no more than one meal per week of fish (any species) from any Ohio water body unless there is a more or less restrictive advisory. Although the one-meal-per-week advice applies mainly to these sensitive populations, the general advisory recommends that everyone follow that advice. Lead is used in batteries, pipes and paints and is emitted from burning fossil fuels. It can affect the central nervous system and damage the kidneys and reproductive system. Copper is mined extensively and used to manufacture wire, sheet metal and pipes. Ingesting large amounts can cause liver and kidney damage. Zinc is a by-product of mining, steel production and coal burning and used in alloys such as brass and bronze. Ingesting large amounts can cause stomach cramps, nausea and vomiting.

Water quality criteria for various metals are established in the Ohio WQS (Administrative Code 3745-1) to protect human health, wildlife and aquatic life from both acute and chronic exposures. Aquatic life criteria, which are contained in OAC 3745-1-35, vary for some of the metals based on water hardness (OAC 3745-1-35, Table 35-9). Different human health and wildlife criteria apply to the Lake Erie (OAC 3745-1-33, Table 33-2) or Ohio River (OAC 3745-1-34, Table 34-1) drainage basins. The drainage basins also have Tier I criteria and Tier II values for additional metals not established elsewhere that are developed following the procedures outlined in OAC 3745-1-40 and 3745-1-42.

Bacteria

High concentrations of *Escherichia coli* (*E. coli*) in a lake or stream may indicate possible contamination of the water with human pathogens. People can be exposed to contaminated water while wading, swimming, fishing or boating. *E. coli* bacteria are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals, such as mammals and birds. While *E. coli* bacteria are harmless in most cases, their presence indicates that the water has been contaminated with fecal material originating from a warm-blooded animal entering the water body either directly or from surface runoff. Indicator bacteria such as *E. coli* can potentially coincide with the presence of pathogenic organisms entering the water through the same pathways but are typically present in the environment in such small amounts that it is impractical to monitor them directly, hence the use of fecal bacteria such as *E. coli* as indicators. While indicator bacteria such as *E. coli* by themselves are usually not pathogenic, some strains of *E. coli* can cause serious illness. Although intestinal organisms eventually perish outside the body, some will remain virulent for a period of time while in the water and may be dangerous sources of infection. This is especially a problem if the fecal material contains pathogens or disease-producing bacteria and viruses. Reactions to exposure can range from an isolated illness such as skin rash, sore throat or ear infection to a more serious wide-spread epidemic. Some types of bacteria that are a concern include *Escherichia*, which cause diarrhea and urinary tract infections, *Salmonella*, which cause typhoid fever and gastroenteritis (food poisoning), and *Shigella*, which cause severe gastroenteritis or bacterial dysentery. Some types of viruses that are a concern include polio, hepatitis A, and encephalitis. Disease-causing microorganisms may also be transmitted through fecal contamination of surface waters and include organisms such as cryptosporidium and giardia.

Since *E. coli* bacteria are associated with warm-blooded animals, there are both human and animal sources. Human sources, including effluent from sewage treatment plants or discharges by on-lot septic systems can present a continuous source. Bacterial contamination from combined sewer overflows are associated with wet weather events. Animal sources are usually more intermittent and are also associated with rainfall, except when domestic livestock have access to the water. Large livestock farms store manure in holding lagoons creating the potential for an accidental spill. Liquid manure applied as fertilizer is a runoff problem if not managed properly and it can seep into field tiles.

Bacteria criteria for the recreational use are established in the Ohio WQS to protect human health during water recreation based upon the quantities of *E. coli* present in the water column. The criteria are seasonal, applying from May 1 through October 31 (OAC 3745-1-37, Table 37-2). The water quality standards also state that streams must be free of any public health nuisance associated with raw or poorly treated sewage during dry weather conditions (OAC 3745-1-04, Part F).

Sediment Contamination

Chemical quality of sediment is relevant because some pollutants can bind strongly to soil particles and are persistent in the environment. Some of these compounds accumulate in the aquatic food chain and may trigger fish consumption advisories, but others are simply a contact hazard because they can cause skin cancer and tumors. The physical and chemical nature of sediment is determined by local geology, land use, and contribution from manmade sources. As some materials enter the water column, they are attracted to the surface electrical charges associated with suspended silt and clay particles. Others simply sink to the bottom due to their high specific gravity. Sediment layers form as suspended particles settle, accumulate and combine with other organic and inorganic materials. Sediment is the most physically, chemically and biologically reactive at the water interface because this is where it is affected by sunlight, current, wave action and benthic organisms. Assessment of the chemical nature of this layer can be used to predict ecological impact.

Sediment data are evaluated using Ohio Sediment Reference Values [SRVs; (Ohio EPA, 2008)], along with guidelines established in *Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald, Ingersoll, & Berger, 2000), and *Ecological Screening Levels* (ESLs) (U.S. EPA, 2003). Ohio EPA's Sediment Reference Value system was derived from samples collected at ecoregional reference sites. SRVs are site-specific ecoregional-based metals concentrations and are used to identify contaminated stream reaches. The MacDonald guidelines are consensus-based using previously developed values. The system predicts that sediments below the threshold effect concentration (TEC) are absent of toxicity and those greater than the probable effect concentration (PEC) are toxic. ESL values, considered protective benchmarks, were derived by U.S. EPA Region 5 using a variety of sources and methods.

Sediment samples collected by Ohio EPA are measured for a number of physical and chemical properties. Physical attributes analyzed include percent particle size distribution (sand ≥60μ, silt 5-59μ, clay ≤4μ), percent solids, and percent organic carbon. Chemical attributes analyzed can include metals, volatile and semi-volatile organic compounds, pesticides, and polychlorinated biphenyls (PCBs).

Materials and Methods

All biological, chemical and physical habitat data collection, processing and analysis methods and procedures adhere to those specified in the *Surface Water Field Sampling Manual* for water quality and flows (Ohio EPA, 2015), *Biological Criteria for the Protection of Aquatic Life*, Volumes II - III (Ohio EPA, 1987b), (Ohio EPA, 1989a), (Ohio EPA, 1989b), (Ohio EPA, 2015a), (Ohio EPA, 2015b.), and the *Qualitative Habitat Evaluation Index (QHEI): Rationale, Methods and Application* (Rankin, The qualitative habitat evaluation index (QHEI): rationale, methods, and application. , 1989).

Determining Use Attainment Status

Use attainment status, also referred to as condition status, is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio WQS. Assessing aquatic use attainment status involves a primary reliance on Ohio EPA's biological criteria (OAC 3745-1-07; Table 7-1). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multi-metric biological indices including the IBI and MIwb, indices measuring the response of the fish community, and the ICI, which indicates the response of the macroinvertebrate community. Three attainment status results are possible at each sampling location - full, partial or non-attainment. Full attainment means all applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (full, partial or non), the Qualitative Habitat Evaluation Index (QHEI) and a sampling location description.

Habitat Assessment

Physical habitat is evaluated using the QHEI developed by Ohio EPA for streams and rivers in Ohio (Rankin, The qualitative habitat evaluation index (QHEI): rationale, methods, and application. , 1989), (Rankin, 1995), (Ohio EPA, 2006). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of instream cover, channel morphology, extent and quality of riparian vegetation, pool, run and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 60 are generally conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently reflect habitat quality sufficient to support exceptional warmwater faunas.

Sediment and Surface Water Assessment

Fine grain sediment samples were collected following the procedures outlined in Ohio EPA's Sediment Sampling Guide (Ohio EPA, 2015) and delivered to Ohio EPA's Division of Environmental Services for evaluation. Sediment data is reported on a dry weight basis. Sediment evaluations were conducted using guidelines established in MacDonald et al. (2000), U.S. EPA (2003) and Ohio EPA (2008).

Surface water samples were collected according to Ohio EPA's *Surface Water Field Sampling Manual* (Ohio EPA, 2015a) and delivered to Ohio EPA's Division of Environmental Services for analysis. Surface water samples are evaluated using comparisons to Ohio WQS criteria, reference conditions or published literature.

Recreation Use Assessment

Recreational use assessments are made at select locations within the study area. Five or more samples are collected within a 90-day period during the recreation season. Most sampling occurs between Memorial Day and Labor Day. Sample locations are generally located toward the downstream end of each HUC-12 watershed. Recreational use assessments are based upon a comparison of the *E. coli* content measured in the surface water against both the applicable geometric mean criteria and statistical threshold values (STV) found in OAC 3745-1-37. Any location where either the geometric mean of the measured values is higher than the applicable geometric mean criterion or where more than 10 percent of the measured values collected at the site are greater than the applicable STV fail to support the recreational use.

Macroinvertebrate Community Assessment

Macroinvertebrates are collected from artificial substrates and from the natural habitats. The artificial substrate collection provides quantitative data and consists of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multi-habitat composite sample is also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (for example, riffle, run, pool, margin). Detailed discussion of macroinvertebrate field and laboratory procedures is contained in *Biological Criteria for the Protection of Aquatic Life*: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA, 1989b), (Ohio EPA, 2015b).

Fish Community Assessment

Fish are sampled using pulsed DC electrofishing methods. Fish are processed in the field, and each individual species is identified. Fish are counted, weighed and any external abnormalities are recorded. Discussion of the fish community assessment methodology used in this report is contained in *Biological Criteria for the Protection of Aquatic Life*: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA, 1989b), (Ohio EPA, 1989b).

Causal Associations

Using the results, conclusions and recommendations of the biological and water quality report requires an understanding of the methodology used to determine the use attainment status and assignment of probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward — the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr, Fausch, Angermeier, Yant, & Schlosser, 1986); (Karr, 1991); (Ohio EPA, 1987a); (Ohio EPA, 1987b); (Yoder, The development and use of bilogical criteria for Ohio surface waters., 1989); (Minor & Borton, 1991); (Yoder, 1991); (Yoder, 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data and biological results (Yoder & Rankin, 1995a), (Yoder & Rankin, 1995b.) and (Yoder & Rankin, 1995c). Thus, the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function.

Watershed Overview

During 2016 and 2017, Ohio EPA conducted a water quality survey in the Symmes Creek and Indian Guyan Creek watersheds as well as direct Ohio River tributaries. The Symmes Creek watershed is in Jackson, Lawrence and Gallia counties and has five NPDES permitted facilities that discharge sanitary wastewater, industrial process water and/or industrial storm water. The Indian Guyan Creek watershed is in Lawrence and Gallia counties and only has one NPDES permitted facility that discharges sanitary wastewater in the headwaters of Drake Fork Indian Guyan Creek and one general permit for industrial storm water. The direct Ohio River tributaries sampled in 2016 include Chickamauga Creek, Buffalo Creek, Twomile Creek, Clean Fork, Big Creek, Teens Run and Swan Creek and are located in Gallia and Lawrence counties. There are no NPDES or general permitted facilities that discharge to the direct Ohio River tributaries.

Figure 3—Location of Symmes, Indian Guyan Creek watershed and direct Ohio River Tribs in Ohio.

This survey included a water resource assessment of 77 streams in the Symmes Creek, Indian Guyan Creek and direct Ohio River tributary watersheds using standard Ohio EPA protocols. Included in this study were assessments of the biological, surface water and recreation condition. A total of 101 biological, 108 water chemistry (including lake sampling), and 23 bacterial stations were sampled. The watershed location is shown in Figure 3. Sampling stations are illustrated in Figure 4 and described in Table 2.

Please email ***epatmdl@epa.ohio.gov*** to request biological, chemical or bacteria data.

Specific objectives of the evaluation were to:

- systematically sample and assess the principal drainage networks of the Symmes Creek and Indian Guyan Creek watersheds, and several other selected Ohio River tributaries in support of the TMDL process;
- gather ambient environmental information (biological, chemical, and physical) from designated water bodies, to assess current beneficial uses (e.g., aquatic life, recreational, water supply);
- evaluate influences from NPDES outfall discharges;
- determine recreational water quality;
- establish baseline ambient biological conditions at stations to evaluate the effectiveness of future pollution abatement efforts;
- verify and update fish tissue consumption advisories;
- determine the attainment status of Aquatic Life Uses; and
- recommend beneficial use designations to undesignated streams, verify current designations of designated streams and recommend revisions to designations where appropriate.

The findings of this evaluation may factor into regulatory actions taken by Ohio EPA (for example, NPDES permits, Director's Final Findings and Orders or the Ohio Water Quality Standards – Ohio Administrative Code 3745-1), and may eventually be incorporated into State Water Quality Management Plans, the Ohio Nonpoint Source Assessment, Total Maximum Daily Loads (TMDLs) and the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d] reports).

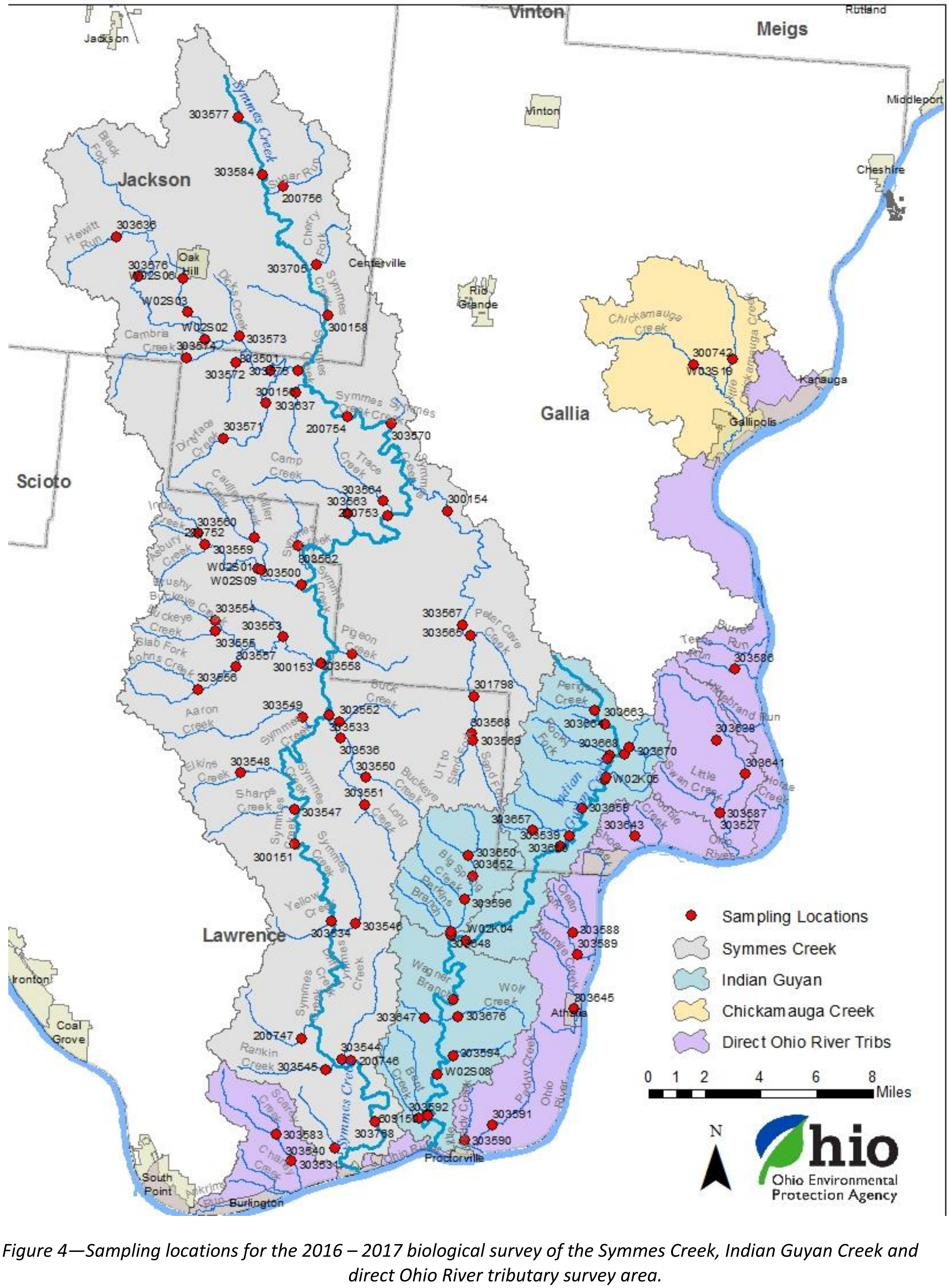


Figure 4—Sampling locations for the 2016 – 2017 biological survey of the Symmes Creek, Indian Guyan Creek and direct Ohio River tributary survey area.

Table 2—Sampling locations in Symmes Creek and Indian Guyan Creek watershed and direct Ohio River tributaries sampled in 2016 and 2107.

Station	Location	Assessment Unit (HUC 12)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude
Symmes Creek (09-700-000)							
303584	At Vega and C-H-D Rd.	05090101 08 03	70.0	F,Mq,C	14.8	38.939303	-82.523140
300158	Jenkins Alben Rd (Twp. Rd. 102)	05090101 08 03	62.8	F2,MQ,C,Sn,B,S	45.8	38.870300	-82.478600
200754	Dst. Coal Branch @ Symmes Creek Rd.	05090101 09 03	56.7	F2,MQ,C,Sn,B,S	125.0	38.818100	-82.464700
200753	At Cadmus at St. Rt. 141	05090101 09 03	47.1	F2,MQ,C	182.0	38.767200	-82.436900
303500	At Waterloo-Mt Vernon Rd.	05090101 09 03	38.7	F2,MQ,C,Sn,B,S	201.9	38.730818	-82.492679
303533	At Arabia at St. Rt. 141	05090101 10 03	31.7	F2,MQ,C	255.3	38.632602	-82.290653
300151	At Aid at St. Rt. 141	05090101 10 04	22.6	F2,MQ,C,Sn,B,S	300.0	38.596200	-82.495100
303534	At Linnville adj. St. Rt. 217	05090101 10 04	17.5	F2,C,B,T	313.2	38.663613	-82.472991
200746	Adj. St. Rt. 243, Dst. McKinney Creek	05090101 10 05	8.4	F2,MQ,C,T,D	346.0	38.484700	-82.455000
303535	Adj. Eaton Rd. (Co. Rd. 32)	05090101 10 05	2.9	F2,MQ,C,B,T	350.5	38.441953	-82.435806
Tributary to Symmes Creek (73.03) (09-700-001)							
303577	At C-H-D Rd.	05090101 08 03	0.1	F,Mq,C	5.7	38.971900	-82.540300
Sugar Run (09-741-000)							
200756	N.E. of Oak Hill at mouth Adj. Co. Rd. 2	05090101 08 03	0.1	F only	4.7	38.933200	-82.519400
Cherry Fork (09-739-000)							
303705	At Cherry Fork Rd.	05090101 08 03	0.4	F,Mq,C	2.51	38.896088	-82.48693
Black Fork Symmes Creek (09-730-000)							
303576	DST Jackson Lake Spillway	05090101 08 02	11.0	F2,MQ,C,D	18.7	38.892376	-82.603307
W02S02	At BlackFork Rd	05090101 08 02	5.8	F2,MQ,C	28.3	38.856700	-82.559700
303501	N. of Gallia at St. Rt. 233	05090101 08 02	2.4	F2,MQ,C,Sn,B,S	47.6	38.841407	-82.516048
303575	Canoe launch off Gallia Rd.	05090101 08 02	0.3	F2,MQ,C,T,D	62.6	38.841538	-82.497828
Hewitt Run (09-738-000)							
303636	At Franklin Valley Rd.	05090101 08 02	0.8	F,Mq,C	4.6	38.911600	-82.614400
Huntingcamp Creek (09-735-000)							
W02S06	Upst. Oak Hill WWTP	05090101 08 02	1.7	F, MQ,C,D	1.8	38.882200	-82.576700
W02S03	Dst. Oak Hill WWTP	05090101 08 02	1.2	F,MQ,C,N	2.4	38.874400	-82.576700
Cambria Creek (A.K.A. Lefthand Fork) (09-734-000)							
303574	At Potts Rd.	05090101 08 02	1.7	F,Mq,C,D	7.2	38.847120	-82.571408
Dicks Creek (09-733-000)							
303573	At Sardis Rd.	05090101 08 02	0.3	F,Mq,C,D	3.0	38.858917	-82.537027
Clear Fork (09-732-000-000)							
303572	At Shafer Rd	05090101 08 02	0.7	F,Mq,C	3.1	38.845171	-82.538638
Dirtyface Creek (09-731-000)							
303571	Adj. C-H-D Rd. near pipeline crossing	05090101 08 01	4.7	F,Mq,C	3.0	38.805580	-82.546144

Station	Location	Assessment Unit (HUC 12)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude
300156	At C-H-D Rd.	05090101 08 01	1.8	F,Mq,C,Sn	12.0	38.824200	-82.518900
Sweetbit Creek (09-700-003)							
303637	At Pumpkintown Rd.	05090101 09 03	0.1	F, Mq, C, D, N	2.7	39.346021	-82.25475
Wolf Run (09-729-000)							
303570	At Symmes Creek Rd.	05090101 09 01	0.1	F,Mq,C	0.9	38.814879	-82.435175
Sand Fork (09-727-000)							
303569	At Palestine- Okey Church Rd. (Twp. Rd. 217)	05090101 09 01	15.1	F,Mq,C	3.0	38.651215	-82.377996
303568	At drive to Timber Ridge Lake	05090101 09 01	14.9	F,Mq,C	8.9	38.654911	-82.379309
301798	At Lecta at St. Rt. 775	05090101 09 01	13.4	F,Mq,C,Sn,B,S	13.8	38.674300	-82.377500
303567	At Peters Cave Rd.	05090101 09 01	10.3	F2,MQ,C	28.3	38.711039	-82.385827
300154	At Patriot-Cadmus Rd.	05090101 09 01	2.7	F2,MQ,C,Sn,B,S	40.4	38.770200	-82.396800
Tributary to Sand Fork (09-727-002)							
303566	Adj Palestine-Okey Church Road.	05090101 09 01	0.4	C Only	3.5	38.648300	-82.382000
Peters Cave Creek (09-728-000)							
303565	Adj. Peters Cave Rd.	05090101 09 01	0.2	F,Mq Only	5.2	38.705649	-82.380344
Trace Creek (09-726-000)							
303564	At private drive off St. Rt. 141	05090101 09 03	0.6	F,Mq,C	2.7	38.774536	-82.439949
Camp Creek (09-725-000)							
303563	At Peniel Rd.	05090101 09 03	0.7	F,Mq,C	4.5	38.768197	-82.463437
Little Buffalo Creek (09-724-000)							
303562	At Carpenter Rd. (Twp. Rd. 182)	05090101 09 03	1.2	F,Mq,C	2.6	38.750556	-82.495944
Buffalo Creek (09-719-000)							
200752	Adj. Buffalo-Olive Rd., dst. Indian Creek	05090101 09 02	5.0	F,Mq,C	3.1	38.752968	-82.558694
W02S09	At Co. Rd. 14	05090101 09 02	1.9	F,Mq,C,B	8.5	38.738600	-82.522200
Indian Creek (09-723-000)							
303560	Near mouth off Buffalo-Olive Rd.	05090101 09 02	0.1	F,Mq Only	0.8	38.756323	-82.562395
Caulley Creek (09-720-000)							
W02S01	Near mouth at Co. Rd. 14	05090101 09 02	0.15	F,Mq,C,R	4.9	38.737800	-82.519700
Miller Creek (09-721-000)							
303559	At Caulley Creek Rd.	05090101 09 02	0.05	F,Mq,C	1	38.754765	-82.524636
Pigeon Creek (09-718-000)							
303558	At Webster Rd.	05090101 10 03	0.55	F,Mq,C	3.2	38.695475	-82.459002
Johns Creek (09-714-000)							
303557	At Etna-Waterloo Rd.	05090101 10 01	5.35	F,Mq,C	9.4	38.687497	-82.53529
300153	S. of Waterloo at St. Rt. 141	05090101 10 01	0.07	F2,MQ,C,B,S,D	22.7	38.690300	-82.479200
Slab Fork (09-717-000)							

Station	Location	Assessment Unit (HUC 12)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude
303556	At Etna-Waterloo Rd.	05090101 10 01	0.1	F,Mq,C	2.57	38.675489	-82.560562
Buckeye Creek (09-715-000)							
303555	At Buckeye Rd. (Trib. to Johns Creek)	05090101 10 02	1.4	F,Mq,C	3.4	38.706281	-82.549588
Brushy Buckeye Creek (09-716-000)							
303554	At Buckeye Rd.	05090101 10 02	1.4	F,Mq,C	3.4	38.706281	-82.549588
Handley Branch (09-714-001)							
303553	Near mouth off Handley Branch Rd.	05090101 10 01	0.1	F,Mq Only	1.7	38.70339	-82.504746
Buck Creek (09-713-000)							
303552	At St. Rt. 141	05090101 10 03	0.35	F,Mq,C	5	38.660259	-82.466477
Long Creek (09-711-000)							
303551	At St. Rt. 775	05090101 10 02	4.3	F,Mq,C	5.3	38.617447	-82.448515
303536	S.E. of Arabia at Zalmon Rd.	05090101 10 02	0.86	F,Mq,C,B,D	14.7	38.651824	-82.465795
Buckeye Creek (09-712-000)							
303550	At St. Rt. 775 (Trib. to Long Creek)	05090101 10 02	0.9	F,Mq,C	3.8	38.63138	-82.448339
Aaron Creek (09-710-000)							
303549	At Elkins Creek Rd.	05090101 10 04	0.65	F,Mq,C,D	8.3	38.662200	-82.490600
Elkins Creek (09-709-000)							
303548	At National Forest pull-off adj. Elkins Creek Rd.	05090101 10 04	1.8	F,Mq,C	3.3	38.632695	-82.530994
Sharps Creek (09-708-000)							
303547	Near mouth	05090101 10 04	0.2	F,Mq,C	4.6	38.614549	-82.495453
Venisonham Creek (09-705-000)							
303546	At St. Rt. 217	05090101 10 04	0.95	F,Mq,C	3.9	38.555939	-82.454028
Leatherwood Creek (09-704-000)							
200747	N.W. of Getaway at St. Rt. 243	05090101 10 04	0.8	F,Mq,C	4	38.495800	-82.488100
Rankin Creek (09-703-000)							
303545	At private drive adj. Rankin Creek Rd.	05090101 10 05	0.55	F,Mq,C	3.9	38.480099	-82.471624
McKinney Creek (09-702-000)							
303544	At St. Rt. 243	05090101 10 05	0.35	F,Mq,C	5	38.485602	-82.461746
Big Branch Creek (09-701-000)							
303540	At Henson Hollow Rd. (Co. Rd. 158)	05090101 10 05	0.55	F,Mq,C	3	38.439714	-82.465202
Indian Guyan Creek (09-100-000)							
303663	At Mercerville Rd.	05090101 07 07	29.05	F,Mq,C	5.2	38.660882	-82.291173
W02K05	N. of Crown City adj. St. Rt. 218	05090101 07 07	26.4	F,Mq,C,D	16	38.632449	-82.290585
303539	At Shoal Creek Rd.	05090101 07 07	21.7	F2,MQ,C	25.4	38.597159	-82.318971
W02K04	At Co. Rd. 67 (Scottown covered bridge)	05090101 07 07	14.7	F2,MQ,C,B,D	33.5	38.547693	-82.380379
303675	At old St. Rt. 775	05090101 07 08	10.6	F2,MQ,C,D	54.1	38.517331	-82.388188

Station	Location	Assessment Unit (HUC 12)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude
W02S08	At Co. Rd. 69	05090101 07 08	5.76	F2,MQ,C,Sn,B,S,T	64	38.478383	-82.398175
609150	Adj. Indian Guyan Rd. dst. Bear Creek.	05090101 07 08	2.95	F2,MQ,C,T	73.3	38.454393	-82.409132
Perigen Creek (09-115-000)							
303664	At Mercerville Rd.	05090101 07 07	0.1	F,Mq,C	2.1	38.667722	-82.298179
Cofer Hollow Run (09-117-000)							
303665	@Mercerville Rd.	05090101 07 07	0.05	C only	0.5	38.662891	-82.296196
Drake Fork (09-114-000)							
303669	At Rocky Fork Rd.	05090101 07 07	0.3	F,Mq,C	2.5	38.645250	-82.277825
Trib to Drake Fork (0.55) (09-114-001)							
303670	At St. Rt. 218	05090101 07 07	0.05	F,Mq,C	0.9	38.648961	-82.274609
Johns Creek (09-113-000)							
303668	At Rocky Fork Rd.	05090101 07 07	0.1	F, C	1.9	38.644910	-82.287667
Rocky Fork (09-112-000)							
303667	At Cecil Rd.	05090101 07 07	0.1	F,Mq,C	3.4	38.643025	-82.289010
Lanes Branch (09-111-000)							
303662	Adj. St. Rt. 218	05090101 07 07	0.1	F,C	1.6	38.633277	-82.289828
Georges Creek (09-110-000)							
303659	At St. Rt. 218	05090101 07 07	0.05	F,Mq,C	1.9	38.617444	-82.305414
Williams Creek (09-116-000)							
303657	At Berry Rd.	05090101 07 07	1.55	F,Mq,C	0.9	38.605272	-82.337841
303656	At St. Rt. 216	05090101 07 07	0.05	F,Mq,C	3.2	38.602839	-82.313589
Garland Creek (09-116-001)							
303655	@ Williams Creek Road	05090101 07 07	0.05	C Only	1	38.607917	-82.331291
Little Indian Guyan Creek (09-108-000)							
303652	At Twp. Rd. 122 S	05090101 07 06	2.7	F,Mq,C	5.9	38.581354	-82.376985
303596	At Big Spring Rd.	05090101 07 06	1.65	F,Mq,C	8.5	38.569159	-82.382093
303532	At Scottown at St. Rt. 217	05090101 07 06	0.13	F,Mq,C,B,D	14.9	38.550463	-82.390336
Watson Creek (09-108-002)							
303650	At Long Creek Rd.	05090101 07 06	0.05	F,Mq,C	1.7	38.591664	-82.379888
Trace Creek (09-108-001)							
303648	Adj. St. Rt. 775 near mouth	05090101 07 06	0.1	F,Mq,C	3.7	38.552295	-82.390441
Wolf Creek (09-106-000)							
303676	At St. Rt. 775	05090101 07 08	0.35	F,Mq,C	4.7	38.507112	-82.390948
Slate Run (09-105-000)							
303647	At Twp. Rd. 192 N	05090101 07 08	0.4	F,Mq,C	1.1	38.506106	-82.401414
Fivemile Creek (09-104-000)							

Station	Location	Assessment Unit (HUC 12)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude
303594	At Seneca Trail	05090101 07 08	0.3	F,Mq,C	3.3	38.488183	-82.388022
Bear Creek (09-102-000)							
303593	At Indian Guyan Rd.	05090101 07 08	0.05	F,Mq,C	2.9	38.457423	-82.404522
Bent Creek (09-101-000)							
303592	At Greasy Ridge Rd.	05090101 07 08	0.05	F,Mq,C	1.9	38.455391	-82.410299
Buffalo Creek (09-020-000)							
303531	At Buffalo Creek Rd.	05090101 09 02	1.1	F,Mq,C,B	6.7	38.432428	-82.493628
Scarey Creek (09-020-001)							
303583	At Lick Creek Rd. (Co. Rd. 15)	05090101 10 07	0.05	F,Mq,C	2.1	38.446214	-82.504166
Paddy Creek (09-021-000)							
303591	At Private Rd. 21501	05090101 07 09	1.65	F,Mq,C	4.9	38.452440	-82.361560
Little Paddy Creek (09-021-001)							
303590	At service road off Walnut St.	05090101 07 09	0.4	F,Mq,C	2.0	38.444663	-82.379754
Twomile Creek (09-022-000)							
303645	At Wylie St.	05090101 07 09	1.45	F,Mq,C	3.0	38.513127	-82.308486
Federal Creek (09-023-000)							
303589	At Federal Creek Rd.	05090101 07 09	0.85	F,Mq,C	4.0	38.541156	-82.307079
Clean Fork (09-024-000)							
303588	Adj. Clean Fork Rd. upst. Federal Creek	05090101 07 09	0.1	F,Mq,C	1.7	38.552747	-82.310379
Big Creek (09-095-000)							
303643	Adj. Big Creek Rd.	05090101 07 09	0.68	F,Mq,C	1.6	38.603102	-82.270155
Swan Creek (09-027-000)							
303641	Adj. Swan Creek Rd.	05090101 07 03	4.25	F,Mq,C	8.3	38.636070	-82.197817
303527	Swan Creek Rd., dst. Little Swan Creek	05090101 07 03	2.35	F,Mq,C,B	14.7	38.615817	-82.213702
Tributary to Swan Creek (5.95) (09-027-001)							
303638	At Hamilton Rd.	05090101 07 03	0.5	F,Mq,C,D	2.2	38.653479	-82.217357
Little Swan Creek (09-028-000)							
303587	At private bridge off Swan Creek Rd.	05090101 07 03	0.05	F,Mq,C	4.2	38.615917	-82.214421
Teens Run (09-031-000)							
303586	At Barcus Hollow Rd.	05090101 07 04	1.2	F,Mq,C	2.5	38.690088	-82.205701
Burrels Run (09-032-000)							
303585	At Clay Chapel Rd.	05090101 07 04	0.9	C Only	1.5	38.701080	-82.195079
Chickamauga Creek (09-037-000)							
300742	At St. Rd. 160	05090101 01 01	5.0	F,Mq,C	12.1	38.847415	-82.235799
Little Chickamauga Creek (09-039-000)							
W03S19	N. of Gallipolis at St. Rt. 160	05090101 01 01	0.16	F,Mq,C	5.9	38.835165	-82.214613

Station	Location	Assessment Unit (HUC 12)	River Mile	Sample Type[1]	Drain. Area	Latitude	Longitude

1 C – water chemistry, B – bacteria, D - datasondes, S - Sediment, F2 - two fish pass, F - one fish pass, Mq - qualitative macroinvertebrate, MQ – quantitative macroinvertebrate, N - Nutrient, Sn – Sentinel, R - Reference Site

Study Area Description

Location and Scope

Symmes Creek, Indian Guyan Creek, Chickamauga Creek and the direct Ohio River tributaries sampled in 2016 and 2017 enter the Ohio River between South Point (the southern-most part of Ohio) in Lawrence County to Gallipolis in Gallia County. The watersheds encompass a total of 556 square miles and are located in the coal bearing Western Allegheny Plateau (WAP) ecoregion, typically characterized by steep hills with narrow valleys and ridges (Omernik J. M., 1987). The mainstem of Symmes Creek flows through Jackson, Gallia and Lawrence counties and enters the Ohio River just upstream of Chesapeake in Lawrence County at river mile (RM) 672.89 (Figure 4). Symmes Creek is 70 miles long and has a drainage area of 357 square miles with an average drop of 3.4 feet per mile (Table 3). Compared to other similarly sized direct Ohio River tributaries in the WAP ecoregion, Symmes Creek is a very low gradient stream. Indian Guyan Creek is 31.5 miles long, drains 77.1 square miles and enters the Ohio River just downstream from Proctorville (upstream from Symmes Creek) at RM 675.42. Indian Guyan Creek has an average gradient of 11.3 feet per mile. Swan Creek is 10.6 miles long, drains 16.8 square miles and enters the Ohio River at RM 694.79 upstream of Crown City. Chickamauga Creek is 9.4 miles long, drains 30.9 square miles and enters the Ohio River at RM 711.28 in Gallipolis. The Raccoon Creek watershed separates Chickamauga Creek from Symmes, Indian Guyan and Swan Creeks.

Table 3—Characteristics of the principal Ohio River tributaries sampled in 2016 (ODNR, 2001).

Stream	County	Length (mi)	Average fall (ft/mi)	Drains (mi^2)
Buffalo Creek	Lawrence	5.8	66.9	7.69
Symmes Creek	Lawrence	70	3.4	375
Indian Guyan Creek	Lawrence	31.5	11.3	77.1
Paddy Creek	Lawrence	5.8	49.6	8.0
Twomile Creek	Lawrence	4.4	48	4.84
Federal Creek	Lawrence	3.5	48.6	4.32
Swan Creek	Gallia	10.6	26.1	16.8
Teens Run	Gallia	3.1	72.3	3.12
Burrels Run	Gallia	2.5	61.2	2.5
Chickamauga Creek	Gallia	9.4	16.6	30.9

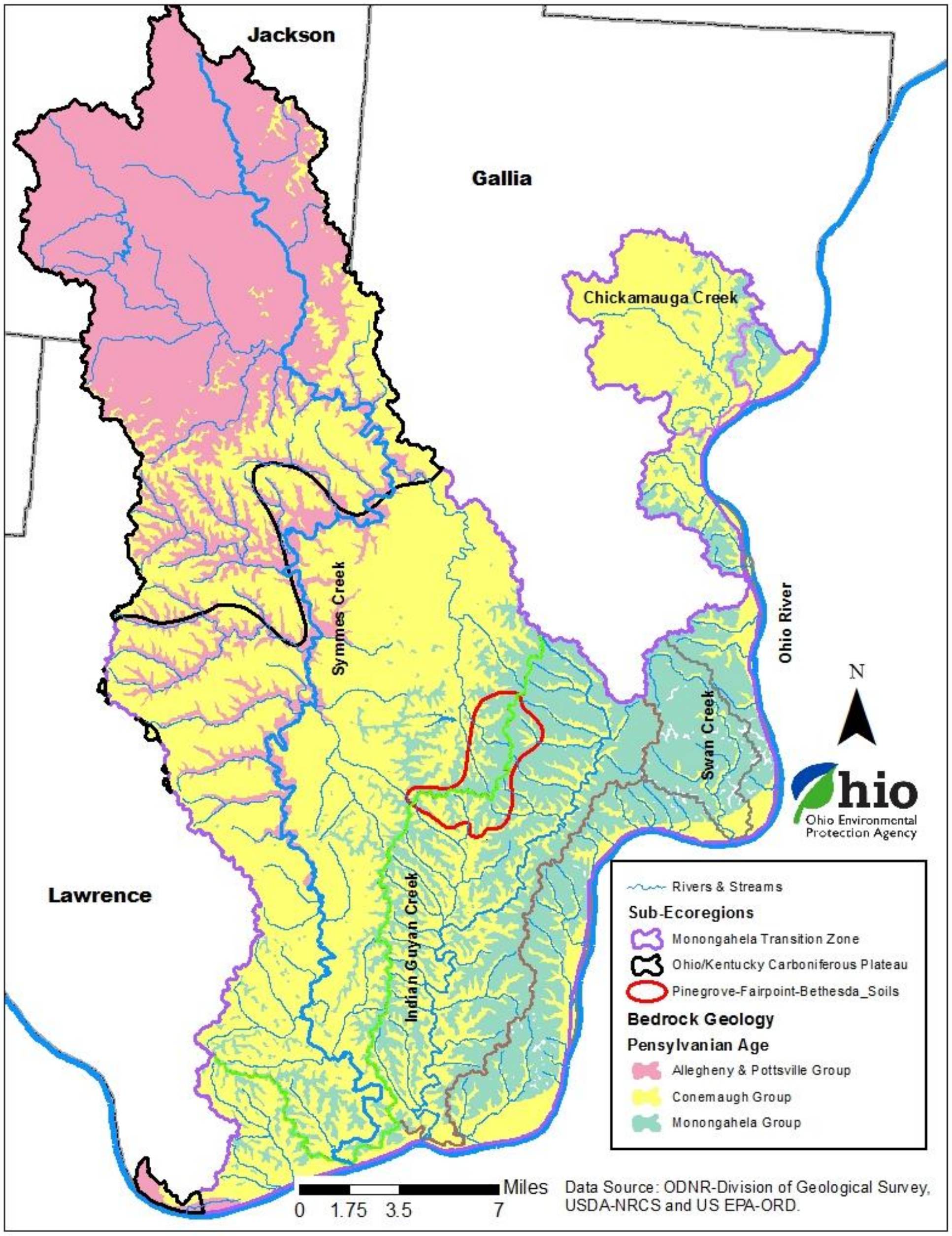
Ecoregions, Geology, and Soils

The study area is entirely within the Western Allegheny Plateau (WAP) ecoregion which consists of Pennsylvanian age bedrock. The WAP is predominately rugged hilly, wooded terrain that was not recently glaciated unlike northern and western Ohio (Omernik & Griffith, 2008). Two sub-ecoregions of the WAP are in the study area: the Monongahela Transition Zone and the Ohio/Kentucky Carboniferous Plateau (**Error! Reference source not found.**). The Monongahela Transition Zone covers 69 percent of the study area with rounded hills and ridges with narrow valleys. The Ohio/Kentucky Carboniferous Plateau covers 31 percent of the study area with broad, flat-bottomed pre-glacial drainage valleys in the northern part of Symmes Creek. These pre-glacial drainages include the buried valley of the Teays era Marietta River in Grassy Fork and the alluvial glacial deposits in Black Fork, Dicks Creek and the entire length of Symmes Creek. The Pennsylvanian age bedrock is made up of Monongahela, Conemaugh and Allegheny and Pottsville Group undivided (youngest to oldest). The Monongahela Group is situated in the most southern and eastern portion of the study area.

The Monongahela Group is characterized by shale, siltstone, sandstone, mudstone and coal (Schumacher, Mott, & Angle, 2013) and comprises only 20 percent of the study area. This group is found mostly on the ridgetops in Indian Guyan Creek and the Ohio River Tributaries. The Monongahela Group has the #8A Pomeroy coal seam which lies directly on top of the Conemaugh Group. The #8A coal seam was heavily surface mined at the Sand Fork and Indian Guyan Creek boundary. Siltstone, shale and mudstone are abundant in the Conemaugh Group. Sandstone, limestone and coal are also found in this group. The coal is mostly thin and impure and lacks the thickness for economic development. The Conemaugh Group makes up about 53 percent of the study area, covering most of the mid-section. The Allegheny and Pottsville Group undivided (APGu) comprises the northwestern third of the study area and is in the Ohio's Hanging Rock Iron District. This group is characterized by shale and sandstone with lesser amounts of limestone, clay, flint, iron ore and coal also found in this group. The abundance of these geologic resources had made and continue to make this group an important major economic asset.

The sandstone (Clarion sandstone) component of the APGu was the preferred sandstone utilized in the construction of the Hanging Rock Iron Furnaces and local building stones. Coal (bituminous) found in the APGu trends from thin to twelve-foot thick. The #4A Clarion, #5 Lower Kittanning, #6 Middle Kittanning and #7 Upper Freeport coal seams were mined. Surface and underground mining techniques have been employed, but recently only surface mining is used. The coal in this group was formed in coastal peat swamps where brackish tide water brought in sulfate ions. The dissolved iron and sulfate ions combined to form pyrite (FeS_2) which, when later when exposed to water and air, form acid mine drainage (sulfuric acid – H_2SO_4). High quality flint clay and plastic clays are abundant in the APGu and provided valuable resource to the six clay plants around Oak Hill in the 1920s (Camp, 2006)**.** Today only one clay plant continues to mine clay in the Oak Hill area.

The most common soil series in Symmes Creek study area include the Vandalia-Upshur-Newark-Guernsey-Elba (USDA, 1998) series which makes up 62.8 percent of the stream survey area. This soil series is located entirely within the Monongahela Transition Zone of the WAP and encompasses nearly all of the Symmes Creek watershed from the Ohio River to river mile 47 at Cadmus. Additionally, this series comprises 91 percent of Indian Guyan Creek watershed, all of Swan Creek except the Ohio River flood plain and stretches over to comprise much of the Chickamauga watershed as well (Table 4). The most consequential soil series is the study area is, perhaps, the Pinegrove-Fairpoint-Bethesda soil series (**Error! Reference source not found.**) in a small area in the headwaters of Sand Fork and Turkey Creek (Symmes Creek) and Indian Guyan Creek tributaries Williams, Garland, Georges Creeks and Rocky Fork. This series comprises about 50 percent of the barren land use within the study area. The soils are a deep, well drained, strongly sloping and moderately steep soil series on mine spoil ridges in areas of surface coal mines. Seventy-seven percent of this series' area has been surface-mined (Pomeroy #8A coal). Pre-law surface mining, which required little land reclamation, in this area may be the cause of the heavy sand load in Sand Fork and Indian Guyan Creek. Overlaying the #8A coal is Pomeroy Sandstone. This sandstone is easily eroded once exposed to weather and averages 18 feet thick (Norling, 1958). This soil series consists of a mixture of rock fragments and partly weathered fine earth material. The rock fragments consist mainly of shale, siltstone, and sandstone. These soils generally are unsuited to row crops, hay, and pasture. National Resources Conservation Service estimates that the Pomeroy sandstone erodes at up to 500 tons per year per acres of sediment loss (Farley, 2018). Approximately 2,000 acres were mined in this area.



Jackson
Gallia
Lawrence
Chickamauga Creek
Symmes Creek
Indian Guyan Creek
Swan Creek
Ohio River
N
Ohio
Ohio Environmental Protection Agency
Rivers & Streams
Sub-Ecoregions
Monongahela Transition Zone
Ohio/Kentucky Carboniferous Plateau
Pinegrove-Fairpoint-Bethesda_Soils
Bedrock Geology
Pensylvanian Age
Allegheny & Pottsville Group
Conemaugh Group
Monongahela Group
Miles
0 1.75 3.5 7
Data Source: ODNR-Division of Geological Survey, USDA-NRCS and US EPA-ORD.

Table 4—Dominant soil series in the study area including percent of watershed, general locations, and major characteristics.

Soil Series	Percent of Watershed	Primary Location	Major Characteristics
Vandalia-Upshur-Newark-Guernsey-Elba	62.8%	Symmes Creek from the Ohio River to Cadmus. 91 percent of Indian Guyan Creek, all of Swan Creek, and nearly all of Chickamauga Creek	Deep to very deep, moderately to well drained soils. Soils are found on ridge tops and shoulders, but the Newark soils are predominately found in flood plains carrying much of the row crop burden.
Steinsburg-Rarden-Clymer-Berks	19.5%	Makes up most of the upper Symmes Creek watershed	Moderately deep to deep, moderately to well drained soils. Rarden soils are mostly forest and pastures and the other three soils types are majority row crop and pasture.
Steinsburg-Shelocta	4.8%	Found only in Buckeye Creek (Johns Creek tributary) and the northern parts of Johns Creek	These soils are wooded. The land use is limited due to slope and a severe hazard of erosion.
Omulga-Doles	3.9%	Upper Symmes Creek and upper Chickamauga Creek in abandon pre-glacial drainages.	These soils are flat and originate from loess and silty colluvium or old alluvium allowing for extensive agriculture.
Shelocta-Latham-Brownsville	3.2%	Jackson Lake, upper Black Fork and Hewitt Run	Deep and moderately deep, gently sloping to very steep, moderate to well drained soils formed in colluvium and residuum from shale, siltstone, and sandstone.
Wheeling-Weinbach-Peoga-Nolin-Elkinsville	3.2%	Inside bends of Ohio River flood plain	Deep, poor to well drained and nearly level soils.
Pinegrove-Fairpoint-Bethesda	2%	Headwaters of Sand Fork and Turkey Creek (Symmes Creek) and Indian Guyan Creek tributaries Williams, Garland, Georges Creeks and Rocky Fork.	Deep, well drained, strongly sloping and moderately steep soils on mine spoil ridges. Extremely erosion prone.

Land Cover and Land Use

The lower portion of Symmes Creek watershed is composed of hilly rough topography dissected by streams. The upper portion of the Symmes Creek watershed has large pre-glacial stream valleys cut by the Marietta River, a tributary to the Teays River. The Teays River was periodically dammed by the early glaciations in Ohio causing the river to back up forming large glacial lakes. As the glacial lakes receded, streams cut new channels which resulted in gorge like paths cut as the new stream flowed south. The lake sediments filled the valley floors causing them to level out. The overall low gradient condition in Symmes Creek is in part caused by the glacial lake sediments in the upper watershed. Low gradient streams also result in wetland-type conditions within and around the stream corridor. In the upper portion of Symmes Creek there are over four-square miles of emergent wetlands and forested/shrub wetlands. Cackley Swamp in Pyro is over 200 acres of wetland and is now a nature preserve. Flooding in upper Symmes Creek is a common problem.

Developed land within the study area comprises 8.9 percent or 49.5 square miles, mostly along the Ohio River (Figure 5). The predominant land cover is forested areas making up 63 percent of the study area. The study area has 102 square miles of public park, forest, wildlife areas and conservation nature preserve that are state owned and non-governmental organizations or NGOs. The Wayne National Forest has 74.5 square miles while the Ohio Department of Natural Resources' Crown City Wildlife Area covers 17.8 square miles. Agriculture is the next largest land use and it covers 21.2 percent of the land use but only 3.8 percent is row crops with the remaining used for livestock pasture and hay. Six percent of the land cover is barren, scrub/shrub and herbaceous grasslands much of which is unreclaimed surface coal mines. Wetlands and open water make-up the remaining 0.75 percent of the land cover. Publicly accessed lakes and impoundments are few across the study area. There are other named lakes within the study area, but all are privately owned. Symmes Creek watershed has the only public lakes.

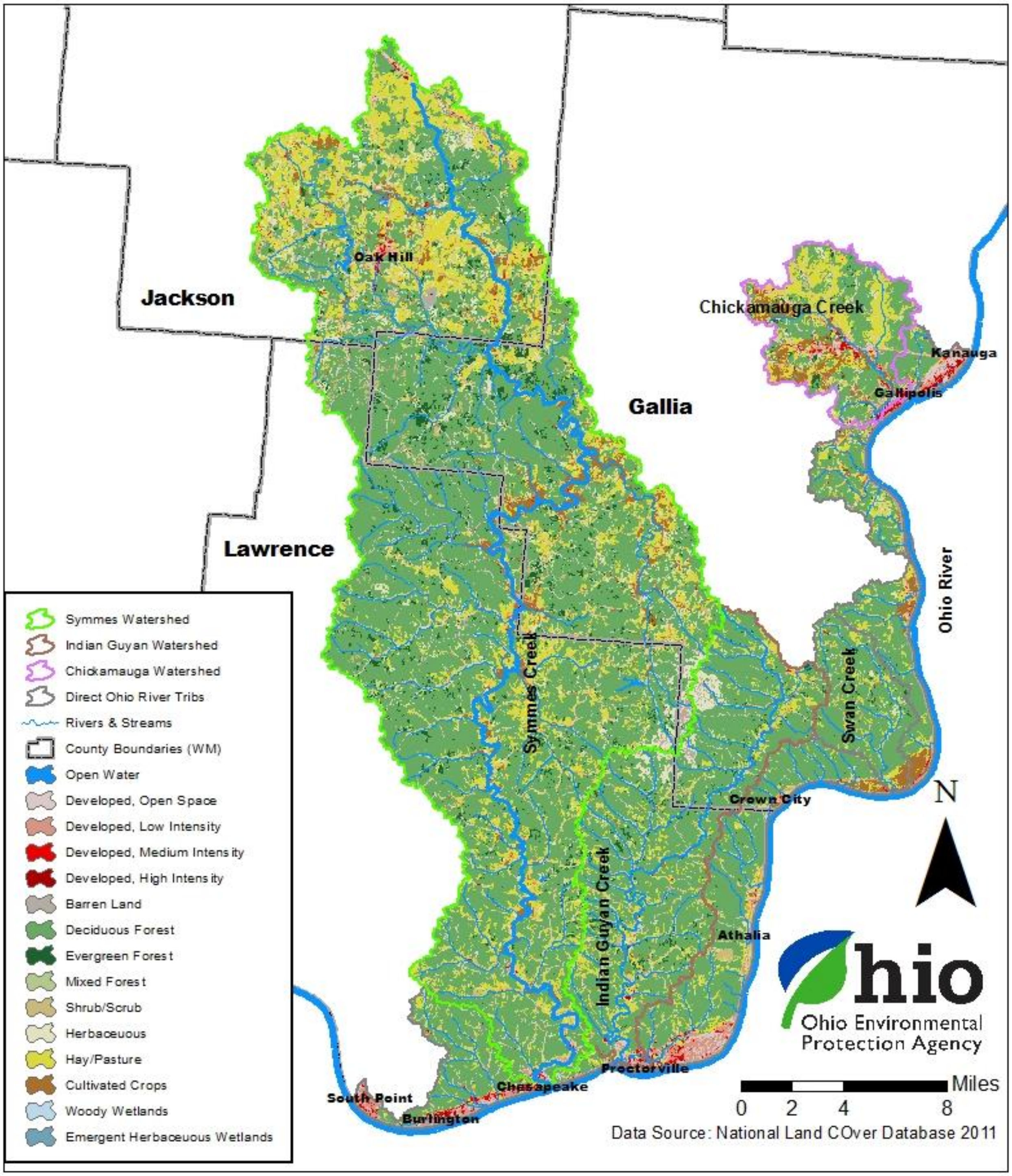


Figure 5—Land use map of the watershed from the 2011 National Land Cover Database (NLCD).

Census Data

According to the 2010 census, the Symmes Creek study area is home to approximately 52,000 people, of which, approximately 14,000 live outside of the incorporated areas. Most of the 38,000 live along the Ohio River with 1500 people within the Oak Hill community. Population densities for Gallia County are 66 people/mi^2, 79 people/mi^2 in Jackson County and 137 people/mi^2 in Lawrence County (US Census Bureau, 2010). In Gallia and Lawrence counties, most people live in the urban areas along the Ohio River. In 2014 the city of Gallipolis had a population of 3,607 (95 percent urban, five percent rural). Population densities in this area are as high as 2,400 people/mi^2 in Proctorville and 1,350 people/mi^2 in Oak Hill. Total population across the three primary counties (Gallia, Jackson and Lawrence) dropped by two to three percent between 2007 and 2010.

Wastewater Discharge Overview

There are many large urban areas found along the Ohio River with Chickamauga Creek flowing through Gallipolis being the largest city. Symmes and Indian Guyan creeks flow through the Union/Rome township area of Chesapeake and Proctorville. These large urban areas require coverage under a Municipal Separate Storm Sewer System (MS4) National Pollutant Discharge Elimination System (NPDES). The MS4 permit requires the urbanized area to develop a Storm Water Management Plan to reduce or eliminate non-point source pollution.

Table 5—Facilities regulated by an NPDES permit (non-storm water) within the study area.

Ohio EPA Permit Number	Facility Name	Design Discharge (MGD)	Wastewater Type, Treatment System	Stream and River Mile at Discharge	County
05090101 08 03 – Headwaters of Symmes Creek					
0IN00047	Harbison Walker International, INC. (Oak Hill)	0.003	Extended Aeration Package Plant	Grassy Fork RM 1.0	Jackson
05090101 08 02 – Black Fork					
0PB00055	Village of Oak Hill WWTP	0.300	Activated Sludge Secondary Clarification	Huntingcamp Cr. Creek RM 1.72	Jackson
05090101 10 04 – Aaron Creek – Symmes Creek					
0PT00032	Symmes Valley Local Schools	0.015	Extended Aeration Package Plant	Trib. to Symmes Cr RM 23.55	Lawrence
05090101 10 05 – McKinney Creek – Symmes Creek					
0PT00063	Collins Career Center – Lawrence County Comm.	0.350	Extended Aeration Package Plant	Symmes Creek RM 10.58	Lawrence
05090101 07 07 – Johns Creek – Indian Guyan Creek					
0PA00105	Mercerville WWTP – Gallia County Comm.	0.024	Extended Aeration Package Plant	Drake Fork Indian Guyan Creek RM 1.62	Gallia

Oak Hill is the only large urban area in the study area stream with a wastewater treatment plant discharging to Huntingcamp Creek, a tributary of Black Fork of Symmes Creek. A total of five individual NPDES permitted facilities discharge sanitary wastewater and industrial storm water into the study area (Table 5). Four of these NPDES permitted facilities are in Symmes Creek watershed. Oak Hill WWTP is the only significant NPDES permit facility. Additionally, there are numerous general NPDES permitted facilities for industrial storm water, hydrostatic test water activities and small sanitary wastewater treatment plants. In 2016, there was one active coal surface mine under an individual NPDES permit, the Cedar Heights Clay Company, which also mined unspecified use clay and shale (Wright & Stucker, 2018). Currently, the company is no longer mining. A. P. Green Refractories, Inc. was mining refractory clay, as well, under a general industrial storm water permit.

Domestic wastewater generated in the study area watershed is serviced mostly by household sewage treatment systems (HSTSs). HSTSs are prevalent throughout rural portions of the study area. The areas served by sanitary sewers are in the cities along the Ohio River like South Point, Burlington, Chesapeake, Proctorville, Crown City, and Gallipolis and in Symmes Creek the city of Oak Hill. The village of Athalia is served by HSTSs. All other areas within the study area are served by HSTSs.

The Oak Hill WWTP had numerous effluent violations and sanitary sewer overflows before and during the 2016 survey due to poor sanitary sewer maintenance and WWTP maintenance and up-keep (Table 6, Table 7 and Appendix L). A Notice of Violation (NOV) was issued by Ohio EPA in 2015 and another in 2016 concluding that the Village had not reported SSOs, had no SSO response plan, needed a Class II operator, had numerous unresolved permit violations and did not maintain the wastewater treatment plant and sewer system properly.

After the second NOV in 2016, the Village of Oak Hill eliminated numerous clean water connections, found and repaired a significant sewer line collapse and rehabilitated a sewer line which resulted in much fewer SSOs. Additionally, the operator of the Oak Hill WWTP received his Class II license and the Village developed an SSO response plan which provided details of sewer work and I/I plans. In 2018, the Village of Oak Hill received a loan from Ohio EPA Office of Financial Assistance (DEFA) through the Water Pollution Control Loan Fund (WPCLF) and completed a major upgrade and unit replacement of the WWTP.

Table 6—Oak Hill sewage treatment plant (STP) permit limit compliance.

Permit No	Reporting Period	Station	Parameter	Limit Type*	Limit	Reported Value	Violation Date
0PB00055*HD	March 2014	001	pH	1D Conc	6.5	6.48	3/18/2014
0PB00055*HD	August 2014	001	TSS	7D Conc	18	19	8/8/2014
0PB00055*HD	August 2014	001	TSS	7D Qty	20.4	39.451	8/8/2014
0PB00055*HD	December 2014	001	TSS	7D Qty	34.1	43.515	12/22/2014
0PB00055*HD	January 2015	001	TSS	7D Conc	30	30.5	1/22/2015
0PB00055*HD	March 2015	001	TSS	30D Qty	22.7	38.7631	3/1/2015
0PB00055*HD	March 2015	001	TSS	7D Qty	34.1	44.1944	3/1/2015
0PB00055*HD	March 2015	001	TSS	7D Conc	30	36	3/8/2015
0PB00055*HD	March 2015	001	TSS	7D Qty	34.1	99.9467	3/8/2015
0PB00055*HD	March 2015	001	$CBOD_5$	7D Qty	26.1	27.5449	3/8/2015
0PB00055*HD	December 2015	001	TSS	7D Conc	30	35.8	12/1/2015
0PB00055*HD	December 2015	001	TSS	7D Qty	34.1	83.5765	12/1/2015
0PB00055*HD	February 2016	001	TSS	30D Conc	20	34.025	2/1/2016
0PB00055*HD	February 2016	001	TSS	30D Qty	22.7	79.4948	2/1/2016
0PB00055*HD	February 2016	001	TSS	7D Qty	34.1	40.5373	2/1/2016

Permit No	Reporting Period	Station	Parameter	Limit Type*	Limit	Reported Value	Violation Date
0PB00055*HD	February 2016	001	$CBOD_5$	30D Qty	17	29.3924	2/1/2016
0PB00055*HD	February 2016	001	TSS	7D Conc	30	98.5	2/15/2016
0PB00055*HD	February 2016	001	TSS	7D Qty	34.1	243.812	2/15/2016
0PB00055*HD	February 2016	001	$CBOD_5$	7D Conc	23	33	2/15/2016
0PB00055*HD	February 2016	001	$CBOD_5$	7D Qty	26.1	81.5402	2/15/2016
0PB00055*HD	August 2016	001	$CBOD_5$	7D Conc	15	16.5	8/8/2016

*concentration units are mg/L and quantity (loading) units are kg/day.

Table 7—Oak Hill STP sanitary sewer overflow monitoring for station 300.

Date	Amount (gallons)	Cause	Stream	Resolved
6/26/2015	5,000	Extreme weather	Drainage Ditch	Yes
7/8/2015	2,000	Extreme weather	Drainage Ditch	Yes
9/29/2015	5,000	Extreme weather	Drainage Ditch	Yes
12/1/2015	2,000	Extreme weather	Drainage Ditch	Yes
2/2/2016	20,000	Extreme weather	Drainage Ditch	Yes
2/15/2016	30,000	Extreme weather	Drainage Ditch	Yes
3/11/2016	5,000	Blockage-grease	Drainage Ditch	yes
3/14/2016	1,000	Extreme weather	Drainage Ditch	Yes
6/23/2016	4,000	Extreme weather	Drainage Ditch	Yes

Mineral Extraction

There are approximately 24,770 acres of surface mines in the Symmes Creek and Indian Guyan Creek watersheds. Surface mining of coal in Jackson County began in 1917 while underground mining of coal began in 1820s. There are numerous small underground coal and clay mines in the Symmes Creek watershed in both Lawrence and Jackson counties. These mines were above drainage with drift mine entries. Large scale surface mining began the 1960s and 1970s in Symmes Creek watershed. Prior to 1972, Ohio had few laws regulating surface mining resulting in extensive abandoned and unreclaimed mine lands (ODNR, 2011). In 1972, Ohio passed a revised Strip Coal Mining Act that was the strongest surface mining law in the nation. Under the law, the land had to be returned to approximate pre-mining contours with replacement of topsoil and vegetation. In 1977, a federal law, the Surface Mining Control and Reclamation Act (SMCRA), was enacted to require all surfaces mines in the nation to meet certain reclamation standards. Title IV of SMCRA established a federal grant program to fund abandoned mine reclamation.

Abandoned surface coal mines deforested land, filled stream valleys with overburden, eliminated headwater streams, removed hilltops, and often left behind large piles of coal waste (gob and/or refuse), highwalls and slurry impoundments. These abandoned surface mines along with deforestation and stream channelization are the source of vast quantities of sediment found in upper Symmes Creek and Sand Fork. In 1967, it was estimated that runoff and seepage from 1,700 acres of unreclaimed or poorly reclaimed surface coal mines contributed a major portion of the AMD in the Symmes Creek watershed. Before reclamation, abandoned coal refuse piles leached thousands of pounds of sulfuric acid and metals into the creeks daily, significantly degrading the water quality of the streams.

Sand Fork of Symmes Creek, Little Indian Guyan and tributaries to Indian Guyan Creek on the northwest portion of the creek had approximately 2000 acres of Pomeroy #8A coal strip mined. The coal had the Pomeroy Sandstone and the Upper Pittsburg Sandstone was above the Pomeroy #8A coal. The Pomeroy Sandstone is easily eroded once exposed to weather and averages 18 feet thick (Norling, 1958). NRCS estimates that the Pomeroy sandstone erodes at up to 500 tons per year per acres of sediment loss (Farley, 2018). Pre-law surface mining in this area is the primary cause of the heavy sand bedload in Sand Fork and Indian Guyan Creek.

The Cambria Creek watershed had numerous drift underground room and pillar coal mines. Most of the mining occurred in the 1930s and 1940s with one operation starting in the 1920s. These mines extracted the # 4, # 5 and # 6 coal seams and as well as limestone and clay. In the 1990s large surface mining operations occurred in the Cambria Creek watershed and again mining the # 4, #5 and # 6 coal seams.

From the 1970s through today, shale, clay, coal and limestone have been extracted within the same mining operation with clay and limestone being the predominate mineral mined. Over 2,000 acres of mineral mining has occurred in Symmes Creek watershed. The mined limestone is used mostly for construction activities while the clay is mined to make a raw specialty material for products ranging from clay tiles and bricks, sanitary and electrical porcelain ware, to foundry clays and hobby ceramics.

Iron Furnaces

Seven charcoal iron furnaces were once operational in the Symmes Creek watershed (Figure 6). The Hanging Rock Iron Region of Ohio helped initiate Ohio into becoming an industrial state. The Jefferson Furnace near Oak Hill was operational from 1836 to 1916, while the Oak Ridge Furnace, north of Aid lasted only two years. Sandstone from the surrounding hills was used to build the furnaces. Iron furnaces required 300 to 350 acres of timber for one year's blast (SCRC, 2000) along with iron ore and limestone. Iron production at the furnaces was very resource intensive requiring as many as 500 men to gather raw materials, operate the furnace and ship the finished product. The typical furnace required more than 325 acres of virgin timber (or 13,000 cords of wood), for charcoal production, to operate for one year (Marple, 1954). This meant vast areas within Symmes Creek were clear cut for charcoal production. Additionally, some areas were logged 3 or 4 times resulting in massive erosion and sedimentation in the surrounding streams. A furnace needed about 5,000 pounds of iron ore which was mined along ridgetop deposits and 300 pounds of limestone for one year of iron production resulting in even more land disturbance and erosion.

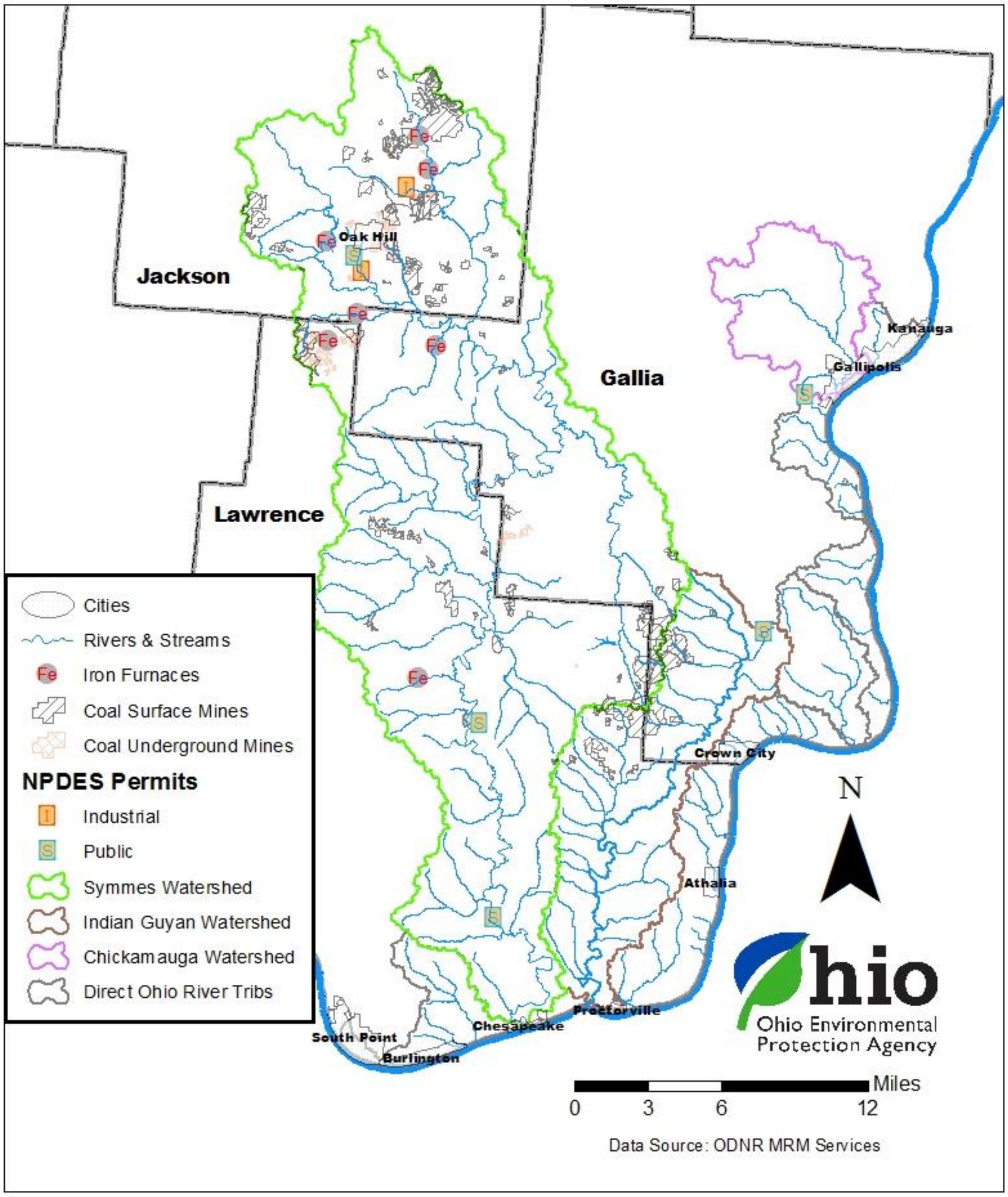


Figure 6—Iron furnaces, coal mining and NPDES facilities within the study area.

Results

Water Chemistry

Surface water chemistry samples were collected from 37 streams (59 locations) in the Symmes Creek watershed, 19 streams (28 locations) in the Indian Guyan Creek watershed and 16 additional Ohio River tributaries in Gallia and Lawrence counties from June 2016 through October 2016. Monthly samples were also collected from ten sentinel locations from March 2016 to February 2017 (Table 2 and Appendix H). Stations were established in free-flowing sections of the stream and were primarily collected from bridge crossings. Surface water samples were collected directly into appropriate containers, preserved, and delivered to Ohio EPA's Division of Environmental Services (DES) laboratory. Collected water was preserved using appropriate methods, as outlined in the Surface Water Field Sampling Manual (for water quality parameters and flows) (Ohio EPA, Surface Water Field Sampling Manual for water quality and flows, 2015). Lake sampling occurred during the 2016 survey in Timbre Ridge Lake and Jackson Lake (See Lakes writeup in Appendix M). Additional chemistry samples were collected from the Oak Hill WWTP (Appendix L).

Data from a USGS gage station in Symmes Creek at the town of Aid was used to show flow trends in the Symmes Creek and Indian Guyan Creek watersheds for the 2016-2017 survey (Figure 9). During the early summer months, flow conditions in Symmes Creek were often elevated above the historic median flows due to rain events but typically remained below the historical median flows from August to December 2016. Chemistry samples were typically collected during low flow conditions; however, a few samples were collected during or after rain events when flows exceeded the historic median flows.

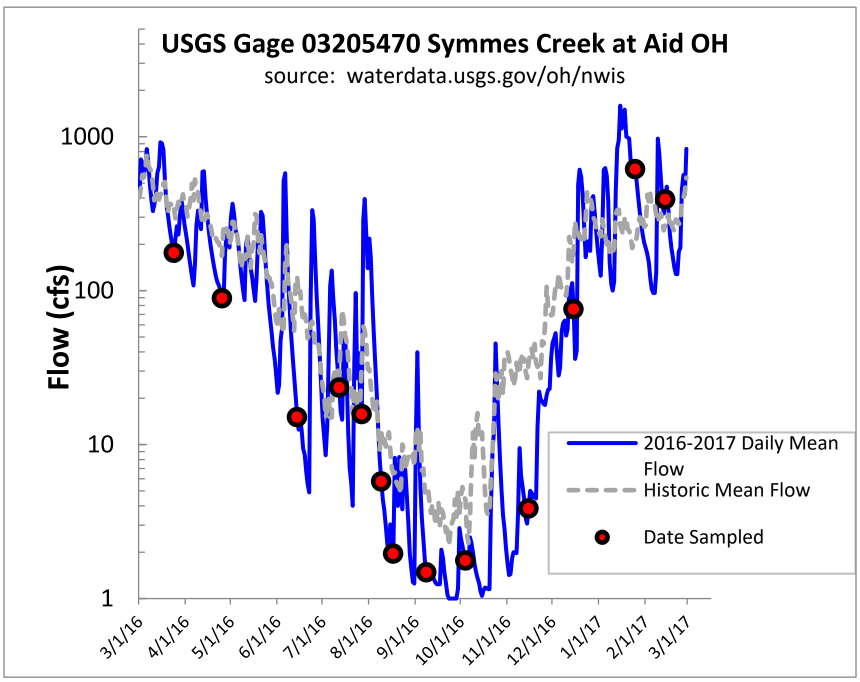


Figure 7 – Flow conditions measured from the USGS gage station on Symmes Creek at the town of Aid, OH during the 2016-2017 Symmes Creek survey with chemistry samples dates indicated on the plot.

Surface water samples were analyzed for metals, nutrients, bromide, total suspended solids (TSS), total dissolved solids (TDS), Escherichia coli (*E. coli*) bacteria, pH, temperature (°C), specific conductance (µmhos/cm), DO (mg/L), and percent DO saturation (Appendix H). Parameters which exceeded the chemical criteria in the Ohio WQS are reported in Table 9. A summary of the stream bacteria results can be found in the Recreation Use section and the full results are in Appendix K. The bacteria results for the lake samples are in Appendix M.

Water quality sondes were deployed at a subset of the chemistry sites to monitor temperature, D.O., pH, and specific conductance (conductivity). Temperature, DO, and pH are influenced by diel (24-hour) patterns. These diel patterns have the greatest impact on streams during critical stable, low streamflow conditions. Specific conductance is not influenced by the same diel triggers but is monitored because it is a strong indicator of changes in streamflow as well as mine drainage. The water quality sondes collect readings hourly to monitor these parameters throughout the diel cycle. Grab readings differ because they only represent one point on the diel cycle. While they are effective at characterizing water quality parameters that change based on hydrologic regime or season, they can miss or not fully characterize parameters that exhibit diel patterns.

Diel patterns in temperature reflect air temperature, solar radiation, base flow (groundwater), discharge, and shading. In general, diel fluctuations in temperature increase as base flow, discharge, and shading decrease. The inverse is also true.

DO responds in a similar diel pattern to temperature, as it is affected by similar factors. In addition, DO trends are directly dependent on temperature. At high temperatures, the solubility of oxygen in water decreases, resulting in an inverse relationship. Without the influence of other environmental conditions, this would cause the two parameters to follow opposite trends. However, the DO produced by photosynthesis is, in most instances, enough to overwhelm the inverse relationship causing the trends to follow similar trajectories. Increasing diel fluctuation relates to an increase in productivity, resulting in DO reaching super saturation during the day with subsequent depletion by respiration at night. The result is a diel trend that typically reaches a maximum in the early evening and a minimum preceding sunrise. In some cases, DO does not exhibit strong diel trends in low flow, warm conditions. Either primary productivity is limited or decomposition of organic matter in the stream is controlling the DO concentrations. Diel monitoring helps to identify DO trends that are more influenced by primary productivity or decomposition.

Stream pH is generally controlled by the local geology that determines the natural alkalinity and acidity of the system. However, diel patterns in pH result as a function of primary productivity. Carbon dioxide, which dissolves in water to form carbonic acid, lower pH at night, then is consumed during photosynthesis, raising the pH of the stream. The result is a maximum pH value observed at a similar time to the maximum DO.

Twenty-five sites were sampled with water quality sondes to represent the general watershed area as well as target areas of concern (i.e. point sources).

Critical conditions for temperature and DO are times when flows are low, temperatures are high, and daylight is long. These are the times that streams are most sensitive to organic and nutrient enrichment. To capture these conditions, sondes are typically deployed during low-flow conditions from June to September. Two deployments occurred in the Symmes Creek and Indian Guyan Creek watersheds. The first deployment occurred at 25 locations from July 26-28, 2016 and the second deployment occurred at 18 locations from August 17-19, 2016. Figure 8 shows these dates relative to the streamflow. Flows were at or below normal in both surveys, representing summer, low flow conditions. The average air temperatures were above normal during much of the summer which is an important component of the critical conditions. Summary plots of all data collected are included in Appendix J.

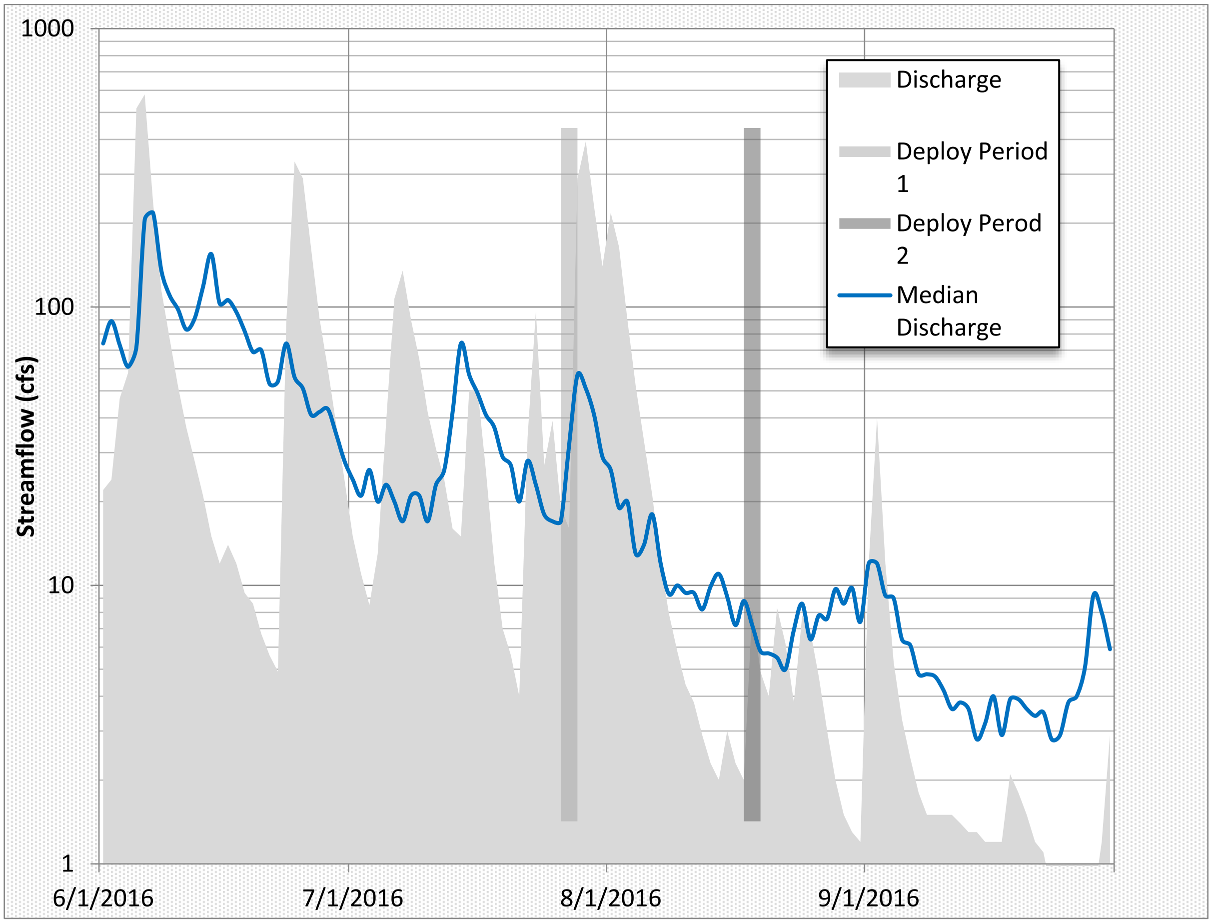


Figure 8—Daily average flow conditions in Symmes Creek at the USGS gage (Symmes Creek at Aid OH) relative to the median streamflow for the 2016 summer sampling season. Water quality sonde deployment are indicated on the plot.

Symmes Creek

The mainstem of Symmes Creek is a naturally low gradient stream with numerous wetlands located in the headwaters. Dissolved oxygen levels were often below the minimum water quality standard throughout the summer (see Table 9 and Table 10), however this did not impact the biological community which was fully attaining the existing WWH aquatic life use from the headwaters to Black Fork and the recommended aquatic life use of EWH from Black Fork to the mouth (Table 1). No other water quality exceedances occurred on the mainstem of Symmes Creek (Table 9).

Mining impacts occurred in the headwaters of the Symmes Creek watershed in Jackson county and in the Sand Fork sub-watershed in Gallia and Lawrence counties (Figure 6). Unreclaimed or poorly reclaimed surface mines continue to discharge mine drainage to several tributaries including Dicks Creek, Hewitt Run, Black Fork, Huntingcamp Creek and Sand Fork (

Table 8). The discharge is typically non-acidic mine drainage or alkaline mine drainage characterized by high conductivity, metals and total dissolved solids but also a neutral to alkaline pH (7-9 SU). Acid mine drainage is extremely detrimental to the aquatic community because pH is often below 6.5 SU creating an inhospitable and often toxic environment. Because the pH tends to be neutral to alkaline with non-acidic mine drainage, the impacts to aquatic life is not as harmful. Elevated levels of specific conductivity, sulfates, TDS, and manganese and magnesium were found in the headwaters of Symmes Creek at RMs 70 and 62.7 but decreased significantly downstream (Figure 11,

Table 8). The Sand Fork sub-watershed had the highest specific conductivity, sulfate, manganese and WQS violations of TDS (

Table 8, Table 9). The most upstream location of Sand Fork is impacted by both mine drainage and a heavy sand bedload from historic logging and mining. The mine discharge to Dicks Creek tended to be acidic mine drainage with high levels of acidity, specific conductivity, aluminum, iron, manganese and magnesium and pH levels below 6.5 SU (

Table 8, Table 9).

Tributaries to Symmes Creek that had dissolved oxygen levels below the minimum water quality standard include Black Fork, Hewitt Run, Huntingcamp Creek, Cambria Creek, Dirtyface Creek, Miller Creek, Pigeon Creek, Buck Creek, Long Creek, Aaron Creek, Sharps Creek, Rankin Creek and Big Branch Creek. The lowest DO averages occurred on Black Fork below the Jackson Lake spillway (3.12 mg/L) and Huntingcamp Creek below the Oak Hill WWTP (3.81 mg/L). Similar to Symmes Creek, Black Fork is a low gradient wetland stream. However, the discharge from the spillway seems to have an additional stress causing non-attainment of the ALU for both fish and macroinvertebrates. In addition to the DO exceedances, Huntingcamp Creek below the Oak Hill WWTP also had a water quality standard exceedance for ammonia (7.95 mg/L) and the highest

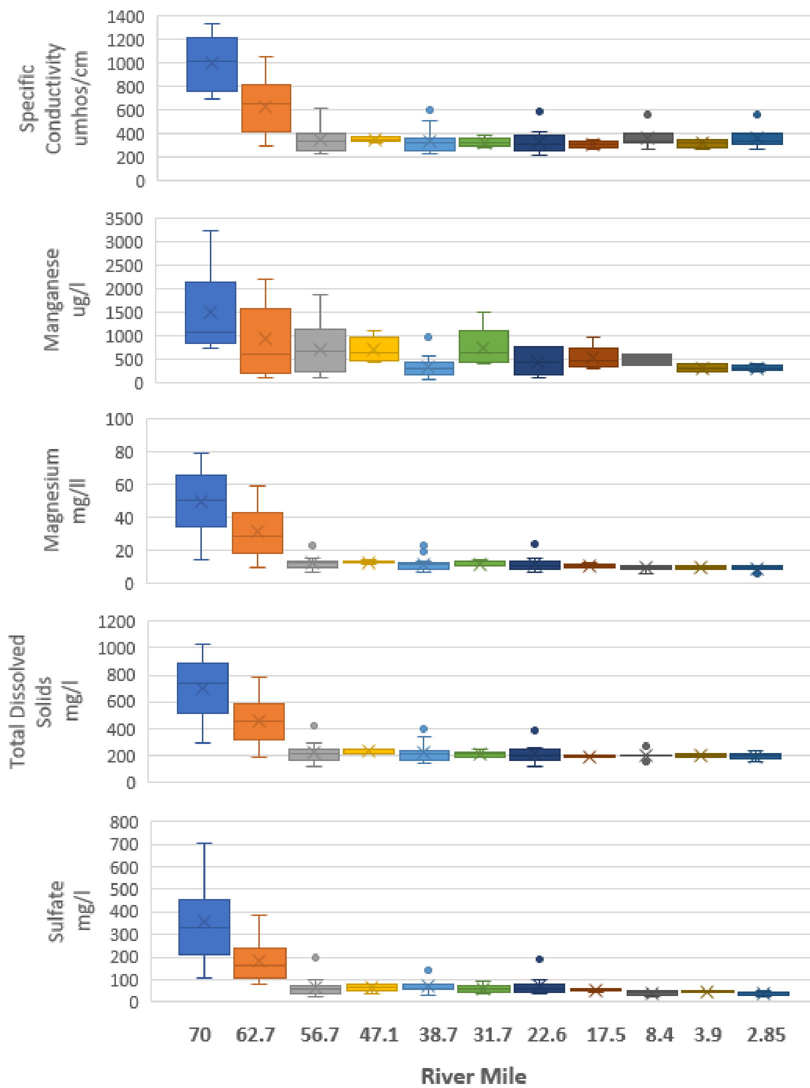


Figure 9 – Box and whisker plots of parameters associated with mine drainage sampled in the mainstem of Symmes Creek from the headwaters (RM 70) to the Ohio River (RM 2.85)

levels of nutrients including total phosphorus (average=1.7mg/L, maximum=2.05mg/L) TKN (average = 1.57mg/L, maximum =8.17 mg/L, and nitrate+nitrite-N (average = 8.22mg/L, maximum = 14.5mg/L). The discharge from the Oak Hill WWTP is the major cause of non-attainment of the ALU for both fish and macroinvertebrates. Temperature exceedances occurred throughout the summer at Buck Creek but did not impact the biological community which ranged from very good to exceptional.

Table 8—Summary statistics for select mining parameters sampled in the Symmes Creek watershed, 2016. The 90th percentile values from reference sites from the WAP ecoregion is shown for comparison at the bottom of the table. Values above the reference conditions are shaded. RM is River Mile and DA is Drainage Area.

Station	Station Name	RM	DA	Sp. Cond.	Iron	Mg	Mn	TDS	Sulfate
303584	SYMMES CREEK @ VEGA AND C-H-D RD.	**70**	14.8	1005	634	50	1505	696	355
300158	SYMMES CREEK @ JENKINS ALBEN RD. (TWP. RD. 102)	**62.7**	39.4	632	2113	130	899	457	181
200754	SYMMES CREEK DST COAL BRANCH @ SYMMES CREEK RD.	**56.7**	125	347	1644	99	683	223	65
200753	SYMMES CREEK AT CADMUS @ ST. RT. 141	**47.1**	182	352	875	13	708	237	65
303500	SYMMES CREEK AT WATERLOO-MT VERNON RD	**38.7**	201.9	338	2145	145	357	225	74
303533	SYMMES CREEK AT SR 141 AT ARABIA	**31.7**	255.3	326	1108	11	732	213	60
300151	SYMMES CREEK AT AID @ ST. RT. 141	**22.6**	300	332	2705	143	482	215	71
303534	SYMMES CREEK SR 217 @ LINNVILLE	**17.5**	313.2	310	1428	10	522	195	53
200746	SYMMES CREEK E OF GETAWAY, ADJ. S.R. 243, DST MCKINNEY CREEK	**8.4**	346	366	1552	9	508	206	40
303768	SYMMES CREEK ADJ. EATON ROAD (CO. RD. 32) UST SKY LAKE	**3.9**	349.5	316	1088	10	305	203	47
303535	SYMMES CREEK @ CR104 BOOTHE EATON RD N OF CHESAPEAKE	**2.85**	350.5	362	1633	9	306	197	38
303577	TRIB. TO SYMMES CREEK (73.07) @ C,H & D RD.	**0.1**	5.7	340	906	11	4534	234	49
303637	SWEETBIT CREEK @ PUMPKINTOWN RD	**0.3**	2	187	1090	8	642	127	8
303540	BIG BRANCH CREEK @ HENSON HOLLOW RD (CO. RD. 158)	**0.55**	3	411	99	11	152	243	36
303544	MCKINNEY CREEK @ ST. RT. 243	**0.35**	5	338	665	10	516	205	35
303545	RANKIN CREEK @ PRIVATE DRIVE OFF RANKINS CREEK RD.	**0.55**	3.9	294	695	8	382	179	27
200747	LEATHERWOOD CREEK NW OF GETAWAY @ ST. RT. 243	**0.8**	4	418	216	10	201	252	36
303546	VENISONHAM CREEK @ ST. RT. 217	**0.95**	3.9	320	237	8	163	190	30
303547	SHARPS CREEK NEAR MOUTH	**0.2**	4.6	314	946	10	447	204	61
303548	ELKINS CREEK @ NATIONAL FOREST PULLOFF ADJ. ELKINS CREEK RD.	**1.8**	3.3	284	89	8	37	173	34
303549	AARON CREEK @ ELKINS CREEK RD.	**0.65**	8.3	407	326	15	165	262	91
303551	LONG CREEK @ ST. RT. 775	**4.3**	5.3	448	637	10	410	267	47

Station	Station Name	RM	DA	Sp. Cond.	Iron	Mg	Mn	TDS	Sulfate
303536	LONG CREEK AT ZALMON RD SE OF ARABIA	**0.86**	14.7	346	900	8	311	203	33
303550	BUCKEYE CREEK (TRIB TO LONG) @ ST. RT. 775	**0.9**	3.8	381	289	8	397	224	36
303552	BUCK CREEK @ ST. RT. 141	**0.35**	5	415	393	10	328	234	30
303557	JOHNS CREEK @ ETNA-WATERLOO RD.	**5.35**	9.4	228	442	7	430	136	21
300153	JOHNS CREEK S OF WATERLOO @ ST. RT. 141	**0.07**	22.7	228	3457	224	277	137	37
303555	BUCKEYE CREEK (TRIB. TO JOHNS. CK.) ADJ. BUCKEYE RD.	**1.45**	3.4	212	438	7	292	131	28
303554	BRUSHY BUCKEYE CREEK @ BUCKEYE RD.	**0.1**	1.9	208	444	7	266	130	28
303556	SLAB FORK @ ETNA-WATERLOO RD.	**0.1**	2.6	192	152	6	150	116	21
303558	PIGEON CREEK @ WEBSTER RD.	**0.55**	3.2	271	251	7	659	166	23
200752	BUFFALO CREEK ADJ. BUFFALO OLIVE RD. DST. INDIAN CK.	**5**	3.1	198	174	6	99	116	18
W02S09	BUFFALO CREEK @ CO. RD. 14	**1.91**	8.5	198	1079	6	358	126	13
W02S01	CAULLEY CREEK NEAR MOUTH @ CO. RD. 14	**0.15**	4.9	192	917	7	192	119	19
303559	MILLER CREEK @ CAULLEY CREEK RD.	**0.05**	1	138	114	5	79	91	22
303562	LITTLE BUFFALO CREEK @ CARPENTER RD. (TWP. 182)	**1.2**	2.6	130	266	5	175	94	24
303563	CAMP CREEK @ PENIEL RD.	**0.65**	4.5	271	933	8	413	157	26
303564	TRACE CREEK @ PRIVATE DRIVE OFF ST. RT. 141	**0.55**	2.7	562	840	9	1115	312	18
303569	SAND FORK @ PALESTINE-OKEY CHURCH RD. (TWP. 217)	**15.1**	3	1670	349	93	2432	1548	990
303568	SAND FORK @ DRIVE TO TIMBER RIDGE LAKE	**14.85**	8.9	1167	356	59	1250	1028	617
301798	SAND FORK AT LECTA @ ST. RT. 775	**13.4**	13.8	821	1635	154	721	657	397
303567	SAND FORK @ PETERS CAVE RD.	**10.25**	28.3	761	300	33	863	589	331
300154	SAND FORK @ PATRIOT-CADMUS RD.	**2.7**	40.4	532	1906	172	338	373	186
303566	TRIB. TO SAND FORK @ PULLOFF ADJ. PALESTINE-OKEY CHURCH RD.	**0.35**	3.5	345	646	10	671	226	93
303565	PETERS CAVE CREEK ADJ. PETERS CAVE RD.	**0.2**	5.2	316	324	9	197	183	53
303570	WOLF RUN @ SYMMES CREEK RD.	**0.1**	0.9	293	489	7	336	185	18
303576	BLACK FORK SYMMES CREEK DST. JACKSON LAKE SPILLWAY	**11.05**	18.7	265	766	9	1418	157	31
W02S02	BLACK FORK SYMMES CREEK S OF OAK HILL @ BLACKFORK RD.	**5.77**	28.3	434	284	12	541	273	52
303501	BLACK FORK @ ST. RT. 233 N.OF GALLIA	**2.4**	47.6	325	1656	97	442	203	53
303575	BLACK FORK SYMMES CREEK @ CANOE LAUNCH OFF GALLIA RD.	**0.3**	62.6	273	769	8	494	175	26
303571	DIRTYFACE CREEK ADJ. C,H & D RD. NEAR PIPELINE CROSSING	**4.7**	3	216	1322	6	738	134	12
300156	DIRTYFACE CREEK @ CH & D RD.	**1.82**	12	154	2726	86	702	109	12

Station	Station Name	RM	DA	Sp. Cond.	Iron	Mg	Mn	TDS	Sulfate
303572	CLEAR FORK @ SHAFER RD.	**0.7**	3.1	206	2280	4	2236	140	18
303573	DICKS CREEK @ SARDIS RD.	**0.3**	3	495	2700	18	2295	360	166
303574	CAMBRIA CREEK (A.K.A. LEFTHAND FORK) @ POTTS RD.	**1.65**	7.2	292	723	8	250	190	41
W02S06	HUNTINGCAMP CREEK JUST UPST. OAK HILL WWTP	**1.71**	1.8	1238	744	49	485	950	453
W02S03	HUNTINGCAMP CREEK DST. OAK HILL WWTP @ DICKENS RD.	**1.2**	2.4	1010	349	24	606	652	183
303636	HEWITT RUN @ FRANKLIN VALLEY RD.	**0.75**	4.6	763	675	39	856	556	266
90th% Reference target value									
Small River: 200-1000 sq mi				**900**	**1982**	**34.6**	**1209**	**665**	**269.1**
Wading 20-200 sq mi				**800**	**1820**	**25**	**610**	**570**	**241.6**
Headwaters: <20 sq. mi				**789**	**1266**	**35**	**379**	**957**	**258.6**

Indian Guyan Creek and Direct Ohio River Tributaries

Dissolved oxygen levels fell below the minimum water quality standard in Slate Run toward the end of the summer (09/08/16) when flows were extremely low in the watershed (Table 9). Average ammonia values were 0.095 mg/L which exceeded the 90th percentile reference value of 0.06 mg/L for headwater streams in the WAP ecoregion (Ohio EPA, 1999). Staff also observed algal production at Slate Run and gray water associated with failing home septic systems.

DO levels also fell below minimum WQS due to low flows in several direct Ohio River tributaries including Scarey Creek, Paddy Creek, Federal Creek, Clean Fork, Chickamauga Creek and Little Chickamauga Creek.

Localized flooding occurred in Swan Creek and other watersheds south of Aid during the week of August 17, 2016 but the low flows recorded at the Symmes Creek gage station in Aid did not reflect the high flows that these southern watersheds experienced. Samples collected during this flood event resulted in water quality exceedances in Swan Creek for iron, barium, copper, lead, and zinc (Table 9). Indian Guyan Creek also experienced high flows and had water quality exceedances on August 17, 2016 for iron and barium. Little Indian Guyan Creek had a water quality exceedance for iron on this date as well. During flood events, streams often have elevated total suspended solids which can increase the concentration of metals, nutrients and bacteria in the water column. During low flow conditions, Indian Guyan Creek, Little Indian Guyan Creek, and Swan Creek had no water quality exceedances and the biological community ranged from very good to exceptional indicating that these localized flooding events had little impact to the streams.

Surface mining occurred in the headwaters of Little Indian Guyan Creek and tributaries to Little Indian Guyan Creek including Garland Creek, Watson Creek, and Williams Creek (Figure 6). Much of the mining was small scale and was not currently impacting Little Indian Guyan Creek, Watson Creek, and Williams Creek, with good to exceptional biological communities. Garland Creek was impacted by mine drainage with numerous indicators including TDS water quality exceedances (Table 9) as well as elevated levels of sulfates, strontium and high conductivity.

Table 9—Exceedances of Ohio EPA WQS criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the Symmes Creek, Indian Guyan Creek and direct Ohio River tributary study area, 2016.

Water parameters are assessed based on water quality criteria for the existing or recommended-R Aquatic Life Use designations. Please refer to Beneficial Use Designations and Recommendations within this report for details about use recommendations.

Stream (River Code) *use designation*[a]				Parameter (Units for DO, ammonia and TDS is mg/L, Temp is °C , pH is SU, and all other parameters are µg/l)
Station	**Location**	**RM**	**DA (MI²)**	
Symmes Creek (09-700-000) *WWH*				
303584	Vega and C-H-D Rd.	70.00	14.8	DO (2.3)‡‡
300158	Jenkins Alben Road	62.76	39.4	DO (3.85, 3.89,3.41 1.75)‡‡
Symmes Creek (09-700-000) *EWH-R*				
200754	Symmes Cr. Road	56.70	125.0	DO (4.9, 4.68, 4.8, 3.37, 4.62, 4.9)‡‡
200753	Cadmus at St. Rt. 141	47.10	182.0	DO (4.93)‡‡
303500	Waterloo-Mt Vernon Rd.	38.70	201.9	DO (4.81, 3.68, 4.67)‡‡
303533	Arabia at SR 141	31.70	255.3	DO (3.71,4.24)‡‡
300151	Aid at SR 141	22.60	300.0	DO (4.79,4.19,4.02,4.56)‡‡
303534	Linnville adj. SR 217	17.53	313.2	DO (4.59)‡‡
200746	E. of Getaway, Adj. SR 243	8.40	346.0	none
303768	Adj. Eaton Rd.	3.90	349.5	none
303535	CR 104 Boothe Eaton Rd	2.85	350.5	DO (4.77, 4.1)‡‡
Trib. to Symmes Creek (RM 73.03) (09-700-001) *WWH-R*				
303577	C-H & D Road	0.10	5.7	none
Black Fork (09-730-000) *WWH*				
303576	Dst. Jackson Lake Spillway	11.00	18.7	DO (2.9, 2.7 5, 3.9, 3.26, 1.74)‡‡
W02S02	S. of Oak Hill at Blackfork Rd.	5.77	28.3	none
303501	N. of Gallia at St. Rt. 233	2.40	47.6	DO (3.84)‡‡
Black Fork (09-730-000) *EWH*				
303575	Canoe launch off Gallia Rd.	0.30	62.6	DO (4.22) ‡‡
Hewitt Run (09-738-000) *WWH*				
303636	Franklin Valley Rd.	0.75	4.6	DO (3.38)‡‡
Huntingcamp Creek (09-735-000) *WWH*				
W02S06	Upstream Oak Hill WWTP	1.71	1.8	none
W02S03	Downstream Oak Hill WWTP	1.20	2.4	DO (2.87, 1.34, 3.1, 3.48, 3.92)‡‡ Ammonia (7.95)*
Cambria Creek (A.K.A. Lefthand Fork) (09-734-000) *WWH*				
303574	Potts Road	1.65	7.2	DO (3.56)‡‡
Dicks Creek (09-733-000) *WWH*				
303573	Sardis Road	0.30	3.0	Iron (5390)∞ DO (3.7) ‡‡ pH (6.48, 5.7)∆
Clear Fork (09-732-000) *WWH*				
303572	Shafer Road	0.30	3.1	Iron (5400)∞
Dirtyface Creek (09-731-000) *EWH*				
303571	Adj. C-H-D Rd. near pipeline crossing	4.70	3.0	DO (4.93, 4.24) ‡‡
Dirtyface Creek (09-731-000) *WWH*				
300156	C-H & D Road	1.82	120	DO (2.92)‡‡

Station	Location	RM	DA (MI^2)	Parameter (Units for DO, ammonia and TDS is mg/L, Temp is °C , pH is SU, and all other parameters are µg/l)
Stream (River Code) *use designation*[a]				
Sweetbit Creek (09-700-003) *WWH-R*				
303637	Pumpkintown Road	0.30	2.0	none
Wolf Run (09-729-000) *WWH*				
303570	Symmes Creek Road	0.10	0.9	none
Sand Fork (09-727-000) *WWH*				
303569	Palestine-Okey Church Rd.	15.10	3.0	TDS (2030, 1840)*
303568	Drive to Timber Ridge Lake	14.85	8.9	TDS (1970, 1640)*
301798	Lecta at St. Rt. 775	13.40	13.8	none
303567	Peters Cave Rd.	10.25	28.3	none
Sand Fork (09-727-000) *EWH-R*				
300154	Patriot-Cadmus Rd.	2.70	40.4	none
Tributary to Sand Fork (09-727-002) *Undesignated*				
303566	Adj Palestine-Okey Church Rd	0.35	3.5	none
Peters Cave Creek (09-728-000) *WWH*				
303565	Adj. Peters Cave Rd.	0.20	5.2	none
Trace Creek (09-726-000) *WWH*				
303564	Private drive off St. Rt. 141	0.55	2.7	none
Camp Creek (09-725-000) *WWH*				
303563	Peniel Rd.	0.65	4.5	none
Little Buffalo Creek (09-724-000) EWH & *-CWH-R*				
303562	Carpenter Rd. TR 182	1.20	2.6	none
Buffalo Creek (09-719-000) *WWH*				
200752	Adj. Buffalo-Olive Rd., dst. Indian Creek	5.00	3.1	none
Buffalo Creek (09-719-000) *EWH-R*				
W02S09	Co. Rd. 14	1.91	8.5	none
Caulley Creek (09-720-000) *EWH-R*				
W02S01	Near mouth at Co. Rd. 14	0.15	4.9	none
Miller Creek (09-721-000) *CWH-R*				
303559	Caulley Creek Rd.	0.05	1.0	DO (4.42)‡‡
Pigeon Creek (09-718-000) *WWH*				
303558	Webster Rd.	0.55	3.2	DO (3.42)‡‡
Johns Creek (09-714-000) *WWH*				
303557	Etna-Waterloo Rd.	5.35	9.4	none
300153	S. of Waterloo at St. Rt. 141	0.07	22.7	none
Slab Fork (09-717-000) *EWH-R*				
303556	Etna-Waterloo Rd.	0.10	2.6	none
Buckeye Creek (Trib to Johns Creek) (09-715-000) *WWH*				
303555	Buckeye Rd.	1.40	3.4	none
Brushy Buckeye Creek (09-716-000) *WWH*				
303554	Buckeye Rd.	0.10	1.9	none
Buck Creek (09-713-000) *EWH-R*				
303552	St. Rt. 141	0.35	5.0	Temperature (30.01, 29.68, 31.21, 30.37)** DO (3.43)‡‡

Stream (River Code) *use designation*[a]				Parameter (Units for DO, ammonia and TDS is mg/L, Temp is °C , pH is SU, and all other parameters are µg/l)
Station	**Location**	**RM**	**DA (MI²)**	
Long Creek (09-711-000) *WWH*				
303551	St. Rt. 775	4.30	5.3	DO (3.03)[‡‡]
303536	S.E. of Arabia at Zalmon Rd.	0.86	14.7	none
Buckeye Creek (Trib to Long Creek) (09-712-000) *EWH-R*				
303550	St. Rt. 775	0.90	3.8	none
Aaron Creek (09-710-000) *WWH*				
303549	Elkins Creek Rd.	0.65	8.3	DO (3.3)[‡‡]
Elkins Creek (09-709-000) *WWH*				
303548	National Forest pull-off adj. Elkins Creek Rd.	1.80	3.3	none
Sharps Creek (09-708-000) *EWH-R*				
303547	Near mouth	0.20	4.6	DO (4.16)[‡‡]
Venisonham Creek (09-705-000) *WWH*				
303546	St. Rt. 217	0.95	3.9	none
Leatherwood Creek (09-704-000) *WWH*				
200747	N.W. of Getaway at St. Rt. 243	0.80	4.0	none
Rankin Creek (09-703-000) *EWH-R*				
303545	Private drive adj. Rankin Cr Rd	0.55	3.9	DO (4.5)[‡‡]
McKinney Creek (09-702-000) *WWH*				
303544	St. Rt. 243	0.35	5.0	none
Big Branch Creek (09-701-000) *WWH*				
303540	Henson Hollow Rd. CR 158	0.55	3.0	DO (3.62)[‡‡]
Indian Guyan Creek (09-100-000) *EWH-R*				
303663	Mercerville Rd.	29.05	5.20	Lead (43.4)*
W02K05	N. of Crown City adj. St. Rt. 218	26.40	16.00	none
303539	Shoal Creek Rd.	21.70	25.40	none
W02K04	CR 67 Scottown covered br.	14.70	33.50	Barium (286)* Iron (17900)[∞]
Indian Guyan Creek (09-100-000) *EWH-R*				
303675	Old St. Rt. 775	10.60	54.10	none
W02S08	Co. Rd. 69	5.76	64.00	Temperature (21.4)[**]
609150	Adj. Ind Guyan Rd. DST Bear Cr	2.95	73.30	none
Perigen Creek (09-115-000) *CWH-R*				
303664	Mercerville Rd.	0.10	2.1	none
Drake Fork (09-114-000) *WWH*				
303669	Rocky Fork Rd.	0.30	2.5	none
Tributary to Drake Fork (0.55) (09-114-001) *WWH-R*				
303670	St. Rt. 218	0.05	0.9	none
Johns Creek (09-113-000) *WWH*				
303668	Rocky Fork Rd.	0.10	1.9	Temperature (30.99, 30.09)[**]
Rocky Fork (09-112-000) *WWH*				
303667	Cecil Rd.	0.10	3.4	DO (3.82) [‡‡]
Lanes Branch (09-111-000) *WWH*				
303662	Adj. St. Rt. 218	0.10	1.6	none
Georges Creek (09-110-000) *EWH-R*				
303659	St. Rt. 218	0.05	1.9	none

Stream (River Code) *use designation*[a]				Parameter (Units for DO, ammonia and TDS is mg/L, Temp is °C , pH is SU, and all other parameters are µg/l)
Station	**Location**	**RM**	**DA (MI^2)**	
Williams Creek (09-116-000) *WWH-R*				
303657	Berry Rd.	1.55	0.90	none
303656	St. Rt. 216	0.05	3.20	none
Garland Creek (09-116-001) *Undesignated*				
303655	Williams Creek Rd	0.05	1.0	TDS (1740)*
Little Indian Guyan Creek (09-108-000) *EWH-R*				
303652	Twp. Rd. 122 S	2.70	5.90	DO (4.39)‡‡
303596	Big Spring Rd.	1.65	8.50	Temperature (29.96, 31.05)**
303532	Scottown at St. Rt. 217	0.13	14.90	Iron (9860) ∞
Watson Creek (09-108-002) *WWH-R*				
303650	Long Creek Rd.	0.05	1.9	none
Trace Creek (09-108-001) *EWH-R*				
303648	Adj. St. Rt. 775 near mouth	0.10	3.7	none
Wolf Creek (09-106-000) *EWH-R*				
303676	St. Rt. 775	0.35	4.7	none
Slate Run (09-105-000) *WWH*				
303647	Twp. Rd. 192 N	0.40	1.1	DO (3.86)‡‡
Fivemile Creek (09-104-000) *EWH-R*				
303594	Seneca Trail	0.30	3.3	none
Bear Creek (09-102-000) *WWH*				
303593	Indian Guyan Rd.	0.05	2.9	none
Bent Creek (09-101-000) *WWH*				
303592	Greasy Ridge Rd.	0.05	1.9	none
Buffalo Creek (09-020-000) *WWH*				
303531	Buffalo Creek Rd. CR 15	1.10	6.7	none
Scarey Creek (09-020-001) *WWH-R*				
303583	Lick Creek Road CR 15	0.05	2.1	DO (3.12)‡‡
Paddy Creek (09-021-000) *WWH*				
303591	Private Rd. 21501	1.65	4.9	DO (3.63)‡‡
Little Paddy Creek (09-021-001) *WWH-R*				
303590	service road off Walnut St.	0.40	2.0	none
Twomile Creek (09-022-000) *WWH*				
303645	Wylie St.	1.45	3.0	none
Federal Creek (09-023-000) *WWH*				
303589	Federal Creek Rd.	0.85	4.0	DO (3.4)‡‡
Clean Fork (09-024-000) *WWH*				
303588	Adj. Clean Fork Rd. upst. Federal Creek	0.10	1.7	DO (3.88)‡‡
Big Creek (09-095-000) *CWH-R*				
303643	Adj. Big Creek Rd.	0.68	1.6	none

Stream (River Code) *use designation*[a]				Parameter (Units for DO, ammonia and TDS is mg/L, Temp is °C , pH is SU, and all other parameters are µg/l)
Station	**Location**	**RM**	**DA (MI²)**	
Swan Creek (09-027-000) *EWH-R*				
303641	Adj. Swan Creek Rd.	4.25	8.3	none
303527	N.E. of Crown City at Swan Creek Rd., dst. Little Swan Creek	2.35	14.7	Iron (68000)[∞] Barium (555)* Copper (42)* Lead (41.3)* Zinc (207)*
Tributary to Swan Creek (RM 5.95)(09-027-001) *WWH-R*				
303638	Hamilton Rd.	0.50	2.2	none
Little Swan Creek (09-028-000) *EWH-R*				
303587	private br. off Swan Creek Rd.	0.05	4.2	none
Teens Run (09-031-000) *EWH-R*				
303586	Barcus Hollow Rd.	1.20	2.5	none
Chickamauga Creek (09-037-000) *WWH*				
300742	St. Rt. 160	5.0	12.1	DO (3.8)[‡‡]
Little Chickamauga Creek (09-039-000) *WWH*				
W03S19	N. of Gallipolis at St. Rt. 160	0.16	5.9	DO (3.61)[‡‡]

a Use designations:

Aquatic Life
EWH - Exceptional warmwater habitat
WWH - Warmwater Habitat
CWH – Cold Water Habitat
Undesignated [WWH criteria apply to 'undesignated' surface waters.]

** Exceedance of OMZM (outside mixing zone maximum) numerical criteria for prevention of acute toxicity.
‡‡ Value below the OMZM (outside mixing zone minimum) numerical criterion for DO (WWH=4.0 mg/L, EWH=5.0 mg/L, CWH=6.0 mg/L).
∞ Exceedance of agricultural water supply criterion.
Δ Exceedance of the pH criteria (6.5-9.0)
* Exceedance of OMZA (outside mixing zone average) numerical criteria for prevention of chronic toxicity.

Ohio promulgates water quality standards through Ohio Administrative Code Chapter 3745-1. The data collected during the sonde deployments are sufficient to evaluate exceedances of the standards for the protection of aquatic life for: maximum daily temperature, minimum DO, 24-hour average DO, pH, and specific conductivity. Absolute minima or maxima exceedances are compared directly to hourly readings reported from the water quality sondes. The 24-hour average for DO is calculated as a rolling 24-hour average of the hourly data. An exceedance of the water quality criteria does not represent stream impairment; rather if biological impairment is present the exceedances help develop a body of evidence that identifies the conditions that are stressing aquatic life. A summary of the exceedances is presented in Table 10. The table includes comments about exceedances that are made based on Ohio EPA staff's best professional judgment.

Seven of the 25 sites had DO exceedances on the first deployment period (7/26/2016 to 7/28/2016) observed. During the second deployment period (8/17/2016 to 8/19/2016), nine out of 18 sites had DO exceedances. The nature of these exceedances is indicative of low reaeration. In general, these streams were noted to have low stream gradients. Combination of low flow condition and low gradient result in reduced reaeration and helping suppress the DO further. These streams with low DO didn't exhibit strong diel fluctuations in DO.

Temperature exceedances of the Symmes Creek only occurred in two streams on the first survey and three other streams on the second survey. The root of these exceedances is likely related to some natural conditions in the stream habitat such as riparian without tree and shallow wide streams in some parts.

The Symmes Creek watershed has very little agricultural activity and therefore, there is little fertilizer and manure application in the watershed. More than 400 chemistry samples were collected within the watershed between June 12 through October 4, 2016. From the survey data the geomean for total phosphorus (TP) is 0.028 mg/L and dissolved inorganic nitrogen (DIN) is 0.2 mg/L. These values are below the threshold at which nutrients typically cause excessive primary production.

Table 10—Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring in the Symmes Creek watershed, 2016.

Criteria are assessed based on criteria for the recommended Aquatic Life Use Designations, please refer to Beneficial Use Designations and Recommendations within this report for details about use recommendations.

Sondes were deployed at 25 sites and a subset of the sites was sampled twice. The first deployment was July 26-28, 2016 and 45-78 hours of data were collected at 25 sites. The second was August 17-19, 2016 resulting in an additional 119-123 hours of data collection at 18 sites. Exceedances occurring during the first survey are identified in bold on the table.

Sonde water quality monitors record hourly readings for the duration of the deployment. Consequently, exceedances can be presented as both a measure of magnitude and duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average DO criteria. The duration is the count of consecutive hours that exceeded the criteria. The magnitude of an exceedance is presented as the most extreme value measured that exceeds the criteria and is presented in parenthesis after the duration. Applicable water quality criteria include: minimum DO[a]; average DO[b]; maximum temperature[c]; pH[d]; and specific conductance[e].

Stream (Stream Code) *Use designation*			
Station	**12-digit HUC**	**River Mile**	**Parameter (value) — (units are C° for temperature, mg/L for dissolved oxygen and µS/cm for specific conductance)**
Symmes Creek (09-700-000) *WWH – PCR – AWS – IWS*			
303584	05090101 08-03	70	**DO min.: 2(3.6)** **DO avg.: 26(4.3)** DO min.: 7(1.5) DO avg.: 23(3.4)
300158	05090101 08-03	62.8	**DO min.: 30(1.1)** **DO avg.: 22(1.5)**
Symmes Creek (09-700-000) *EWH-R – PCR – AWS – IWS*			
200754	05090101 09-03	56.7	**DO min.: 1(3.9)** **DO avg.: 23(4.5)** DO min.: 14(2.6) DO avg.: 22(3.6)
303500	05090101 09-03	38.7	none
300151	05090101 10-04	22.6	Temp. max.:4(29.9) DO min.: 6(3.8) DO avg.: 22(4.3)
200746	05090101 10-05	8.4	none
303535	05090101 10-05	2.9	Temp. max.: 4(30.2)

Station	12-digit HUC	River Mile	Parameter (value) — (units are C° for temperature, mg/L for dissolved oxygen and µS/cm for specific conductance)
Stream (Stream Code) *Use designation*			
Black Fork Symmes Creek (09-730-000) *WWH – PCR - AWS - IWS*			
303576	05090101 08-02	11	**DO min.: 44(1.8)** **DO avg.: 21(2.6)** DO min.: 35(1.9); 4(2.8) DO avg.: 21(2.3)
303501	05090101 08-02	2.4	**DO min.: 3(3.8); 15(3.7)** **DO avg.: 22(3.9)** DO min.: 1(3.9) DO avg.: 5(4.8)
Black Fork Symmes Creek (09-730-000) *EWH – PCR - AWS - IWS*			
303575	05090101 08-02	0.3	DO avg.: 6(5.8)
Cambria Creek (09-734-000) *WWH – PCR - AWS – IWS*			
303574	05090101 08-02	1.7	none
Dirtyface Creek (09-731-000) *WWH – PCR - AWS - IWS*			
300156	05090101 08-01	1.8	**DO avg.: 25(4.5)** DO avg.: 21(4.8)
Sandfork Symmes Creek (09-727-000) *WWH – PCR - AWS - IWS*			
301798	05090101 09-01	13.4	none
300154	05090101 09-01	2.7	none
Johns Creek (09-714-000) *WWH – PCR - AWS - IWS*			
300153	05090101 10-01	0.07	none
Long Creek (09-711-000) *WWH – PCR - AWS - IWS*			
303536	05090101 10-02	0.86	**Temp. max.: 29.6(2)**
Aaron Creek (09-710-000) *WWH – PCR - AWS - IWS*			
303549	05090101 10-04	0.65	none
Indian Guyan Creek (09-100-000) *EWH-R – PCR - AWS - IWS*			
W02K05	05090101 07-07	26.4	Temp. max.: 4(29.9)
W02K04	05090101 07-07	14.7	none
303675	05090101 07-08	10.6	DO min.: 1(2.1); 1(0.2)
W02S08	05090101 07-08	5.76	none
Little Indian Guyan Creek (09-100-000) *EWH-R – PCR - AWS - IWS*			
303532	05090101 07-06	0.13	none
Swan Creek (12-200-002) *EWH-R – PCR - AWS - IWS*			
303527	05090101 07-03	2.35	**Temp. max.: 5(30.3)**
Huntingcamp Creek (12-200-004) *WWH – PCR - AWS - IWS*			
W02S06	05090101 08-02	1.70	none
W02S03	05090101 08-02	1.2	**DO avg.: 8(4.7)** DO min.: 2(3.0), 10(3.5) DO avg.: 20(4.5)

WAP – Western Alleghany Plateau
a Applicable minimum DO criterion - WWH: 4.0 mg/L, EWH=5.0 mg/L
b Applicable minimum 24-hour average DO criterion - WWH: 5.0 mg/L, EWH=6.0 mg/L
c The General Ohio River basin daily maximum temperature criteria apply; See OAC 3745-1-35, Table 35-11(A).
d The criteria for pH is 6.5-9.0 S.U.
e The criteria for specific conductivity is 2400 µS/cm.

Sediment

Sediment samples were collected from ten locations in both the Symmes Creek watershed and Indian Guyan Creek watershed during August 2016 to determine background sediment quality. Samples were collected following the Sediment Sampling Guide and Methodologies, 5th Edition (Ohio EPA, Sediment Sampling Guide and Methodologies (3rd Edition), 2015). Sediment samples were conservatively sampled by focusing on depositional areas containing at least 30 percent fine grain material (silt and clay particles). These areas typically are represented by higher contaminant levels, compared to sands and gravel. Samples were analyzed for particle size, metals, nutrients and semi-volatile organic compounds. Metal, nutrients and particle size results are listed in Table 11 and the results for all chemical parameters tested are in Appendix I.

Sediment sample results were evaluated using Tier I and Tier II procedures for aquatic life described in the Guidance on Evaluating Sediment Contaminant Results (Ohio EPA, 2010) and Sediment Sampling Data Quality Objectives for Biological and Water Quality Studies, Version 1.0 located in Section B of the Surface Water Field Sampling Manual - Appendix III (Ohio EPA, Surface Water Field Sampling Manual - Appendix III - Sediment Sampling, 2015b.) .

Numeric Sediment Quality Guidelines (SQGs) that are used include Ohio Sediment Reference Values (SRVs) for metals contained in the Ecological Risk Assessment Guidance (Ohio EPA, Ecological Risk Assessment Guidance Document, 2008) and toxicity values in the Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems (MacDonald, Ingersoll, & Berger, 2000). The consensus-based sediment guidelines define two levels of ecotoxic effects. A *Threshold Effect Concentration* (TEC) is a level of sediment chemical quality below which harmful effects are unlikely to be observed. A *Probable Effect Concentration* (PEC) indicates a level above which harmful effects are likely to be observed. When contaminants are at concentrations above the PEC either appropriate treatment options should be explored to remediate the problem or consideration should be given to investigate if bioavailability affects toxicity. This would likely require further investigation and studies to be done. Harmful effects are unlikely below the TEC and more likely above the PEC.

Indian Guyan Creek is a high gradient direct Ohio River tributary with sparse deposits of fine-grained material. No values above the SRV, TEC or PEC were observed in the sample from Indian Guyan Creek (Table 11) and all organic value results were below the detection limit (Appendix I).

The mainstem of Symmes Creek is sluggish and low gradient with numerous deposits of sandy substrates. Black Fork of Symmes Creek is associated with wetlands and is also low gradient with numerous beaver dams and deposits of silt. Despite the large amounts of fine-grained deposits in the Symmes Creek watershed, no parameters were above the SRV or PEC levels. Nickel and zinc were above the TEC in Johns Creek at SR 141 and nickel was also above the TEC in both Sand Fork at SR 775 in Lecta and Symmes Creek at SR 141 in Aid. Symmes Creek in Aid also had a detection of pyrene and fluoanthene which are polycyclic aromatic hydrocarbons (PAHs) derived from coal-tar. Sources of the PAHs could be from coal-tar-based driveway sealers, road dust, tire particles, diesel engine exhaust, gasoline engine exhaust or used motor oil.

Table 11—Chemical parameters measured above SQGs in surficial sediment samples collected by Ohio EPA in the Symmes Creek and Indian Guyan Creek watersheds during 2016. Sediment Reference Values (SRV), Threshold Effect Concentration (TEC) and Probable Effect Concentration (PEC) for the WAP ecoregion are listed for each parameter and are in bold if the result exceeds the respective Sediment Quality Guidelines (SQG).

Location (Station) HUC 12 Parameter	Result (mg/kg)	Sediment Reference Values (mg/kg)	Threshold Effect Concentration (mg/kg)	Probable Effect Concentration (mg/kg)
Symmes Creek at SR 141 at Aid (300151) (05090101 10 04)				
Nickel (mg/kg)	23.4	61	**22.7**	48.6
Johns Creek at SR 141 S. of Waterloo (300153) (05090101 10 01)				
Nickel (mg/kg)	29.5	61	**22.7**	48.6
Zinc (mg/kg)	166	**170**	121	459
Sand Fork at St. Rt. 775 at Lecta (301798) (05090101 09 01)				
Zinc (mg/kg)	139	170	**121**	459

Stream Physical Habitat

Stream physical habitat is evaluated using the Qualitative Habitat Evaluation Index (QHEI), a qualitative, visual habitat assessment method correlated with fish community condition (Ohio EPA 2006, 1989). Stream physical habitat was evaluated at 101 fish sampling locations encompassing 106 individual QHEI assessments (Table 13,Table 14). Overall, QHEI scores in streams throughout the study area ranged from poor to excellent with the majority of scores falling within the good-exceptional ranges (Table 13, Table 14). This is somewhat expected given the extensive amounts of forested areas and relatively unimpacted nature of streams in this study area compared to more agricultural or urban watershed systems.

Figure 10 – Habitat features in Symmes Creek and Black Fork.

The majority of Symmes Creek mainstem is generally sluggish and low gradient. Instream habitat features of this low-energy stream included an abundance of deep pools and other of types of instream cover, especially large woody debris. Instream substrates were overwhelmingly predominated by fine sand and smaller pea gravels. Current velocities were generally slow and sluggish overall, though areas of swifter flow and coarser substrates/riffles were present. Stable woody snags were important features "creating" riffle-type habitats and areas of constriction, with swifter and more heterogeneous flow types (Figure 12).

Wetland areas are common and somewhat widespread in the upper reaches of Symmes Creek and tributaries in this area, especially the Black Fork sub-watershed. The confluence of Black Fork and Symmes Creek functionally form the transitional area between the upper and lower portions of the Symmes Creek watershed. As such, many streams in upper portions of the Symmes Creek and Black Fork sub-watershed display physical habitat characteristics typical of wetland-type or generally lentic stream systems, including: slower and less diverse flow velocities, simplified stream development and more pool areas, finer substrates with more siltation, and presence of rooted aquatic macrophytes. These physical traits generally result in comparatively lower QHEI scores (Figure 13, Figure 14). These physical traits often give rise to a naturally stressful, chemically reduced environment (e.g. generally lower pH and D.O. concentrations, higher background ammonia or metals concentrations). A preponderance of these wetland-

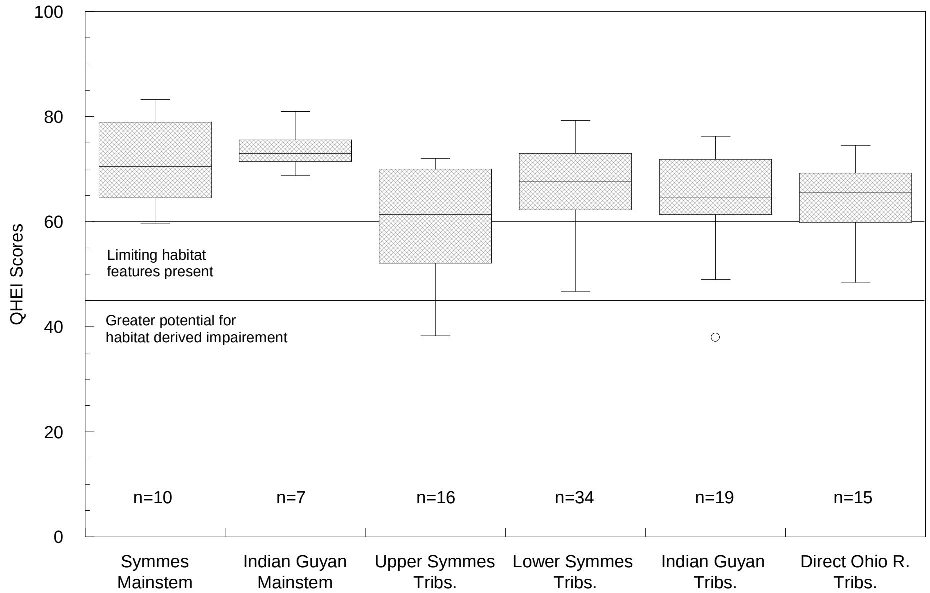


Figure 11 – Aggregared QHEI scores from all streams within the study area, 2016-17. Scores were parsed into indicated sub-basin categories.

type habitat features throughout a stream reach can naturally limit biological community performance through both physical habitat constraints and the naturally stressful chemical environment.

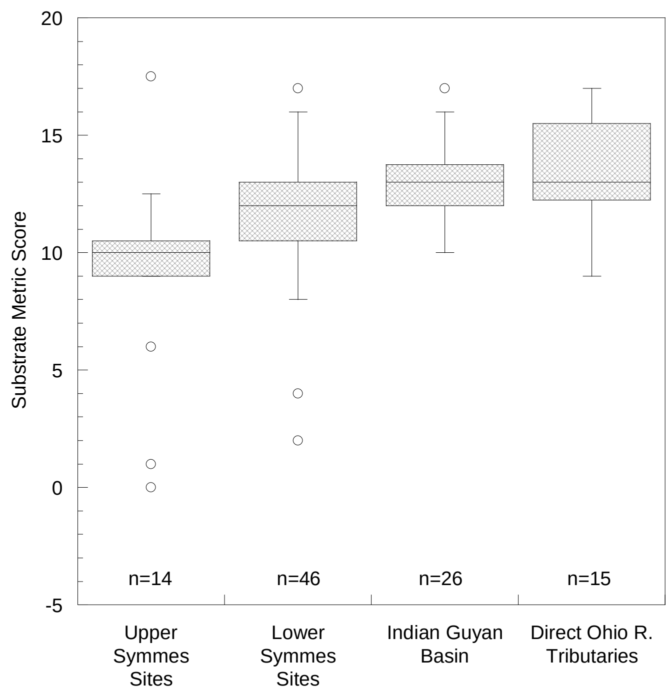


Figure 12 – Aggregated QHEI substrate sub-metric scores from the survey area parsed by sub-basin.

Tributaries to Symmes Creek downstream from the Black Fork confluence generally exhibited higher QHEI scores, fewer wetland-type stream habitat characteristics, and more characteristics associated with typical, lotic stream systems. These tributaries typically were higher gradient with well-defined pool-riffle-run complexes, faster and more diverse current velocities, and more coarse substrates overall (Appendix G, Figure 13, Figure 14).

Streams in the Indian Guyan Creek watershed and the other direct Ohio River tributaries were comparatively higher gradient systems, with generally coarse substrates and relatively high QHEI scores (Figure 13, Figure 14). QHEI scores tended to be somewhat higher in Indian Guyan Creek mainstem compared to Symmes Creek mainstem. HEI scores were similar between the lower Symmes Creek tributaries, Indian Guyan Creek tributaries, and other direct Ohio River tributaries. The lowest median and lowest overall scores were in the upper Symmes Creek tributaries (Figure 13). Many streams with small drainage areas often experienced some degree of natural desiccation over the summer sampling season typically from August to September. Reduced baseflow was evident over the course of the relatively dry summer and many stream segments were reduced to interstitial or intermittent pool habitats as the summer progressed (Figure 15). Where collected twice in the same year, QHEI scores tended to decrease later in the year (

Table 12). However, in many of these streams, hyporheic (beneath the stream bed) streamflow was still sufficient to fully or partially support biological communities consistent with ecoregional expectations in these remaining pool environments. Caulley Creek is an example where the QHEI score went from exceptional (73.5) on July 7, 2016 to poor (41) on September 14, 2016 with a 32.5-point difference. The biology scored exceptional for both the fish and aquatic insects and was recommended EWH. Habitat scores collected late in the season do not often represent the biological performance of these small drainages. The biological sampling index period (mid-June to mid-October) in the biocriteria manual (Ohio EPA, 1987b) are based on larger streams but smaller drainages should most likely be assessed from late spring through early summer (May through July) to evaluate the true potential of these stream.

Stream segments with mean QHEI values of at least 60 typically indicate a level of macrohabitat quality sufficient to support an assemblage of aquatic organisms fully consistent with the WWH aquatic life use designation; reach averages with values greater than 70 or 75 are generally considered adequate to fully support EWH (Ohio EPA 1989, Rankin 1995). Reach averages with values between 45 and 60 indicate limiting components of habitat are present that may negatively influence biological performance. Values below 45 indicate a higher probability of habitat derived aquatic life use impairment but should not be viewed as determinant. Due to the potential for compensatory stream features (*e.g.*, strong groundwater connectivity) or other attributes, average QHEI scores below the benchmark WWH value of 60 do not necessarily preclude these streams from fully supporting WWH or even EWH assemblages.

Figure 13 – Cherry Fork RM 0.4, 303705 (left) and Johns Creek RM 0.1, 300153 (right). Note low stream flows during late season sampling events. Low stream flows and generally desiccated conditions were routinely encountered in many tributaries late in the summer sampling season.

Table 12—Comparison of QHEI scores from tributaries to Symmes Creek conducted in early summer (June-July) compared to late summer (August- September) in 2016 in streams with small drainage areas (>10 mi²)

Station	Location	Recommended ALU	DA	QHEI Score June-July	QHEI Score August-September	Fish /Aquatic insect narrative
W02S09	Buffalo Creek	EWH	8.5	68	53.3	Very good/exceptional
W02S01	Caulley Creek	EWH	4.9	73.5	41	Exceptional/Exceptional
303562	L. Buffalo Creek	EWH/CWH	2.6	67.3	45	Very Good/Very Good

Both aggregated and individual QHEI scores relative to these benchmark values are displayed in Figure 13 and Figure 16, respectively. Habitat quality in many streams was sufficient to support both WWH and EWH communities, even at very small drainages or in streams that were desiccated or interstitial later during the summer sampling period (Table 1, Figure 15, Figure 16). As previously discussed, the most common limiting habitat features in many streams were related to either low late season flows or wetland-like physical habitat conditions.

Locations with QHEI scores above the benchmark value of 60 typically indicate a level of macrohabitat quality sufficient to support warmwater biological communities. However, several sampling locations with QHEI scores greater than 60 displayed biological impairment, including: Cherry Fork RM 0.40, Black Fork Symmes Creek RM 11.0, Huntingcamp Creek RM 1.71, Clear Fork RM 0.30, Indian Creek RM 0.10, and Little Chickamauga Creek RM 0.16.

Reach averages with values between 45 and 55 indicate habitat limitations are present and may be negatively influencing biological performance. Impaired locations where QHEI scores fell within this range included: Hewitt Run RM 0.75, Dicks Creek RM 0.30, Wolf Run RM 0.10, Peters Cave Creek RM 0.20, Slate Run RM 0.40, Paddy Creek RM 1.65, and Twomile Creek RM 1.45.

Stream locations with QHEI values below 45 indicate a greater potential for aquatic life impairments ~~s~~ due to poor habitat quality. Impaired stream segments with QHEI values lower than 45 included: Tributary to Symmes Creek (73.03) RM 0.1, Sweetbit Creek RM 0.30, and Huntingcamp Creek RM 1.20.

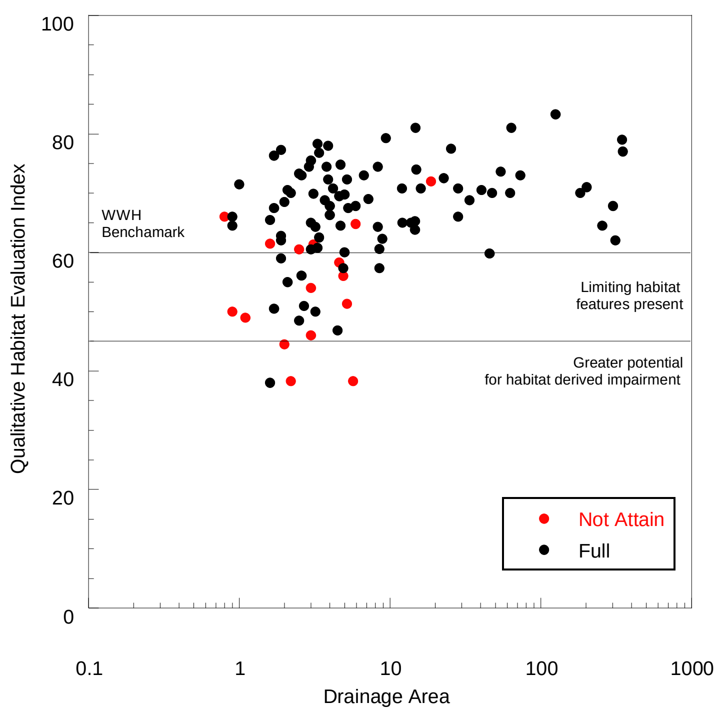


Figure 14—QHEI scores displayed by drainage area from the study area, 2016 and 2017. Scores are parsed according to attainment of the existing or recommended ALU.

The significance of physical habitat as it related to biological community impairments observed at these locations is discussed in further detail within the Aquatic Life & Impairment Discussion portion of this document.

Table 13—QHEI attributes for Symmes Creek, Indian Guyan Creek, and direct Ohio River Tributaries sampled in 2016 -2017.

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Grad-ient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	WWH Attributes	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	High-Influence Modified Attributes	Recovering Channel	Heavy/Moderate Substrates	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Mod. Influence Modified Attributes	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
Sugar Run (09-741-000)																																			
Year:	2016																																		
200756	0.1	64.5	12.20	X				X	X			X		4						0					X				X	X	X	X	5	0.20	1.40
Cherry Fork (09-739-000)																																			
Year:	2016																																		
303705	0.4	60.5	16.30	X				X	X			X		4						0		X			X				X	X	X	X	6	0.20	1.60
Hewitt Run (09-738-000)																																			
Year:	2016																																		
303636	0.8	58.3	4.50	X				X	X			X		4						0		X			X				X	X	X	X	6	0.20	1.60
Huntingcamp Creek (09-735-000)																																			
Year:	2016																																		
W02S03	1.4	38.3	6.58						X			X		2		X		X		2	X	X			X	X		X	X	X	X	X	9	1.33	3.33
Year:	2017																																		
W02S06	1.8	61.5	17.09					X	X			X		3				X		1	X	X			X	X			X	X	X		7	0.75	2.25
Lefthand Fork (09-734-000)																																			
Year:	2016																																		
303574	1.7	69.0	9.30	X	X		X	X	X			X		6						0		X							X	X	X		4	0.14	0.86
Dicks Creek (09-733-000)																																			
Year:	2016																																		
303573	0.1	46.0	16.13				X		X					2		X		X	X	3	X	X			X	X			X	X	X	X	8	1.67	3.00
Clear Fork (09-732-000)																																			
Year:	2016																																		
303572	0.7	61.3	21.05	X					X			X		3						0		X			X	X			X	X		X	6	0.25	2.00
Dirtyface Creek (09-731-000)																																			
Year:	2016																																		
303571	4.7	60.5	12.90	X			X	X	X			X	X	6				X		1	X	X		X	X			X	X	X	X		8	0.43	1.43
300156	1.8	70.8	11.30	X			X	X	X	X	X	X		7						0		X			X					X	X		4	0.13	0.75
Black Fork (09-730-000)																																			
Year:	2016																																		
303576	11.1	72.0	33.33	X	X			X	X			X		5						0					X	X			X	X	X		5	0.17	1.17
W02S02	5.8	70.8	3.74	X				X	X			X	X	5						0		X			X				X	X			4	0.17	1.00
303501	2.4	70.0	7.30	X			X	X	X			X		5						0		X		X	X				X	X	X		6	0.17	1.33
303575	0.3	70.0	3.26	X			X	X	X			X		5						0		X		X					X	X	X		5	0.17	1.17
Wolf Creek (09-729-000)																																			
Year:	2016																																		
303570	0.1	50.0	20.00		X			X						2				X	X	2	X	X			X	X			X	X	X	X	8	1.33	3.33

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	WWH Attributes	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	High-Influence Modified Attributes	Recovering Channel	Heavy/Moderate Substrates	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Mod. Influence Modified Attributes	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
Peter Cave Creek (09-728-000)																																			
Year:	2016																																		
303565	0.2	51.3	9.43		X			X	X			X		4						0	X	X		X	X	X		X	X	X	X	X	10	0.40	2.40
Sand Fork (09-727-000)																																			
Year:	2016																																		
303569	15.1	65.0	10.75	X	X		X	X	X			X		6						0	X	X		X				X	X	X	X		7	0.29	1.29
303568	14.9	62.3	10.75	X			X	X	X	X		X		6						0		X		X				X		X	X		5	0.14	1.00
301798	13.4	65.0	9.70					X	X			X		3						0	X	X		X	X	X			X	X	X		8	0.50	2.50
303567	10.3	66.0	6.27					X	X			X		3						0	X	X		X	X	X			X	X	X		8	0.50	2.50
300154	2.7	70.5	3.47	X			X	X	X	X		X	X	7						0		X		X						X	X		4	0.13	0.75
Trace Creek (09-726-000)																																			
Year:	2016																																		
303564	0.6	51.0	10.00	X				X	X		X	X		5						0		X		X	X			X	X	X	X	X	8	0.17	1.67
Camp Creek (09-725-000)																																			
Year:	2016																																		
303563	0.7	46.8	15.84		X				X					2				X	X	2	X	X		X	X	X			X	X		X	8	1.33	3.33
Little Buffalo Creek (09-724-000)																																			
Year:	2016																																		
303562	1.2	67.3	10.00	X	X		X	X	X			X		6						0		X		X	X				X	X	X		6	0.14	1.14
Indian Creek (09-723-000)																																			
Year:	2016																																		
303560	0.1	66.0	20.00	X	X		X	X	X		X		X	7				X	X	2					X			X	X		X	X	5	0.38	0.75
Miller Creek (09-721-000)																																			
Year:	2016																																		
303559	0.1	71.5	40.00	X	X		X	X	X		X	X	X	8						0		X		X				X	X		X	X	6	0.11	0.78
Caulley Creek (09-720-000)																																			
Year:	2016																																		
W02S01	0.2	73.5	8.89	X	X		X	X	X		X	X	X	8						0		X		X					X		X		4	0.11	0.67
Buffalo Creek (09-719-000)																																			
Year:	2016																																		
200752	5.0	67.0	9.30	X	X		X	X	X			X		6						0		X						X	X	X	X	X	6	0.14	1.00
W02S09	1.9	68.0	7.12	X			X	X	X			X		5						0		X		X	X				X	X	X		6	0.17	1.33
Year:	2017																																		
200752	5.0	72.8	9.30	X	X		X	X	X		X	X	X	8						0									X				1	0.11	0.33
Pigeon Creek (09-718-000)																																			
Year:	2016																																		
303558	0.6	50.0	22.47	X	X			X				X		4				X		1		X		X	X			X	X	X		X	7	0.40	1.80

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Grad-ient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	WWH Attributes	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	High-Influence Modified Attributes	Recovering Channel	Heavy/Moderate Substrates	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Mod. Influence Modified Attributes	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
Slab Fork (09-717-000)																																			
Year:	2016																																		
303556	0.1	73.0	11.62	X	X		X	X	X		X	X	X	8						0	X							X	X				3	0.22	0.44
Brushy Buckeye Creek (09-716-000)																																			
Year:	2016																																		
303554	0.1	77.3	28.23	X	X		X	X	X		X	X	X	8						0				X					X				2	0.11	0.44
Buckeye Creek (09-715-000)																																			
Year:	2016																																		
303555	1.5	76.8	13.92	X	X		X	X	X			X	X	7						0		X		X	X				X	X			5	0.13	0.75
Handley Branch (09-714-001)																																			
Year:	2016																																		
303553	0.1	50.5	33.68	X				X	X		X	X		5				X		1		X		X	X	X		X	X			X	7	0.33	1.50
Johns Creek (09-714-000)																																			
Year:	2016																																		
303557	5.4	79.3	7.78	X	X		X	X	X		X	X	X	8						0		X		X					X		X		4	0.11	0.56
300153	0.1	72.5	11.11	X			X	X	X	X		X		6						0		X		X				X		X	X		5	0.14	1.00
Buck Creek (09-713-000)																																			
Year:	2016																																		
303552	0.4	60.0	22.55	X	X			X	X			X		5						0		X		X	X			X	X	X	X	X	8	0.17	1.67
Buckeye Creek (09-712-000)																																			
Year:	2016																																		
303550	0.9	74.5	16.00	X	X		X	X	X	X	X	X	X	9						0		X		X						X	X		4	0.10	0.60
Long Creek (09-711-000)																																			
Year:	2016																																		
303551	4.3	67.5	19.42	X	X		X	X	X		X	X	X	8						0		X							X	X			3	0.11	0.44
303536	0.9	65.3	10.00	X				X	X			X		4						0	X	X			X				X	X	X		6	0.40	1.60
Aaron Creek (09-710-000)																																			
Year:	2016																																		
303549	0.7	64.3	11.32	X			X	X	X			X		5						0	X	X		X	X	X			X	X	X		8	0.33	1.67
Elkins Creek (09-709-000)																																			
Year:	2016																																		
303548	1.8	78.3	26.67	X	X		X	X	X		X	X	X	8						0									X	X			2	0.11	0.33
Sharps Creek (09-708-000)																																			
Year:	2016																																		
303547	0.2	69.5	20.99	X			X	X	X			X		5						0				X	X				X	X	X		5	0.17	1.17
Venisonham Creek (09-705-000)																																			
Year:	2016																																		
303546	1.0	72.3	16.67	X	X		X	X	X		X	X	X	8						0		X		X					X	X		X	5	0.11	0.78

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	WWH Attributes	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	High-Influence Modified Attributes	Recovering Channel	Heavy/Moderate Substrates	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Mod. Influence Modified Attributes	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
Leatherwood Creek (09-704-000)																																			
Year:	2016																																		
200747	0.8	**67.8**	22.47	X	X		X	X	X		X	X	X	8						0		X			X				X	X	X	X	6	0.11	0.89
Rankin Creek (09-703-000)																																			
Year:	2016																																		
303545	0.6	**78.0**	20.77	X	X		X	X	X		X	X	X	8						0		X		X					X				3	0.11	0.44
Mckinney Creek (09-702-000)																																			
Year:	2016																																		
303544	0.4	**69.8**	13.39	X			X	X	X		X	X	X	7						0		X		X					X	X	X		5	0.13	0.88
Big Branch Creek (09-701-000)																																			
Year:	2016																																		
303540	0.8	**75.5**	23.81	X	X		X	X	X			X	X	7						0		X							X	X	X		4	0.13	0.75
Sweetbit Creek (09-700-003)																																			
Year:	2016																																		
303637	0.3	**44.5**	4.91	X				X	X			X		4		X				1		X			X				X	X		X	5	0.40	1.20
Trib. To Symmes Creek (Rm 73.07) (09-700-001)																																			
Year:	2016																																		
303577	73.0	**38.3**	2.85	X								X		2				X		1		X			X	X		X	X	X		X	7	0.67	2.67
Symmes Creek (09-700-000)																																			
Year:	2016																																		
303584	70.0	**81.0**	5.78	X	X		X	X	X		X	X	X	8						0		X							X				2	0.11	0.33
300158	64.8	**59.8**	3.28	X					X			X		3						0		X		X	X	X			X	X	X		7	0.25	2.25
200754	56.7	**83.3**	2.08	X	X		X	X	X	X		X		7						0		X								X	X		3	0.13	0.63
200753	45.7	**70.0**	1.89	X				X	X			X		4						0		X		X	X				X	X	X		6	0.20	1.60
303500	36.9	**71.0**	1.88	X			X	X	X			X		5						0		X	X	X	X				X	X	X		7	0.17	1.33
303533	31.2	**64.5**	1.88						X			X		2						0	X	X	X	X	X	X			X	X	X		9	0.67	3.33
300151	22.6	**67.8**	1.78	X					X			X		3						0		X	X	X	X	X			X	X	X		8	0.25	2.25
303534	17.5	**62.0**	1.88	X	X		X	X	X			X		6						0		X							X	X		X	4	0.14	0.86
200746	9.7	**79.0**	3.38	X	X			X	X	X		X	X	7						0		X		X	X					X			4	0.13	0.75
303768	3.9	**77.0**	5.43	X			X	X	X	X		X	X	7						0		X	X	X						X	X		5	0.13	0.75
Williams Creek (09-116-000)																																			
Year:	2016																																		
303657	1.6	**66.0**	35.71		X		X		X		X	X	X	6						0	X					X		X	X				4	0.29	0.71
303656	0.1	**64.3**	18.26		X		X	X	X				X	5					X	1	X	X		X	X				X	X	X		7	0.50	1.50
Perigen Creek (09-115-000)																																			
Year:	2016																																		
303664	0.1	**70.5**	20.77	X	X		X	X	X		X	X	X	8						0						X		X	X			X	4	0.11	0.56

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrate	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	WWH Attributes	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	High-Influence Modified Attributes	Recovering Channel	Heavy/Moderate Substrate	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Mod. Influence Modified Attributes	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
Trib To Drake Fork (0.55) (09-114-001)																																			
Year:	2016																																		
303670	0.1	64.5	59.20	X	X		X	X	X		X		X	7					X	1						X			X				2	0.25	0.38
Drake Fork (09-114-000)																																			
Year:	2016																																		
303669	0.3	73.3	17.52	X			X	X	X			X		5						0		X		X					X	X	X		5	0.17	1.17
Johns Creek (09-113-000)																																			
Year:	2016																																		
303668	0.1	59.0	30.77	X	X		X	X	X			X		6						0	X	X						X	X	X	X	X	7	0.29	1.14
Rocky Fork Indian Guyan Creek (09-112-000)																																			
Year:	2016																																		
303667	0.1	62.5	20.55		X		X	X	X			X		5						0	X	X		X	X	X		X	X	X	X		9	0.33	1.83
Lanes Branch (09-111-000)																																			
Year:	2016																																		
303662	0.1	38.0	38.88											0				X	X	2	X	X		X	X	X			X	X		X	8	4.00	10.00
Georges Creek (09-110-000)																																			
Year:	2016																																		
303659	0.2	62.0	25.54		X				X		X	X	X	5						0	X				X	X		X	X			X	6	0.33	1.17
Watson Creek (09-108-002)																																			
Year:	2016																																		
303650	0.1	76.3	21.81	X	X		X	X	X			X	X	7						0				X					X	X	X		4	0.13	0.75
Trace Creek (09-108-001)																																			
Year:	2016																																		
303648	0.1	68.8	30.00	X	X		X	X	X			X		6						0		X		X					X	X	X		5	0.14	1.00
Little Indian Guyan Creek (09-108-000)																																			
Year:	2016																																		
303652	2.7	67.8	11.56	X	X		X	X	X			X		6						0		X		X	X				X	X	X		6	0.14	1.14
303596	1.7	57.3	11.56				X	X	X	X		X		5						0	X	X		X	X	X		X		X	X		8	0.33	1.67
303532	0.1	74.0	9.76	X	X		X	X	X			X		6						0									X	X	X		3	0.14	0.71
Wolf Creek (09-106-000)																																			
Year:	2016																																		
303676	0.4	74.8	15.50	X	X		X	X	X		X	X	X	8						0				X					X	X	X		4	0.11	0.67
Slate Run (09-105-000)																																			
Year:	2016																																		
303647	0.4	49.0	44.40	X	X			X				X		4				X		1					X			X	X	X	X	X	6	0.40	1.60
Fivemile Creek (09-104-000)																																			
Year:	2016																																		
303594	0.3	60.8	25.93	X	X			X	X			X		5						0	X	X		X	X	X			X	X	X	X	9	0.33	1.83

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	WWH Attributes	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	High-Influence Modified Attributes	Recovering Channel	Heavy/Moderate Substrate	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	Mod. Influence Modified Attributes	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
Bear Creek (09-102-000)																																			
Year:	2016																																		
303593	0.1	74.5	16.30	X			X	X	X			X		5						0		X		X					X	X	X		5	0.17	1.17
Bent Creek (09-101-000)																																			
Year:	2016																																		
303592	0.1	62.8	32.00	X	X			X	X			X		5						0		X		X	X				X	X	X	X	7	0.17	1.50
Indian Guyan Creek (09-100-000)																																			
Year:	2016																																		
303663	29.1	72.3	15.15	X	X		X	X	X	X		X		7						0				X	X					X	X	X	5	0.13	0.88
W02K05	26.4	70.8	6.90	X	X		X	X	X			X		6						0	X	X		X	X	X			X	X	X		8	0.29	1.43
303539	21.7	77.5	6.64	X	X		X	X	X	X		X		7						0		X								X	X		3	0.13	0.63
W02K04	15.3	68.8	6.83	X			X	X	X	X		X		6						0		X		X				X		X	X		5	0.14	1.00
303675	10.6	73.8	4.71	X			X	X	X	X		X		6						0		X								X	X		3	0.14	0.71
303675	10.6	73.5	4.71	X	X		X	X	X		X	X	X	8						0					X				X				2	0.11	0.44
W02S08	5.8	81.0	6.29	X	X		X	X	X	X	X	X	X	9						0													0	0.10	0.20
609150	3.0	73.0	5.24	X			X	X	X			X		5						0				X	X				X	X	X		5	0.17	1.17
Big Creek (09-095-000)																																			
Year:	2016																																		
303643	0.5	65.5	56.34	X	X			X	X		X	X	X	7						0					X			X	X		X	X	5	0.13	0.88
Little Chickamauga Creek (09-039-000)																																			
Year:	2016																																		
W03S19	0.2	64.8	17.39	X	X			X	X			X		5						0		X		X	X				X	X	X		6	0.17	1.33
Chickamauga Creek (09-037-000)																																			
Year:	2016																																		
300742	5.0	65.0	7.30	X	X			X	X			X		5						0	X	X		X	X				X	X	X		7	0.33	1.33
Teens Run (09-031-000)																																			
Year:	2016																																		
303586	1.2	48.5	38.46	X	X						X			3				X	X	2					X	X		X	X			X	5	0.75	1.75
Little Swan Creek (09-028-000)																																			
Year:	2016																																		
303587	0.1	70.8	22.22	X	X		X	X	X		X	X	X	8						0				X		X		X	X				4	0.11	0.56
Trib To Swan Creek (5.95) (09-027-001)																																			
Year:	2016																																		
303638	0.5	70.0	52.63	X	X		X	X	X		X	X	X	8						0									X				1	0.11	0.22
Swan Creek (09-027-000)																																			
Year:	2016																																		
303641	4.6	74.5	13.70	X	X		X	X	X			X		6						0		X		X					X	X	X		5	0.14	0.86
303527	2.4	63.8	16.95		X			X	X			X		4						0	X	X		X	X	X			X	X	X		8	0.40	2.00

Key QHEI Components				WWH Attributes											MWH Attributes																				
Station	River Mile	QHEI	Grad-ient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrate	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth > 40cm	Low/Normal Riffle Embeddedness	**WWH Attributes**	Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	**High-Influence Modified Attributes**	Recovering Channel	Heavy/Moderate Substrates	Sand Substrates (Boat)	Hardpan Substrate Origin	Fair/Poor Development	Low Sinuosity	Only 1 or 2 Cover Types	Intermittent/Poor Pools	No Fast Current	High/Moderate Embeddedness	High/Mod. Riffle Embeddedness	No Riffle	**Mod. Influence Modified Attributes**	MWH H.I.+1 / WWH+1 Ratio	MWH M.I. / WWH Ratio
Clean Fork (09-024-000)																																			
Year:	2016																																		
303588	0.1	**67.5**	41.81	X	X		X	X	X		X	X	X	8						0								X	X				2	0.11	0.33
Federal Creek (09-023-000)																																			
Year:	2016																																		
303589	0.9	**66.3**	22.22	X	X		X	X	X			X		6						0		X				X		X	X	X	X		6	0.14	1.14
Twomile Creek (09-022-000)																																			
Year:	2016																																		
303645	1.5	**54.0**	14.28		X		X	X	X			X		5				X		1	X	X				X		X	X	X	X		7	0.50	1.50
Little Paddy Creek (09-021-001)																																			
Year:	2016																																		
303590	0.4	**68.5**	24.39		X			X	X			X		4						0	X	X		X	X	X			X	X	X		8	0.40	2.00
Paddy Creek (09-021-000)																																			
Year:	2016																																		
303591	1.7	**56.0**	18.47	X				X			X	X		4				X		1				X	X			X	X		X	X	6	0.40	1.60
Scarey Creek (09-020-001)																																			
Year:	2016																																		
303583	0.2	**55.0**	53.30		X		X		X		X		X	5					X	1	X				X	X			X	X	X		6	0.50	1.17
Buffalo Creek (09-020-000)																																			
Year:	2016																																		
303531	1.1	**73.0**	33.90	X	X		X	X	X		X	X		7						0					X				X	X	X	X	5	0.13	0.75

Table 14—Summary of QHEI scores and individual metric breakdowns from streams within the study area. Locations that are *italicized* indicate two QHEI scores were collected during each of the two fish sampling events conducted during 2016. Locations noted by [brackets] indicated QHEI scores collected during 2017.

Station	Stream	River Mile (RM)	Drainage Area (DA)	QHEI[a]	Substrate	Instream Cover	Channel	Riparian	Pool	Riffle	Gradient
Symmes Creek watershed											
303584	Symmes Creek	70	14.8	81	17.5	18	16.5	8	10	5	6
300158	Symmes Creek	62.76	45.8	59.75	10.5	15	10	5.25	9	4	6
200754	Symmes Creek	56.7	125	83.25	13	19	16	9.75	12	5.5	8
200753	Symmes Creek	47.1	182	70	10.5	17	13.5	9	9	5	6
303500	Symmes Creek	38.7	201.9	71	10.5	19	15	6.5	9	5	6
303533	Symmes Creek	31.7	255.3	64.5	10	17	9.5	7	9.5	5.5	6
300151	Symmes Creek	22.6	302	67.75	12	16	12	6.75	10	5	6
303534	Symmes Creek	17.53	313.2	62	11.5	15	16	4.5	9	0	6
200746	Symmes Creek	8.4	346	79	13	20	14	5	12	7	8
303768	Symmes Creek	3.9	349.6	77	12	17	16	4	12	6	10
303577	Tributary to Symmes Creek (73.07)	0.1	5.7	38.25	4	6	11.5	8.75	4	0	4
200756	Sugar Run	0.1	4.7	64.5	10.5	14	14.5	8.5	8	1	8
303705	Cherry Fork	0.4	2.5	60.5	9.5	15	13	5.5	7	0.5	10
303576	Black Fork Symmes Creek	11.05	18.7	72	12	16	13.5	10	10	4.5	6
W02S02	Black Fork Symmes Creek	5.77	28.3	70.75	9	20	14	7.75	10	4	6
303501	Black Fork Symmes Creek	2.4	47.6	70	10	15	14.5	10	10	2.5	8
303575	Black Fork Symmes Creek	0.3	62.6	70	10.5	15	15.5	9.5	10	3.5	6
303636	Hewitt Run	0.75	4.6	58.25	9	17	14.5	6.75	7	0	4
[W02S06]	[Huntingcamp Creek]	[1.71]	[1.6]	[61.5]	[10]	[14]	[10.5]	[5]	[10]	[2]	[10]
W02S03	Huntingcamp Creek	1.2	2.2	38.25	0	10	10	6.25	5	1	6
303574	Cambria Creek	1.65	7.2	69	12.5	16	16	8	7.5	3	6
303573	Dicks Creek	0.3	3	46	1	10	11	8.5	4	1.5	10

Station	Stream	River Mile (RM)	Drainage Area (DA)	QHEI[a]	Substrate	Instream Cover	Channel	Riparian	Pool	Riffle	Gradient
303572	Clear Fork	0.7	3.1	61.25	6	17	12	9.25	7	0	10
303571	Dirtyface Creek	4.7	3	60.5	10.5	10	13.5	9	6	3.5	8
300156	*Dirtyface Creek*	*1.82*	*12*	*70.75*	*10.5*	*15*	*15*	*7.75*	*11*	*1.5*	*10*
303637	Sweetbit Creek	0.3	2	44.5	2	16	12	5.5	5	0	4
303570	Wolf Run	0.1	0.9	50	10.5	7	10.5	7	4	1	10
303569	Sand Fork	15.1	3	65	10.5	15	13.5	9	5	4	8
303568	Sand Fork	14.85	8.9	62.25	9	14	14	6.75	6.5	4	8
301798	Sand Fork	13.4	13.8	65	11.5	16	10.5	6	8	3	10
303567	Sand Fork	10.25	28.3	66	10	15	10	7.5	9.5	4	10
300154	Sand Fork	2.7	40.4	70.5	10	15	16.5	7	11	5	6
303565	Peters Cave Creek	0.2	5.2	51.25	11.5	14	10	4.25	5	0.5	6
303564	Trace Creek	0.55	2.7	51	8	12	15	4.5	4	1.5	6
303563	Camp Creek	0.65	4.5	46.75	10.5	12	9	5.25	0	0	10
303562	*Little Buffalo Creek*	*1.2*	*2.6*	*67.25*	*13*	*16*	*14*	*8.25*	*7*	*3*	*6*
200752	Buffalo Creek	5	3.1	67	14	15	16	10	4.5	1.5	6
[200752]	[Buffalo Creek]	[5]	[3.1]	[72.75]	[13]	[15]	[17]	[9.75]	[7]	[5]	[6]
W02S09	*Buffalo Creek*	*1.91*	*8.5*	*68*	*11.5*	*15*	*15*	*9.5*	*6.5*	*4.5*	*6*
303560	Indian Creek	0.05	0.8	66	16	9	17	10	1	3	10
W02S01	*Caulley Creek*	*0.15*	*4.9*	*73.5*	*14*	*15*	*16.5*	*9*	*8*	*5*	*6*
303559	Miller Creek	0.05	1	71.5	15.5	13	17.5	10	5	2.5	8
303558	Pigeon Creek	0.55	3.2	50	13	8	12	6	1	0	10
303557	Johns Creek	5.35	9.4	79.25	13	19	17	5.75	10	4.5	10
300153	Johns Creek	0.07	22.7	72.5	12.5	14	16.5	8	7	4.5	10
303556	Slab Fork	0.1	2.6	73	17	15	15.5	6.5	6	5	8
303555	Buckeye Creek (Trib. to Johns Ck.)	1.45	3.4	76.75	14	18	16.5	7.75	8	4.5	8
303554	Brushy Buckeye Creek	0.1	1.9	77.25	15	16	16.5	8.75	7	4	10
303553	Handley Branch	0.1	1.7	50.5	11	10	11.5	9	1	0	8

Station	Stream	River Mile (RM)	Drainage Area (DA)	QHEI[a]	Substrate	Instream Cover	Channel	Riparian	Pool	Riffle	Gradient
303552	Buck Creek	0.35	5	60	11	13	14	6.5	4	1.5	10
303551	Long Creek	4.3	5.3	67.5	12.5	15	14	3.5	8	4.5	10
303536	Long Creek	0.86	14.7	65.25	12	15	12.5	4.75	8	3	10
303550	Buckeye Creek (Trib. to Long Ck.)	0.9	3.8	74.5	11.5	15	16	6.5	11	4.5	10
303549	Aaron Creek	0.65	8.3	64.25	12.5	16	11.5	4.25	10	2	8
303548	Elkins Creek	1.8	3.3	78.25	15.5	19	15.5	7.25	7	4	10
303547	Sharps Creek	0.2	4.6	69.5	13	17	14	6	7	2.5	10
303546	Venisonham Creek	0.95	3.9	72.25	12	16	17	5.25	9	3	10
200747	Leatherwood Creek	0.8	4	67.75	12	15	15	5.25	8	2.5	10
303545	Rankin Creek	0.55	3.9	78	15.5	16	16	5	10	5.5	10
303544	McKinney Creek	0.35	5	69.75	11	16	16	5.25	10	3.5	8
303540	Big Branch Creek	0.55	3	75.5	13.5	15	17	5	10	5	10
Indian Guyan Creek watershed											
303663	Indian Guyan Creek	29.05	5.2	72.25	13.5	16	15	6.75	9	2	10
W02K05	Indian Guyan Creek	26.4	16	70.75	13	16	13	7.75	8	3	10
303539	Indian Guyan Creek	21.7	25.4	77.5	13.5	17	16	5.5	12	3.5	10
W02K04	Indian Guyan Creek	15.3	33.6	68.75	12.5	15	15.5	5.75	7	3	10
303675	Indian Guyan Creek	10.6	54.1	73.75	12.5	16	16	7.25	11	5	6
303675	Indian Guyan Creek	10.6	54.1	73.5	15	14	17	7.5	10	4	6
W02S08	Indian Guyan Creek	5.76	64	81	15	18	15	6.5	12	6.5	8
609150	Indian Guyan Creek	2.95	73.3	73	13	15	15	8	10	4	8
303664	Perigen Creek	0.1	2.1	70.5	16	14	15.5	7	5	3	10
303669	Drake Fork	0.27	2.5	73.25	12.5	17	16.5	7.25	8	2	10
303670	Tributary to Drake Fk. (0.55)	0.05	0.9	64.5	16	14	16	6	4	4.5	4
303668	Johns Creek	0.1	1.9	59	12.5	13	13.5	5	5	2	8
303667	Rocky Fork	0.08	3.4	62.5	13	14	11.5	4.5	5.5	4	10
303662	Lanes Branch	0.1	1.6	38	10	7	8	5	0	0	8

Station	Stream	River Mile (RM)	Drainage Area (DA)	QHEI[a]	Substrate	Instream Cover	Channel	Riparian	Pool	Riffle	Gradient
303659	Georges Creek	0.05	1.9	62	14	15	10	5.5	4	3.5	10
303657	Williams Creek	1.55	0.9	66	17	12	12.5	7	5	4.5	8
303656	Williams Creek	0.05	3.2	64.25	13	14	12	6.75	5	3.5	10
303652	Little Indian Guyan Creek	2.7	5.9	67.75	13.5	15	13.5	5.25	10	2.5	8
303596	Little Indian Guyan Creek	1.65	8.5	57.25	10	14	11	3.75	7	3.5	8
303532	Little Indian Guyan Creek	0.13	14.9	74	11.5	17	16	6	10	3.5	10
303650	Watson Creek	0.05	1.7	76.25	12	16	16.5	7.75	10	4	10
303648	Trace Creek	0.1	3.7	68.75	11	17	14	6.25	8	2.5	10
303676	Wolf Creek	0.35	4.7	74.75	14.5	16	14	7.75	8	4.5	10
303647	Slate Run	0.4	1.1	49	12	9	12.5	5	4	2.5	4
303594	Fivemile Creek	0.3	3.3	60.75	13	15	11	3.75	6	2	10
303593	Bear Creek	0.05	2.9	74.5	10	17	16.5	10	9	2	10
303592	Bent Creek	0.05	1.9	62.75	12	14	15	6.25	6	1.5	8
Direct Ohio River tributaries											
303531	Buffalo Creek	1.1	6.7	73	15.5	16	15	8	8	2.5	8
303583	Scarey Creek	0.05	2.1	55	15.5	11	11	5.5	4	4	4
303591	Paddy Creek	1.65	4.9	56	12	9	13	6.5	4	1.5	10
303590	Little Paddy Creek	0.4	2	68.5	12.5	16	10.5	7.5	9	3	10
303645	Twomile Creek	1.45	3	54	10	11	12.5	4	5	3.5	8
303589	Federal Creek	0.85	4	66.25	13	15	13.5	6.25	6	2.5	10
303588	Clean Fork	0.1	1.7	67.5	17	13	16.5	7.5	5	4.5	4
303643	Big Creek	0.68	1.6	65.5	15	14	15.5	10	4	3	4
303641	Swan Creek	4.25	8.3	74.5	14	17	16.5	6.5	9.5	3	8
303527	Swan Creek	2.35	14.7	63.75	13	15	9.5	4.75	8	3.5	10
303638	Tributary to Swan Creek (5.95)	0.5	2.2	70	16	16	16.5	6	7	4.5	4
303587	Little Swan Creek	0.05	4.2	70.75	16	12	16	6.25	6	4.5	10
303586	Teens Run	1.2	2.5	48.5	13	7	12	7.5	1	0	8

Station	Stream	River Mile (RM)	Drainage Area (DA)	QHEI[a]	Substrate	Instream Cover	Channel	Riparian	Pool	Riffle	Gradient
300742	Chickamauga Creek	5	12.1	65	9	15	13	8	7	3	10
W03S19	Little Chickamauga Creek	0.16	5.9	64.75	11	15	12	5.75	8	3	10

a

Narrative QHEI rating	Headwaters DA < 20mi²	Larger Streams
Excellent	≥70	≥75
Good	55 to 69	60 to 74
Fair	43 to 54	54 to 59
Poor	30 to 42	30 to 44
Very Poor	<30	<30

Fish Community

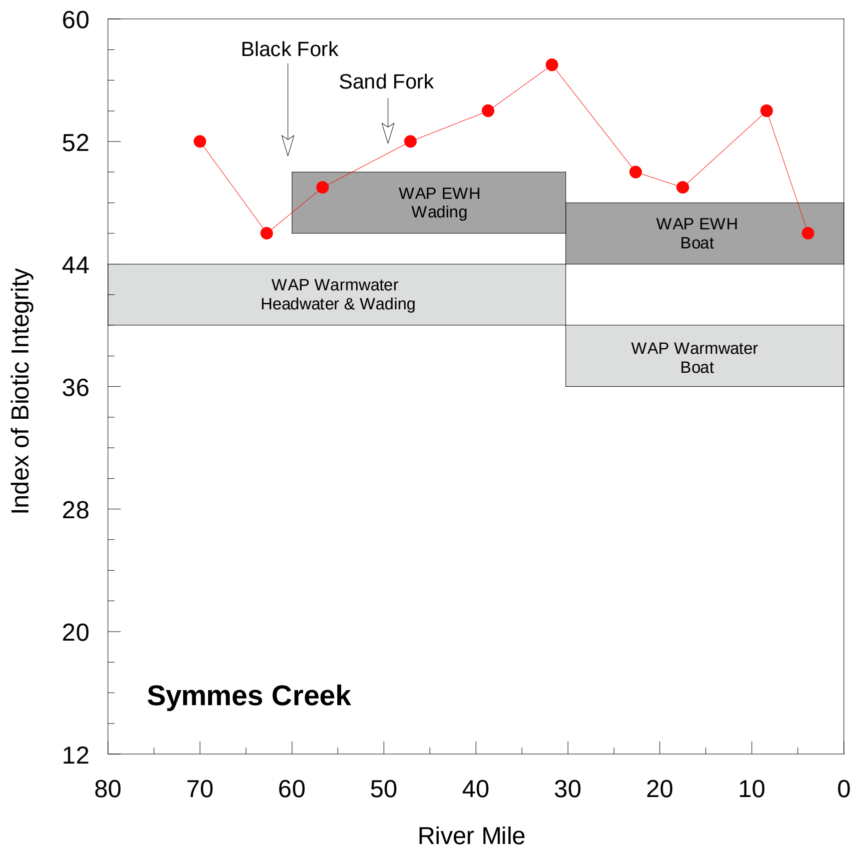
Approximately 67,984 individual fish representing 72 unique species were collected from Symmes Creek, Indian Guyan Creek, and the other direct Ohio River tributaries sampled between June and October 2016 and 2017. The survey effort included 125 fish sampling events from 101 locations. The current survey represented the first comprehensive survey conducted by the Ohio EPA for many of these streams. The survey included the collection of water chemistry, water quality sonde, and other specific types of data detailed in this report. Relative numbers, biomass, species collected per location, and distribution maps are presented in Appendix E. IBI, MIwb, and IBI metric scores are contained in Appendix E. Fish numbers and biomass are standardized to a distance of 0.3 km for headwater and wading sites and 1 km for boat sites; these standardized values will herein be referred to as “relative abundance” and “relative biomass”. All streams in this study area are located in the Western Alleghany Plateau (WAP) ecoregion.

Sampling locations were evaluated using either the WWH or EWH biocriteria. Of the 101 sampling locations where fish data were collected, 91 (90.1 percent) met applicable fish community criteria and ten (9.9 percent) locations did not meet fish community criteria (Table 16). All Symmes Creek and Indian Guyan Creek mainstem locations fully met applicable fish biocriteria (Figure 17, Figure 18, Table 16). Symmes Creek tributaries comprised nine of the ten locations that did not meet applicable fish biocriteria, while the other site was located within the direct Ohio River tributaries portion of the study area (Figure 20).

Average IBI and MIwb scores from both Symmes Creek ($\bar{X}$ =50.9, 10.09) and Indian Guyan Creek ($\bar{X}$ =51.1, 9.46) mainstems indicated exceptional overall performance, with individual scores ranging from very good to exceptional (Figure 17, Figure 18, and Table 16).

Individual IBI scores from tributary streams across all sub-basins ranged from poor to exceptional (Table 16). The ten dominant fish species in terms of proportional abundances and biomass are displayed in Table 15. Additionally, two state listed fish species were collected during the survey, including lake chubsuckers (threatened) at multiple locations throughout the Symmes Creek watershed (Appendix E), and a single juvenile muskellunge (species of concern) specimen collected in Federal Creek RM 0.85 (303589). Lake chubsuckers were collected from two locations in Black Fork RM 5.77 and RM 2.4 (W02S02, 303501), Clear Fork RM 0.7 (303572), Hewitt Run RM 0.75 (303636), Sweetbit Creek RM 0.3 (303637), and Symmes Creek RM 62.76 (300158). Lake chubsuckers rely on permanent wetland-type habitats and are often found in natural lakes and very sluggish streams or marshes with dense aquatic vegetation and clear waters. These complex conditions exist in portions of the upper Symmes Creek watershed (ODNR, 2012). The Symmes Creek watershed accounts for 61 percent of locational sampling records (11 of 18 instances) for the lake chubsucker collected by Ohio EPA since 1979; West Branch Cuyahoga River sub-basin was the second highest (4 of 18 instances).

Fish community performance, collectively, was somewhat lower in the Symmes Creek tributaries compared to the direct Ohio River and Indian Guyan Creek tributaries (Figure 20, Figure 21). However, mean IBI scores for Symmes Creek tributaries were still in the very good range. Fish community performance in Black Fork and Sand Fork ranged from fair to exceptional and only fell short of applicable criteria at one location in Black Fork (Figure 19, Table 16). Overall, fish community performance in Indian Guyan Creek and direct Ohio River tributaries was in the very good to exceptional range, while individual site scores ranged from fair to exceptional (Figure 21, Table 16).



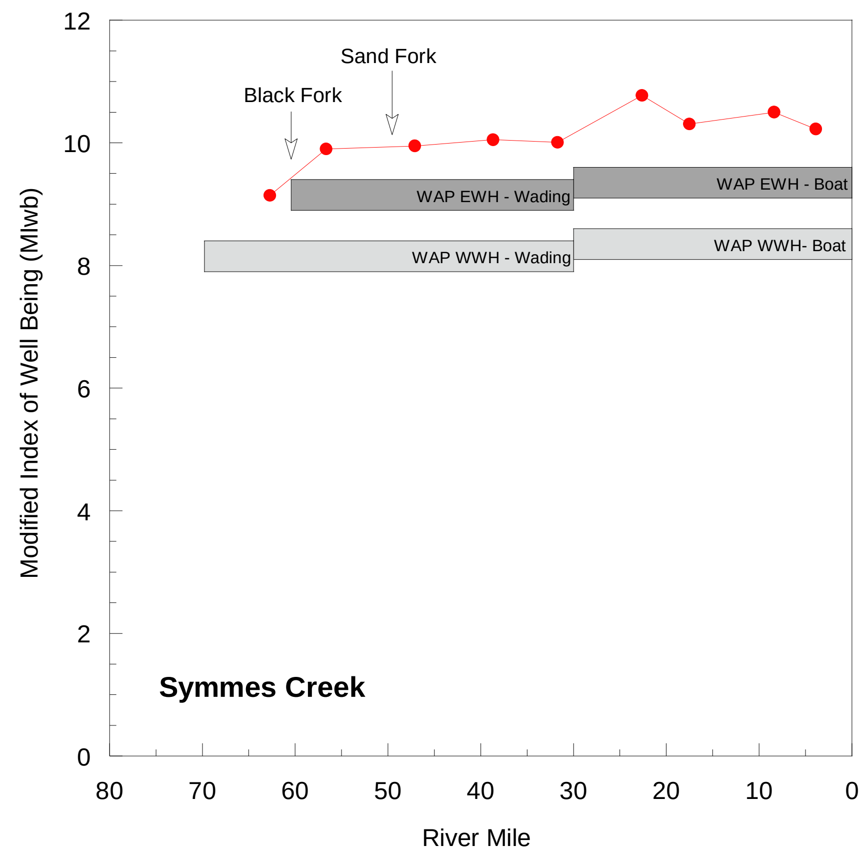


Figure 15—Longitudinal performance of fish community indices from Symmes Creek, 2016. IBI scores are displayed on the left and MIwb scores are displayed on the right. The shaded portions represent applicable biocriteria and areas of non-significant departure from said values.

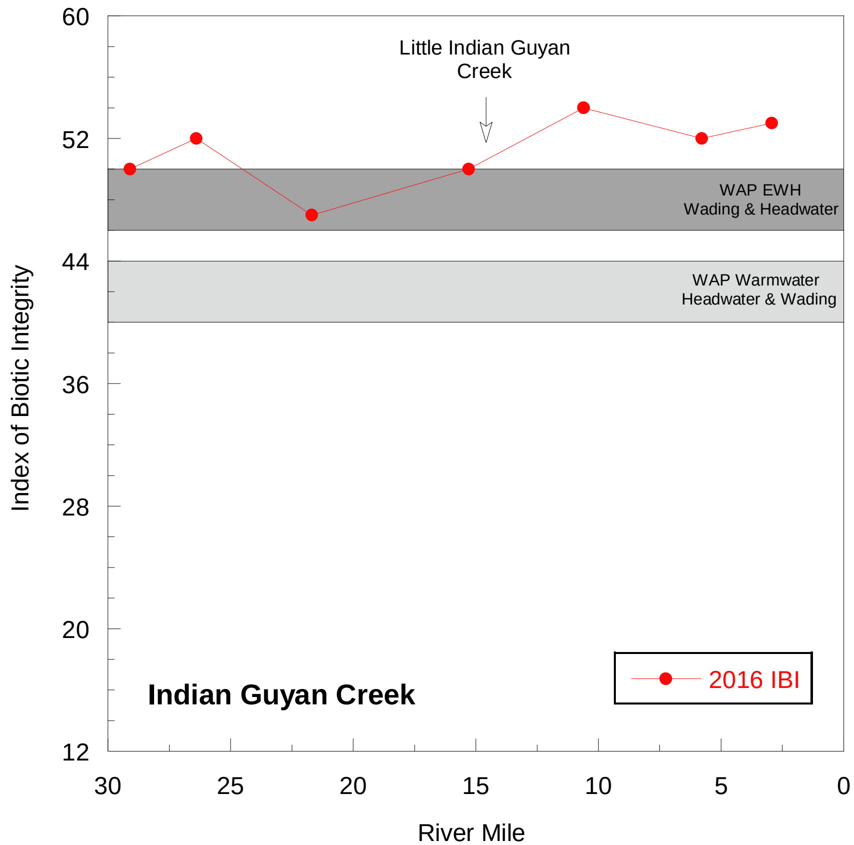


Figure 16—Longitudinal performance of IBI from Indian Guyan Creek, 2016. The shaded portions represent applicable biocriteria and areas of non-significant departure from said values.

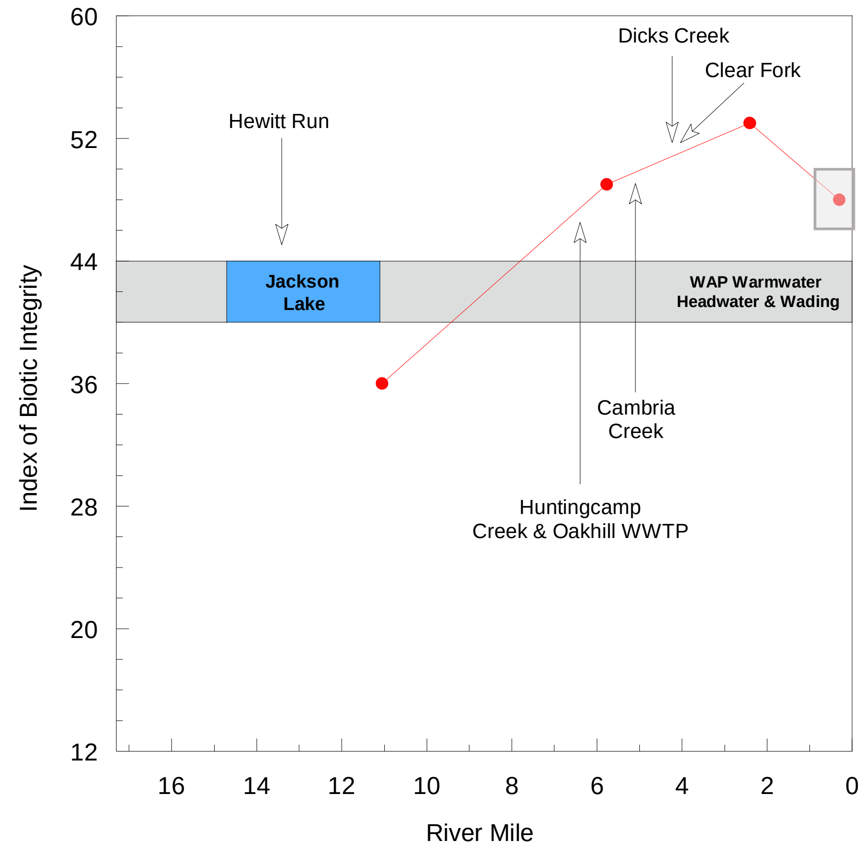


Figure 17—Longitudinal performance of IBI from Black Fork Symmes Creek, 2016. The grey shaded portions represent applicable biocriteria and areas of non-significant departure from said values. The blue shaded region represents the longitudinal extent of Jackson Lake.

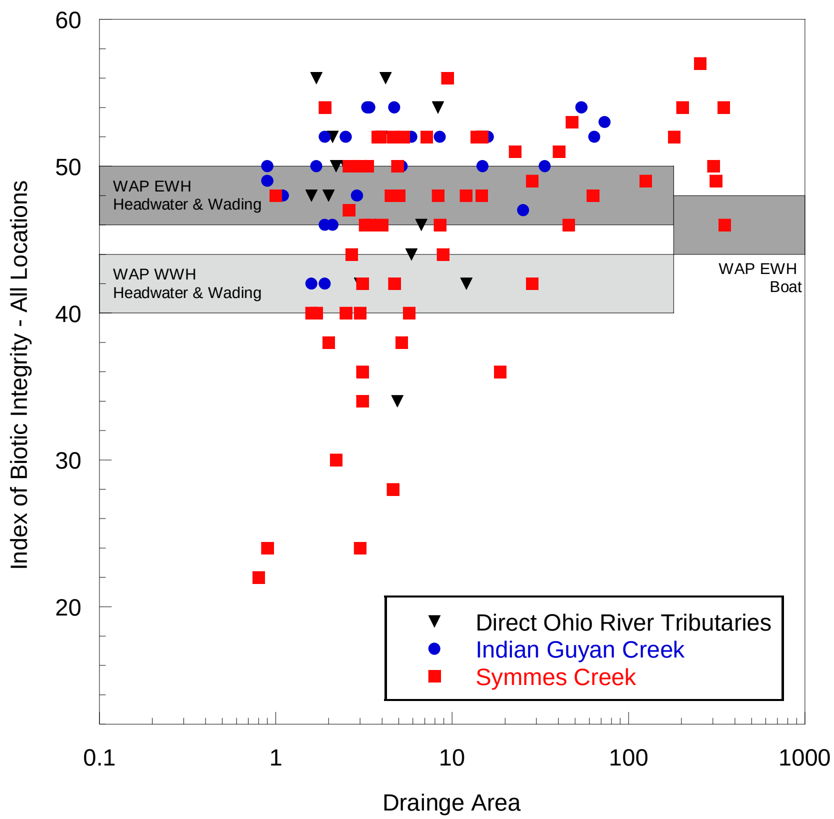


Figure 18—Scatter plot of IBI performance from all streams displayed by drainage area and parsed by major drainage basins. The shaded portions represent applicable biocriteria and areas of non-significant departure from said values.

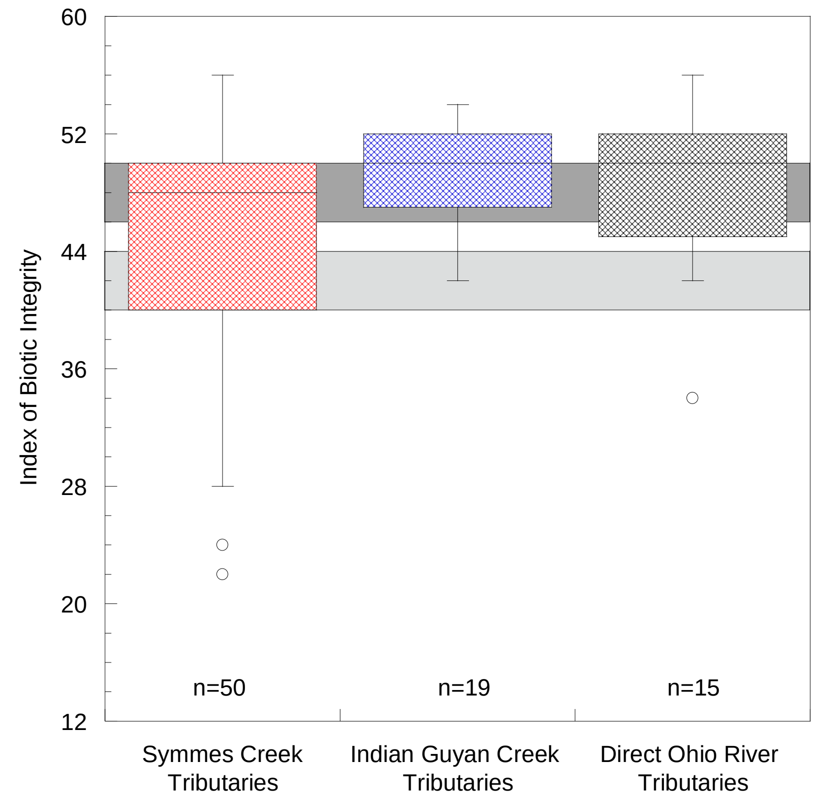


Figure 19—Box plots of IBI performance from tributary streams within the study area parsed by major drainage basin, 2016. The shaded portions represent headwater/wading EWH and WWH criteria, respectively, and areas of non-significant departure from said values

Table 15—Percent abundance and percent of biomass for all fish species collected from all locations during 2016 and 2017 within the indicated waterbodies.

Symmes Creek Mainstem		Symmes Creek Tributaries	Indian Guyan Creek mainstem		Indian Guyan Creek Tributaries	Direct Ohio River Tributaries
% by Number	**% by Weight**	**% by Number**	**% by Number**	**% by Weight**	**% by Number**	**% by Number**
Bluntnose Minnow (10.9%)	Freshwater Drum (19.8%)	Creek Chub (25.9%)	Central Stoneroller (14.6%)	Freshwater Drum (16.1%)	Creek Chub (25.7%)	Central Stoneroller (23.5%)
Longear Sunfish (9.3%)	Golden Redhorse (14.3%)	Striped Shiner (12.5%)	Striped Shiner (12.2%)	Golden Redhorse (14.1%)	Central Stoneroller (24.5%)	Creek Chub (20.6%)
Striped Shiner (8.3%)	Common Carp (11.3%)	Central Stoneroller (10.9%)	Bluntnose Minnow (11.5%)	Northern Hog Sucker (10.1%)	South. Redbelly Dace (8.1%)	Striped Shiner (8.3%)
Golden Redhorse (7.4%)	Silver Redhorse (9.1%)	Bluntnose Minnow (7.7%)	Creek Chub (10.9%)	Spotted Bass (9.1%)	Striped Shiner (8.1%)	Western Blacknose Dace (6.3%)
Emerald Shiner (7.0%)	Gizzard Shad (6.9%)	Fantail Darter (5.6%)	Sand Shiner (6.8%)	Channel Catfish (7.9%)	Western Blacknose Dace (7.4%)	Fantail Darter (5.6%)
Banded Darter (4.3%)	Channel Catfish (5.0%)	Johnny Darter (4.8%)	Silverjaw Minnow (4.8%)	Striped Shiner (6.5%)	Fantail Darter (5.2%)	Bluntnose Minnow (5.3%)
Steelcolor Shiner (3.8%)	Flathead Catfish (4.7%)	South. Redbelly Dace (3.8%)	Fantail Darter (4.7%)	Rock Bass (5.9%)	Silverjaw Minnow (4.9%)	Johnny Darter (5.1%)
Gizzard Shad (3.8%)	Smallmouth Buffalo (4.4%)	White Sucker (3.6%)	Johnny Darter (4.2%)	Longear Sunfish (5.1%)	Bluntnose Minnow (4.2%)	South. Redbelly Dace (4.4%)
Fantail Darter (3.8%)	Longear Sunfish (3.1%)	Longear Sunfish (3.2%)	Greenside Darter (4.1%)	Creek Chub (4.7%)	Johnny Darter (3.5%)	Green Sunfish (4.0%)
Northern Hog Sucker (3.6%)	Spotted Bass (2.9%)	Silverjaw Minnow (3.1%)	Northern Hog Sucker (3.8%)	White Sucker (4.6%)	White Sucker (3.4%)	White Sucker (3.7%)

Table 16—Fish community summaries based on pulsed D.C. electrofishing conducted by Ohio EPA in the Symmes Creek and Indian Guyan Creek watersheds and direct Ohio River tributaries, 2016. IBI and MIwb scores followed by an asterisk (*) indicate scores failed to meet biocriteria for the existing or recommended aquatic life use and "ns" is in non-significant departure of the existing or recommended ALU.

Station	12-digit WAU (05090101)	River Mile	Drainage Area	Cumulative Fish Species & Hybrids	Relative Number	Relative Biomass (kg)	QHEI	IBI	MIwb	Narrative Evaluation (IBI/MIwb)
Symmes Creek (09-700-000)										
303584	08-03	70.0	14.8	21	526	-	81.0	52	-	Exceptional
300158	08-03	64.8	39.4	29	435	19.4	59.75	46	9.14	Very Good/Very Good
200754	09-03	56.7	125.0	38	1293	39.5	83.25	49	9.9	Very Good/Very Good
200753	09-03	47.1	182.0	39	486	22.4	70.0	52	9.95	Exceptional/Exceptional
303500	09-03	38.7	201.9	37	777	14.4	71.0	54	10.05	Exceptional/Exceptional
303533	10-03	31.7	255.3	41	1009	25.4	64.5	57	10.01	Exceptional/Exceptional
300151	10-04	22.6	300.0	44	766	112.3	67.75	50	10.77	Exceptional/Exceptional
303534	10-04	17.5	313.2	41	647	84.6	62.0	49	10.32	Exceptional/Exceptional
200746	10-05	8.4	346.0	36	457	94.3	79.0	54	10.5	Exceptional/Exceptional
303768	10-05	3.9	349.5	41	1120	47.1	77.0	46	10.23	Very Good/Exceptional
Tributary to Symmes Creek (RM 73.03) (09-700-001)										
303577	08-03	0.1	5.7	17	546	-	38.25	40	-	Marginally Good
Sugar Run (09-741-000)										
200756	08-03	0.1	4.7	22	752	-	64.5	42	-	Marginally Good
Cherry Fork (04-062-000)										
303705	08-03	0.4	2.5	17	280	-	60.5	40	-	Marginally Good
Black Fork (09-730-000)										
303576	08-02	11.0	18.7	14	236	-	72.0	36	-	Fair
W02S02	08-02	5.77	28.3	31	612	9.2	70.75	49	9.07	Very Good/Very Good
303501	08-02	2.4	47.6	32	524	10.7	70.0	52	9.23	Exceptional/Very Good
303575	08-02	0.3	62.6	31	586	8.1	70.0	48	9.22	Very Good/Very Good
Hewett Run (09-738-000)										
303575	08-02	0.75	4.6	11	552	-	58.25	28	-	Fair
Huntingcamp Creek (09-735-000)										
W02S06	08-02	1.71	1.8	[11]	[505]	-	[61.5]	40	-	Marginally Good

Station	12-digit WAU (05090101)	River Mile	Drainage Area	Cumulative Fish Species & Hybrids	Relative Number	Relative Biomass (kg)	QHEI	IBI	MIwb	Narrative Evaluation (IBI/MIwb)
W02S03	08-02	1.20	2.4	11	888	-	38.25	30	-	Fair
Cambria Creek (A.K.A. Lefthand Fork) (09-734-000)										
303574	08-02	1.65	7.2	21	618	-	69.0	52	-	Exceptional
Dicks Creek (09-733-000)										
303573	08-02	0.3	3.0	4	30	-	46.0	24	-	Poor
Clear Fork (09-732-000)										
303572	08-02	0.7	3.1	10	242	-	61.25	34	-	Fair
Dirtyface Creek (09-731-000)										
303571	08-01	4.7	3.0	14	876	-	60.5	50	-	Exceptional
300156	08-01	1.82	12.0	27	567	-	70.75	52	-	Exceptional
Sweetbit Creek (09-700-003)										
303637	09-03	0.3	2.0	11	220	-	44.5	38	-	Fair
Wolf Run (09-729-000)										
303570	09-03	0.1	0.9	3	188	-	50.0	24	-	Poor
Sand Fork (09-727-000)										
303569	09-01	15.1	3	13	294	-	65.0	40	-	Marginally Good
303568	09-01	14.85	8.9	16	512	-	62.25	44	-	Good
301798	09-01	13.4	13.8	23	482	-	65.0	52	-	Exceptional
303567	09-01	10.25	28.3	24	796	10.2	66.0	42	8.47	Marginally Good/Good
Sand Fork (09-727-000)										
300154	09-01	2.7	40.4	32	1175	14.2	70.5	51	9.70	Exceptional/Exceptional
Peters Cave Creek (09-728-000)										
303565	09-01	0.2	5.2	18	904	-	51.25	38	-	Fair
Trace Creek (09-726-000)										
303564	09-03	0.55	2.7	18	1160	-	51.0	44	-	Good
Camp Creek (09-725-000)										
303563	09-03	0.65	4.5	17	1860	-	46.75	48	-	Very Good
Little Buffalo Creek (09-724-000)										
303562	09-03	1.2	2.6	14	838	-	56.1	47	-	Very Good

Station	12-digit WAU (05090101)	River Mile	Drainage Area	Cumulative Fish Species & Hybrids	Relative Number	Relative Biomass (kg)	QHEI	IBI	MIwb	Narrative Evaluation (IBI/MIwb)
Buffalo Creek (09-719-000)										
[200752]	09-02	[5]	[3.1]	[14]	[585]	-	[72.75]	[42]	-	Marginally Good
200752	09-02	5	3.1	9	708	-	67.0	36	-	Fair
Buffalo Creek (09-719-000)										
W02S09	09-02	1.91	8.5	18	801	-	60.6	46	-	Very Good
Indian Creek (09-723-000)										
303560	09-02	0.05	0.8	2	44	-	66.0	22	-	Poor
Caulley Creek (09-720-000)										
W02S01	09-02	0.15	4.9	18	992	-	57.25	52	-	Exceptional
Miller Creek (09-721-000)										
303559	09-02	0.05	1.0	9	758	-	71.5	48	-	Very Good
Pigeon Creek (09-718-000)										
303558	10-03	0.55	3.2	18	720	-	50.0	46	-	Very Good
Johns Creek (09-714-000)										
303557	10-01	5.35	9.4	23	1296	-	79.25	56	-	Exceptional
300153	10-01	0.07	22.7	25	875	3.9	72.50	51	8.39	Exceptional/Good
Slab Fork (09-717-000)										
303556	10-01	0.1	2.6	13	1418	-	73.0	50	-	Exceptional
Buckeye Creek (09-715-000)										
303555	10-01	1.4	3.4	17	534	-	76.75	46	-	Very Good
Brushy Buckeye Creek (09-716-000)										
303554	10-01	0.1	1.9	13	624	-	77.25	54	-	Exceptional
Handley Branch (09-714-001)										
303553	10-01	0.1	1.7	12	402	-	50.5	40	-	Marginally Good
Buck Creek (09-713-000)										
303552	10-03	0.35	5.0	18	1538	-	60.0	48	-	Very Good
Long Creek (09-711-000)										
303551	10-02	4.3	5.3	19	2670	-	67.50	52	-	Exceptional
303536	10-02	0.86	14.7	22	1490	-	65.25	48	-	Very Good

Station	12-digit WAU (05090101)	River Mile	Drainage Area	Cumulative Fish Species & Hybrids	Relative Number	Relative Biomass (kg)	QHEI	IBI	MIwb	Narrative Evaluation (IBI/MIwb)
Buckeye Creek (09-712-000)										
303550	10-02	0.9	3.8	17	1094	-	74.50	52	-	Exceptional
Aaron Creek (09-710-000)										
303549	10-04	0.65	8.3	20	906	-	64.25	48	-	Very Good
Elkins Creek (09-709-000)										
303548	10-04	1.8	3.3	17	2114	-	78.25	50	-	Exceptional
Sharps Creek (09-708-000)										
303547	10-04	0.20	4.6	21	1130	-	69.5	52	-	Exceptional
Venisonham Creek (09-705-000)										
303546	10-04	0.95	3.9	21	1012	-	72.25	52	-	Exceptional
Leatherwood Creek (09-704-000)										
200747	10-04	0.8	4.0	16	1024	-	67.75	46	-	Very Good
Rankin Creek (09-703-000)										
303545	10-05	0.55	3.9	14	1878	-	78.0	52	-	Exceptional
McKinney Creek (09-702-000)										
303544	10-05	0.35	5.0	22	770	-	69.75	48	-	Very Good
Big Branch Creek (09-701-000)										
303540	10-05	0.55	3.0	14	1708	-	75.5	50	-	Exceptional
Indian Guyan Creek (09-701-000)										
303663	07-07	29.05	5.2	16	1706	-	72.25	50	-	Exceptional
W02K05	07-07	26.4	16.0	24	2110	-	70.75	52	-	Exceptional
303539	07-07	21.7	25.4	24	1282.5	12.2	77.5	47	9.10	Very Good/Very Good
W02K04	07-07	15.3	33.6	29	1128	10.0	68.75	50	9.42	Exceptional/ Exceptional
303675	07-08	10.6	54.1	32	1023	14.7	73.6	54	9.80	Exceptional/ Exceptional
W02S08	07-08	5.76	64.0	31	874	16.4	81.0	52	9.90	Exceptional/Exceptional
609150	07-08	2.95	73.3	34	607	9.0	73.0	53	9.10	Exceptional
Perigen Creek (09-115-000)										
303664	07-07	0.1	2.1	10	1034	-	70.50	46	-	Very Good

Station	12-digit WAU (05090101)	River Mile	Drainage Area	Cumulative Fish Species & Hybrids	Relative Number	Relative Biomass (kg)	QHEI	IBI	MIwb	Narrative Evaluation (IBI/MIwb)
Drake Fork (09-114-000)										
303669	07-07	0.3	2.5	21	1368	-	73.25	52	-	Exceptional
Trib. to Drake Fork (RM 0.55) (09-114-001)										
303670	07-07	0.05	0.9	11	1824	-	64.50	50	-	Exceptional
Johns Creek (09-113-000)										
303668	07-07	0.1	1.9	12	832	-	59.0	42	-	Marginally Good
Rocky Fork (09-114-000)										
303667	07-07	0.1	3.4	17	3216	-	62.50	54	-	Exceptional
Lanes Branch (09-111-000)										
303662	07-07	0.1	1.6	12	910	-	38.0	42	-	Marginally Good
Georges Creek (09-110-000)										
303659	07-07	0.05	1.9	13	2576	-	62.0	52	-	Exceptional
Williams Creek (09-116-000)										
303657	07-07	1.55	0.9	11	1659	-	66	49	-	Very Good
303656	07-07	0.05	3.2	13	1684	-	64.25	50	-	Exceptional
Little Indian Guyan Creek (09-108-000)										
303652	07-06	2.7	5.9	21	1559	-	67.75	52	-	Exceptional
303596	07-06	1.65	8.5	18	1170	-	57.25	52	-	Exceptional
303532	07-06	0.13	14.9	18	1016	-	74.0	50	-	Exceptional
Watson Creek (09-108-002)										
303650	07-06	0.05	1.7	15	1020	-	76.25	50	-	Exceptional
Trace Creek (09-108-001)										
303648	07-06	0.10	3.7	17	978	-	68.75	46	-	Very Good
Wolf Creek (09-106-000)										
303676	07-08	0.35	4.7	19	1365	-	74.75	54	-	Exceptional
Slate Run (09-105-000)										
303647	07-08	0.40	1.1	13	1050	-	49.0	48	-	Exceptional
Fivemile Creek (09-104-000)										
303594	07-08	0.30	3.3	20	1736	-	60.75	54	-	Exceptional

Station	12-digit WAU (05090101)	River Mile	Drainage Area	Cumulative Fish Species & Hybrids	Relative Number	Relative Biomass (kg)	QHEI	IBI	MIwb	Narrative Evaluation (IBI/MIwb)
Bear Creek (09-102-000)										
303593	07-08	0.05	2.9	19	1148	-	74.50	48	-	Very Good
Bent Creek (09-101-000)										
303592	07-08	0.05	1.9	14	900	-	62.75	46	-	Very Good
Direct Ohio River Tributaries										
Buffalo Creek (09-020-000)										
303531	10-07	1.1	6.7	19	1488	-	73.0	46	-	Very Good
Scarey Creek (09-020-001)										
303583	10-07	0.15	2.1	10	1512	-	55.0	52	-	Exceptional
Paddy Creek (09-021-000)										
303591	07-09	1.65	4.9	16	382	-	56.0	34	-	Fair
Little Paddy Creek (09-021-001)										
303590	07-09	0.40	2.0	24	1008	-	68.5	48	-	Very Good
Twomile Creek (09-022-000)										
303645	07-09	1.45	3.0	14	386	-	54.0	42	-	Marginally Good
Federal Creek (09-023-000)										
303589	07-09	0.85	4.0	19	1135	-	66.25	52	-	Exceptional
Clean Fork (09-024-000)										
303588	07-09	0.10	1.7	18	1470	-	67.5	56	-	Exceptional
Big Creek (09-095-000)										
303643	07-09	0.68	1.6	14	1305	-	65.5	48	-	Very Good
Swan Creek (09-027-000)										
303641	07-03	4.25	8.3	18	1642	-	74.5	54	-	Exceptional
303527	07-03	2.35	14.7	24	1064	-	63.75	52	-	Exceptional
Trib. to Swan Creek (RM 5.95) (09-028-001)										
303638	07-03	0.50	2.2	14	2246	-	70.0	50	-	Exceptional
Little Swan Creek (09-028-000)										
303587	07-03	0.05	4.2	15	1266	-	70.75	56	-	Exceptional

Station	12-digit WAU (05090101)	River Mile	Drainage Area	Cumulative Fish Species & Hybrids	Relative Number	Relative Biomass (kg)	QHEI	IBI	MIwb	Narrative Evaluation (IBI/MIwb)
Teens Run (09-031-000)										
303586	07-07	1.20	2.5	16	1496	-	48.5	50	-	Exceptional
Chickamauga Creek (09-037-000)										
300742	01-01	5.0	12.1	19	510	-	65.0	42	-	Marginally Good
Little Chickamauga Creek (09-039-000)										
W03S19	01-01	0.16	5.9	16	1144	-	64.75	44	-	Good

Macroinvertebrate Community

This section is a summary of the macroinvertebrate data collected for the Symmes Creek, Indian Guyan Creek and the direct Ohio River tributaries in 2016-2017. The full macroinvertebrate community report is available in Appendix B and D, the individual macroinvertebrate site data is in Appendix B and ICI summary data are presented in Appendix C. A total of 96 sites were evaluated for aquatic life use (ALU) verification and attainment in 2016-17 (Table 18). In the aggregate total, 86 of 96 macroinvertebrate community sample sites fully attained (~90 percent = FULL) the existing or recommended ALU biocriterion designated with 10 percent of sites in Non-attainment.

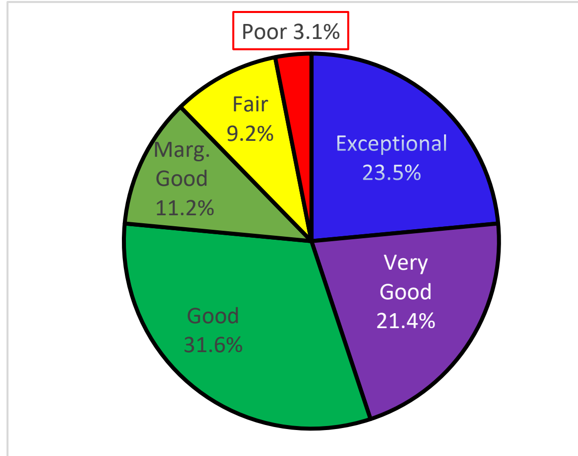


Figure 20—Percentages of macroinvertebrate community quality narrative evaluations for 98 sampled stream reaches in Symmes Creek Basin, Indian Guyan Creek Basin, and select Direct Ohio River Tributaries, 2016-17.

Among the total attaining sample sites, 23 sampled stations were exceptional (E), and 21 sites were assessed as very good (VG) quality communities. Good (G) quality communities were documented at 31 sites, while eleven sample sites were documented with marginally good (MG) quality communities (Figure 22).

There were nine fair quality community sample sites that did not meet the WWH biocriterion. There were three poor quality sample sites that caused non-attainment (Figure 22, Table 18). Six of nine impaired fair quality, and two of three poor quality macrobenthic communities sampled were in the Symmes Creek sub-basin. One impaired (poor) site was sampled in the Indian Guyan Creek sub-basin. Two direct Ohio River tributary sample sites were also impaired as documented by a fair quality macroinvertebrate community.

The 2016-2017 survey of Symmes Creek was the first comprehensive watershed survey in Symmes Creek, Indian Guyan Creek and direct Ohio River tributaries conducted by Ohio EPA. Historically, only four previous macroinvertebrate samples were collected by Ohio EPA in the Symmes Creek watershed which included Symmes Creek mainstem at RM 8.4 (1990), Buffalo Creek at RM 1.90 (1990), and Caulley Creek at RM 0.2 in 1984 and 1990. Only one location on Indian Guyan Creek at RM 1.7 was sampled in 1990.

Among the sensitive taxa collected were freshwater mussels. The last mussel survey of the Symmes Creek mains stem was conducted in 2004-05 (Hoggarth, Kimberly, & Allan, 2007). Eighteen species were collected in the mainstem of Symmes Creek in 2004-05, including one live Northern Spectaclecase (Villosa lienosa) – a state endangered (SE) species with lower numbers than recorded earlier (Watters 1992). Eleven mussel taxa were collected during the OEPA 2016-17 survey among the nine mainstem sites during macroinvertebrate sampling. Ten of the previously documented 23 species historically present were again collected among our nine mainstem sample sites. One new mussel species was documented in the Symmes

Creek mainstem during the 2016-2017 survey. The Deertoe mussel (*Truncilla truncata*), a SE mussel species, was collected near St. Rt. 141 at Aid (RM 22.9). The Deertoe and the Wabash Pigtoe (*Fusconaia flava*) mussels were found only as fresh dead specimens during the 2016-17 survey. The sampled reaches in 2016-17 with the highest mussel species diversity were found in the Wayne National Forest (RM 56.7) and near Aid (RM 22.9). Other documented mussel species collected were listed below in Table 17 .

Table 17—Freshwater mussels collected in Symmes Creek basin during OEPA 2016-17 survey (live or fresh dead). MI is moderately intolerant and SC is Species of Concern in Ohio.

Mussel Taxa	Common Name	Tol. Category	Collection Location by River Mile
Amblem plicata	Threeridge	MI	Symmes Creek (56.7)
Fusconaia flava	Wabash Pigtoe	MI	Symmes Creek (22.9) (fresh dead only observed)
Lampsilis cardium	Plain Pocketbook	MI	Symmes Creek (56.7)
Lampsilis siliquoidea	Fatmucket	MI	Symmes Creek (64.8, 56.7, 22.9), Long Creek (0.86)
Lasmigona complanate	White Heelsplitter	MI	Symmes Creek (56.7)
Leptodea fragilis	Fragile Papershell	MI	Symmes Creek (64.8, 56.7, 31.15, 22.9), Black Fork (5.8, 2.9)
Potamilus alatus	Pink Heelsplitter	MI	Symmes Creek (22.9)
Pyganodon grandis	Giant Floater	F	Symmes Creek (56.7)
Tritogonia verrucose	Pistolgrip	MI	Symmes Creek (56.7, 36.85, 22.9, 8.4)
Truncilla truncata	Deertoe	MI (SC)	Symmes Creek (22.9) (fresh dead only observed)
Quadrula quadrula	Mapleleaf	MI	Symmes Creek (22.9)

Among the Symmes Creek tributaries sampled, mussels were documented at only these three sample sites: in Black Fork at RMs 5.8 and 2.9 and in Long Creek at Zalmon Rd. (RM 0.86). Some Fragile Papershell mussels (*Leptodea fragilis*), present in 1987 but not collected in the 2004-05 survey, were again found in Black Fork during the 2016 survey in sampled reaches where the stream was larger with more stable volume – over 28 and 47 square miles, respectively. The Fatmucket (*Lampsilis siliquoidea*), a common MI mussel in the Symmes Creek basin, was collected in Long Creek near the mouth (14.7 $mi.^2$).

Table 18—Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in selected Symmes Creek, Indian Guyan Creek, and other direct Ohio River tributary survey samples. Survey sampling at sites were from June to September 2016, with follow-up samples June to September 2017 noted. The watershed survey area was located entirely within the Western Alleghany Plateau (WAP) ecoregion[A]. (River Mile (RM) and Drainage Area (DA) in parentheses are the Point of Record).

Station	RM	DA (mi.^{2})	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Symmes Creek (09-700-000)													
303584	69.95 (70.0)	14.8	50	32	32	9 / 10	4 / 4	0	6	M/218	*Chimarra* (MI) and hydropsychid caddisflies (F)	42	-
300158	62.7	39.4	46	-	46	14 / 14	12 / 12	0	9	M	Hydropsychid caddisflies (F)	(-) X12	Good
200754	56.7	125	81	43	63	20 / 23	19 / 23	0	8	M - H / 1565	*Rheotanytarsus* sp. midges, hydropsychid caddisflies (F), fingernail clams (F), *Stenacron* sp. (F), sensitive heptageniid and *Isonychia* sp. mayflies (MI)	50	-
200753	47.1 **2017**	182	63	26	58	22 / 22	17 / 18	0	8	M - H / 1106	Baetid (F,MI), *Isonychia* sp. mayflies (MI), and hydropsychid caddisflies (F, MI)	42	-
303500	36.85 (38.7)	221 (201.9)	75	42	57	22 / 23	20 / 21	0	6	M / 464	*Isonychia* sp. (MI), *Macaffertium* spp. (MI), and baetid mayflies (F, MI)	50	-
303533	31.15 (31.7)	276.1 (255.3)	67	44	46	22 / 22	19 / 23	1	6	M / 258	*Isonychia* sp. and *Macaffertium* spp. mayflies (MI) and hydropsychid caddisflies (F, MI)	50	-
300151	22.9 (22.6)	301	74	38	56	16 / 20	22 / 26	1	10	M / 496	*Isonychia* sp. and heptageneid (*Macaffertium* spp. and *Leucrocuta* sp.) mayflies (MI)	52	-
200746	8.4	346	82	60	47	20 / 27	23 / 31	3	4	M - H / 571	*Isonychia* sp. and *Macaffertium* spp. mayflies (MI)	46	-
303768	5.0 (3.9)	349	63	44	42	19 / 20	19 / 21	0	6	M/771	*Isonychia* sp. mayflies (MI), *Chimarra* caddisflies (MI)	48	-
Tributary to Symmes Creek (RM 73.03) (09-700-001)													
303577	0.1	5.7	39	-	39	4 / 4	1 / 1	0	23	M - H	Fingernail clams (F), burrowing mayfly (*Hexagenia bilineata*) (F), beetles (F, MT, T), scuds (F, MT), hemipterans (MT, T)	-	Fair

Station	RM	DA (mi.^{2})	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Sugar Run (09-741-000)													
200756	0.01	4.7	-	-	-	-	-	-	-	-	Not Sampled – Dry on 9/6/16	-	-
Cherry Fork (04-062-000)													
303705	0.4	2.5	39	-	39	6 / 6	1 / 1	0	17	M - L	*Paraleptophlebia* sp. (F/MI), midges (F, MT, T)	-	Fair
Black Fork (09-730-000)													
303576	11.05 (11.0)	18.7	35	-	35	6 / 6	1 / 1	0	16	M - L	Midges (F, MT, T), Caenis sp. mayflies (F)	-	Fair
W02S02	5.8 (5.77)	28.3	50	-	50	10 / 10	8 / 8	0	16	M - L	Hydropsychid caddisflies (F), heptageneid mayflies (F), fingernail clams (F, MT, T)	-	Good
303501	2.9 (2.4)	47.6	38	-	38	12 / 12	10 / 10	0	7	M - L	Hydropsychid caddisflies (F)	-	Good
303575	0.2 (0.1)	62.6	64	38	45	16 / 20	13 / 17	0	6	M / 299	*Isonychia* sp. (MI), *Macaffertium* (MI) & *Stenacron* spp.(F) mayflies, hydropsychid caddisflies (F)	52	-
Hewett Run (09-738-000)													
303636	0.75	4.6	40	-	40	6 / 6	3 / 3	0	14	M - H	Haliplid beetles (MT)	-	Fair
Huntingcamp Creek (09-735-000)													
W02S06	1.75 (1.71)	1.6 (1.8)	30	20	23	2 / 2	0 / 0	1	10	M - L	Hydropsychid caddisflies (F), midges (F, MT, T)	26	-
W02S03	1.45 (1.20)	1.7 (1.20)	27	16	22	1 / 1	0 / 0	1	13	H - M / 448	Midges (T, F, MT)	-	Poor
Cambria Creek (A.K.A. Lefthand Fork) (09-734-000)													
303574	1.65	7.2	46	-	46	13 / 13	12 / 12	0	8	M – L	Flathead mayfly *Macaffertium vicarium* (MI), *Helichus sp*. beetles, *Chimarra spp*. caddisflies (mostly *C. aterrima*) (MI), & dragonfly larvae (F,MT)	-	Good
Dicks Creek (09-733-000)													
303573	0.3	3.0	21	-	21	0 / 0	1 / 1	0	10	Low	Damselflies (F), isopods (T), fingernail clams (F)	-	Poor

Station	RM	DA (mi.²)	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Clear Fork (09-732-000)													
303572	0.7	3.1	22	-	22	2 / 2	2 / 2	0	9	Low	Damselflies (F,MT,T), dragonflies (F,MT), scuds (F)	-	Fair
Dirtyface Creek (09-731-000)													
303571	4.7	3.0	46	-	46	15 / 15	10 / 10	1	8	Low	*Helichus sp*. beetles (F), *Paraleptophlebia sp*. mayflies (F), dragonflies (F,MT)	-	Very Good
300156	1.82	12.0	44	-	44	12 / 12	9 / 9	0	12	Low	*Midges* (F,MT)	-	Good
Sweetbit Creek (09-700-003)													
303637	0.3	2.0	60	-	60	9 / 9	5 / 5	3	22	M - L	Midges (F,MI,CW,MT,T), Leptophlebiid mayflies (F,MI), fingernail clams (F,MT), *Cheumatopsyche sp*. (F)	-	Good
Wolf Run (09-729-000)													
303570	0.1	0.9	43	-	43	4 / 4	4 / 4	1	15	Low	Hydropsychid caddisflies (F), midges (F,MT,T)	-	Fair
Sand Fork (09-727-000)													
303569	15.1	3.0	37	-	37	8 / 8	7 / 7	0	6	Low	Midges (F,MT,T), hydropsychid caddisflies (F)	-	Marginally Good
303568	14.85 (14.9)	8.9	45	-	45	12 / 12	11 / 11	0	9	Low	Midges (F,MT,T), baetid mayflies (genera – *Paracloeodes*, *Procloeon*, and *Neocloeon*) (MI)	-	Good
301798	13.4	13.8	61	41	40	15 / 22	11 / 16	0	8	M - L / 484	Margin baetids (MI), *Corbicula fluminea* (F), *Baetisca sp*. mayfly (MI), elmid and *Helichus* sp. beetles (F)	48	-
303567	10.25	28.3	38	-	38	17 / 17	14 / 14	0	3	M - L	Hydropsychid (F) and *Chimarra* spp. caddisflies (MI), baetid mayflies (F,MI), *Corbicula fluminea* (F), *Dubiraphia* sp. beetles (F)	(-) X17	Very Good
Sand Fork (09-727-000)													
300154	3.3 (2.7)	40.0	76	44	51	16 / 22	15 / 18	0	7	M - L / 455	Hydropsychid caddisflies (F), *Sphaerium* sp. (F)	(44) X15	Exceptional
Peters Cave Creek (09-728-000)													
303565	0.2	5.2	57	-	57	17 / 17	12 / 12	1	12	Mod.	Midges (F,MT,T), *Caenis* sp. mayflies (F)	-	Very Good

Station	RM	DA (mi.²)	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Trace Creek (09-726-000)													
303564	0.55	2.7	44	-	44	8 / 8	6 / 6	1	13	M - L	Hydropsychid caddisflies (F), midges (F,MT,T), *Caenis* mayflies (F)	-	Marginally Good
Camp Creek (09-725-000)													
303563	0.65	4.5	49	-	49	17 / 17	10 / 10	2	11	M - L	Hydropsychid caddisflies (F), baetid mayflies (F,MI), heptageneid mayflies (F,MI)	-	Very Good
Little Buffalo Creek (09-724-000)													
303562	1.2 **2017**	2.6	49	-	49	17 / 17	13 / 13	3	11	M - L	*Paraleptophlebia* sp. & margin baetids (F,MI), Beetles (*Helichus*, *Stenelmis,* + others) (F,MT,T), *Caenis* sp.(F), dragonflies & crayfish (MT,F+ St. E.[b]/Special Interest)	-	Very Good
Buffalo Creek (09-719-000)													
200752	5.55 (5.0)	3.0	39	-	39	13 / 13	10 / 10	1	4	M - L	*Helichus* sp. beetles (F), margin baetid & *Paraleptophlebia* sp.(F)	-	Good
200752	5.15 **2017**	3.1 (3.0)	49	-	46	14 / 14	12 / 12	1	10	M - L	*Perlesta* sp. stoneflies (F), *Helichus* sp. beetles (F), mayflies (F,MI)	-	Good
W02S09	1.9 (1.91)	8.5	56	-	56	18 / 18	14 / 14	1	11	M - L	Hydropsychids (F), *Helichus* sp. (F), *Isonychia* sp. (MI)	-	Exceptional
Caulley Creek (09-720-000)													
W02S01	0.15	4.9	56	-	56	19 / 19	19 / 19	0	3	Mod.	*Isonychia* sp. mayflies (MI), hydropsychids (F)	-	Exceptional
Miller Creek (09-721-000)													
303559	0.05	1.0	34	-	34	7 / 7	7 / 7	2	6	Low	*Helichus* sp. beetles (F), heptageniid (F,MI), burrowing (MI) & *Caenis* sp. mayflies (F)	-	Good
303559	0.05 **2017**	1.0	35	-	35	13 / 13	7 / 7	1	10	M – L	*Helichus* sp. beetles (F), crayfish (MT), *Paraleptophlebia* sp. (F) and baetid mayflies (MI,F,I)	-	Good

Station	RM	DA (mi.^{2})	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Pigeon Creek (09-718-000)													
303558	0.55	3.2	41	-	41	10 / 10	9 / 9	2	8	M - L	Hydropsychid caddisflies (F), *Helichus* sp. beetles (F), riffle beetles (F), *Stenonema femoratum* mayflies (F)	-	Good
Johns Creek (09-714-000)													
303557	5.35	9.4	46	-	46	11 / 11	11 / 11	0	8	M - L	*Isonychia* sp. mayflies (MI), *Macaffertium vicarium* mayflies (MI), hydropsychid caddisflies (F)	-	Good
300153	0.07	22.7	42	-	42	15 / 15	11 / 11	0	6	M - L	Baetid mayflies (MI,I), *Stenacron* sp. and *Macaff.* vicarium mayflies (F,MI), *Helichus* sp. beetles	-	Very Good
Slab Fork (09-717-000)													
303556	0.45 (0.10)	2.6	39	-	39	15 / 15	11 / 11	1	5	Mod.	*Chimarra aterrima* caddisflies (MI), *Isonychia* sp. mayflies (MI), hydropsychid caddisflies (F), *Macaffertium vicarium* mayflies (MI)	-	Very Good
Buckeye Creek (09-715-000)													
303555	1.45 (1.40)	3.4	45	-	45	13 / 13	8 / 8	1	11	M - L	Hydropsychid (F) and *Chimarra* spp. caddisflies (MI)	-	Good
Brushy Buckeye Creek (09-716-000)													
303554	0.1	1.9	38	-	38	12 / 12	11 / 11	1	4	Low	*Helichus* sp. beetles (F), hydropsychids (F), baetids (MI)	-	Good
Handley Branch (09-714-001)													
303553	0.1	1.7	33	-	33	10 / 10	7 / 7	2	8	Low	Mayflies (*Stenonema femoratum*, *Paraleptophlebia* sp., *Caenis* sp., (F), *Neocloeon* sp. (MI)), midges (F,T)	-	Good
Buck Creek (09-713-000)													
303552	0.35	5.0	58	-	58	20 / 20	14 / 14	0	14	Mod.	Baetid (MI,F,I), heptageniid & *Caenis* sp. mayflies (F)	-	Exceptional
Long Creek (09-711-000)													
303551	4.3	5.3	32	-	32	12 / 12	7 / 7	0	6	Mod.	Hydropsychid caddisflies (F), *Caenis* sp. mayflies (F), baetid mayflies (MI)	-	Good

Station	RM	DA (mi.^{2})	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
303536	0.86	14.7	73	42	48	18 / 19	16 / 18	1	8	Mod.	*Isonychia* sp. mayflies (MI), baetid mayflies (MI,F), *Caenis* sp. mayflies (F), Asian clams (F)	42	-
Buckeye Creek (09-712-000)													
303550	0.9	3.8	33	-	33	14 / 14	9 / 9	0	3	Mod.	Baetid mayflies (F,MI), *Chimarra* spp. caddisflies (MI)	-	Very Good
Aaron Creek (09-710-000)													
303549	0.65	8.3	30	-	30	12 / 12	8 / 8	1	4	Mod.	Hydropsychid (F), *Chimarra obscura* caddisflies (MI), *Caenis* sp. mayflies (F), midges (F,MI,T)	-	Good
Elkins Creek (09-709-000)													
303548	1.8	3.3	36	-	36	9 / 9	9 / 9	1	4	M - L	*Rheotanytarsus* sp. & other midges (F,CW,MI,T), hydropsychid caddisflies (F), baetid mayflies (F,MI), *Caenis* sp. mayflies (F)	-	Good
Sharps Creek (09-708-000)													
303547	0.2	4.6	55	-	55	14 / 14	10 / 10	0	8	M - L	Hydropsychids (F), heptageniid & *Caenis* sp. mayflies including *Macaff. vicarium* (MI,F), midges (F,MI,T)	-	Very Good
Venisonham Creek (09-705-000)													
303546	0.95	3.9	40	-	40	11 / 11	6 / 6	0	7	M - L	Hydropsychid caddisflies (F), heptageniid & *Caenis* sp. mayflies including *Macaff. vicarium* (MI,F)	-	Good
Leatherwood Creek (09-704-000)													
200747	0.8	4.0	46	-	46	14 / 14	10 / 10	2	9	Mod.	Baetid (MI,F), heptageniid & *Caenis* sp. mayflies (F)	-	Very Good
Rankin Creek (09-703-000)													
303545	0.55	3.9	45	-	45	15 / 15	12 / 12	0	8	Mod.	*Isonychia* sp. mayflies (MI), baetid mayflies (MI,F), *Stenonema femoratum* and *Caenis* sp. mayflies (F)	-	Very Good
McKinney Creek (09-702-000)													
303544	0.35	5.0	26	-	26	9 / 9	6 / 6	0	2	M – L	*Isonychia* sp. mayflies (MI), hydropsychid caddisflies (F), *Caenis* sp. mayflies (F)	-	Marginally Good

Station	RM	DA (mi.²)	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Big Branch Creek (09-701-000)													
303540	0.75	3.0	29	-	29	7 / 7	3 / 3	3	5	M – L	Hydropsychid caddisflies (F,CW), midges (F,T)	-	Marginally Good
Indian Guyan Creek Basin													
Indian Guyan Creek (09-701-000)													
303663	29.05 (29.1)	5.2	59	-	59	19 / 19	13 / 13	0	10	Mod.	Hydropsychid caddisflies (F,MI), heptageniid (with *Macaff. vicarium*) (MI,F) and baetid mayflies (F,MI,I)	-	Exceptional
W02K05	26.4	16.0	78	53	50	15 / 20	12 / 19	1	6	M – L / 310	*Chimarra* spp. and hydropsychid caddisflies (MI,F), *Helichus* sp. beetles (F), *Stenonema femoratum* (F), midges (F,MI,T)	46	-
303539	21.65 (21.7) **2017**	25.4	66	43	37	15 / 20	12 / 20	1	4	M – L / 296	Hydropsychid caddisflies (F), baetid mayflies (MI,F,I)	48	-
W2K04	15.3	33.6	44	-	44	19 / 19	16 / 16	0	7	Mod.	*Isonychia* sp. (MI) and heptageneid (MI,F) mayflies	(-) X12	Exceptional
303675	10.6	54.1	37	-	37	18 / 18	13 / 13	0	4	Mod.	*Isonychia* sp. (MI), baetid mayflies (F,MI)	(-) X12	Exceptional
W02S08	5.76	64.0	68	47	35	18 / 22	16 / 21	3	5	M – L / 451	*Isonychia* sp. (MI), *Macaffertium* spp., and baetid mayflies (MI,F), hydropsychid caddisflies (F)	54	-
609150	2.4 (2.95)	73.3	79	57	42	21 / 28	17 / 24	2	3	M – L / 474	*Isonychia* sp. (MI), baetid mayflies (F,MI), *Baetisca* sp. mayflies (MI), *Corbicula fluminea* clams (F)	48	-
Perigen Creek (09-115-000)													
303664	0.1	2.1	30	-	30	9 / 9	10 / 10	3	5	M - L	Heptageniid mayflies (F,MI) & *Caenis* sp. mayflies (F)	-	Good
Drake Fork (09-114-000)													
303669	0.27 (0.30)	2.5	42	-	42	11 / 11	7 / 7	0	8	M - L	Hydropsychid caddisflies (F), heptageniid mayflies (F) and *Caenis* sp. mayflies (F)	-	Good

Station	RM	DA (mi.^{2})	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Trib. to Drake Fork (RM 0.55) (09-114-001)													
303670	0.05	0.9	42	-	42	9 / 9	7 / 7	1	11	M - L	Hydropsychids (F), heptageniids (F), midges (F,MI,CW)	-	Good
Rocky Fork (09-114-000)													
303667	0.08 (0.10)	3.4	54	-	54	8 / 8	5 / 5	0	12	M - L	Hydropsychid caddisflies (F)	-	Marginally Good
Georges Creek (09-110-000)													
303659	0.05	1.9	50	-	50	14 / 14	12 / 12	1	10	M - L	*Caenis* sp. mayflies (F), *Cheumatopsyche* sp. (F) in *interstitial* flow	-	Very Good
Williams Creek (09-116-000)													
303657	1.55	0.9	53	-	53	9 / 9	9/ 9	1	10	M - L	Hydropsychid caddisflies (F,MI), midges (F,MI,T), and *Caenis* sp. mayflies (F)	-	Good
303656	0.05	3.2	47	-	47	13 / 13	8 / 8	0	9	M - L	Midges (F,T), and *Caenis* sp. mayflies (F)	-	Good
Little Indian Guyan Creek (09-108-000)													
303652	2.7 **(2017)**	5.9	36	-	36	15 / *22* (*2017+ 2016*)	11 / *16* (*2017+ 2016*)	3 *(4)*	6	Low	Baetid mayflies (F,MI), midges (F,MI,CW)	-	Very Good
303596	1.65	8.5	51	-	51	19 / 19	15 / 15	0	8	Low	Baetid mayflies (F,MI), midges (F,MI,CW)	-	Exceptional
303532	0.13	14.9	94	62	54	25 / 32	21 / 31	3	5	M - L / 150	Baetid (F,MI) & *Caenis* sp. mayflies (F), *Cheumatopsyche* sp. (F)	56	-
Watson Creek (09-108-002)													
303650	0.05	1.7	31	-	31	9 / 9	7 / 7	0	4	Low	Polypedilum & tanytarsini midges (F,T), & *Caenis* sp. mayflies (F)	-	Good
Trace Creek (09-108-001)													
303648	0.1	3.7	53	-	53	20 / 20	18 / 18	0	7	Low	Midges (F,MT,T), hydropsychid caddisflies (F), baetid mayflies (F,MI,I)	-	Exceptional
Wolf Creek (09-106-000)													
303676	0.35	4.7	40	-	40	14 / 14	12 / 12	0	3	Low	Midges (F,MI), heptageneid (F,MI) & *Caenis* sp. mayflies (F), and baetid mayflies (F,MI,I)	-	Very Good

Station	RM	DA (mi.^{2})	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Slate Run (09-105-000)													
303647	0.4	1.1	25	-	25	2 / 2	0 / 0	0	14	Low	Midges, mostly *Chironomus (C.) decorus gr*. (T, F,VT)	-	Poor
Fivemile Creek (09-104-000)													
303594	0.3	3.3	44	-	44	15 / 15	11 / 11	0	6	Low	Baetid mayflies (F,MI,I), hydropsychid caddisflies (F,MI), midges (F,MI,T), and *Caenis* sp. mayflies (F)	-	Very Good
Bear Creek (09-102-000)													
303593	0.05	2.9	54	-	54	11 / 11	6 / 6	1	14	Low	Baetid, heptageneid, & *Caenis* sp. mayflies (F,MI), midges (F,CW,T)	-	Good
Bent Creek (09-101-000)													
303592	0.05	1.9	43	-	43	10 / 10	5 / 5	3	11	M - L	Midges (F,CW,MT,T) and *Caenis* sp. mayflies (F)	-	Good
Direct Ohio River Tributaries													
Buffalo Creek (09-020-000)													
303531	1.1	6.7	31	-	31	7 / 7	1 / 1	0	5	M - L	Midges (F, MT,T) and hydropsychid caddisflies (F)	-	Marginally Good
Scarey Creek (09-020-001)													
303583	1.1	6.7	23	-	23	6 / 6	2 / 2	0	1	M - L	Hydropsychid caddisflies (F) and heptageneid mayflies (F)	-	Marginally Good
Paddy Creek (09-021-000)													
303591	1.65	4.9	26	-	26	9 / 9	4 / 4	1	5	M - L	Hydropsychid caddisflies (F), Baetis spp. (F) and *Neocloeon* sp. (MI) mayflies	-	Good
Little Paddy Creek (09-021-001)													
303590	0.4	2.0	67	-	67	9 / 9	2 / 2	1	35	M - L	*Stenonema femoratum* mayflies (F), scuds (F,MT), *Cheumatopsyche* sp. caddisflies (F)	-	Marginally Good
Twomile Creek (09-022-000)													
303645	1.45	3.0	45	-	45	7 / 7	4 / 4	3	16	Low	Midges (T,F,VT,CW) and *Stenonema femoratum* mayflies (F)	-	Fair

Station	RM	DA (mi.²)	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Federal Creek (09-023-000)													
303589	0.85	4.0	49	-	49	11 / 11	8 / 8	0	11	M - H	Hydropsychid caddisflies (F), midges (F,MT,T,MI), *Caenis* sp. mayflies (F)	-	Good
Clean Fork (09-024-000)													
303588	0.1	1.7	18	-	18	6 / 6	4 / 4	0	2	Low	*Cheumatopsyche* sp. (F), *Caenis* sp. mayflies (F), tipulids (F,MI)	-	Marginally Good
Big Creek (09-095-000)													
303643	0.48	1.6	31	-	31	9 / 9	9 / 9	4	7	Low	*Caenis* sp. mayflies (F), heptageneid mayflies (F,MI)	-	Good
Swan Creek (09-027-000)													
303641	4.25	8.3	52	-	52	17 / 17	14 / 14	0	7	M - L	*Chimarra obscura* (MI) & hydropsychid caddisflies (F), *Stenonema femoratum* mayflies (F)	-	Very Good
303527	2.35	14.7	39	-	39	15 / 15	10 / 10	0	7	M - H	Baetid (F, MI) & Caenis sp. (F) mayflies, midges (F,T,MI)	-	Very Good
Trib. to Swan Creek (RM 5.95) (09-028-001)													
303638	0.5	2.2	46	-	46	8 / 8	7 / 7	0	6	M - L	Hydropsychid caddisflies (F), tanytarsini midges and other midges (F,MI)	-	Marginally Good
Little Swan Creek (09-028-000)													
303587	0.05	4.2	46	-	46	16 / 16	11 / 11	1	9	Low	*Stenonema femoratum* (F) & *Macaff. vicarium* mayflies (MI), *Chimarra spp.* (MI) and hydropsychid caddisflies (F)	-	Very Good
Teens Run (09-031-000)													
303586	1.2	2.5	58	-	58	17 / 17	11 / 11	4	10	Mod.	Baetid mayflies including *Diphetor hageni* (MI,F), *Stenonema femoratum* mayflies (F), and midges (F,MI,CW,MT,T)	-	Exceptional
Chickamauga Creek (09-037-000)													
300742	4.8	6.5	33	-	33	10 / 10	3 / 3	1	5	Mod.	Baetid mayflies (F,MI), hydropsychid caddisflies (F)	-	Marginally Good

Station	RM	DA (mi.²)	Total Taxa	Qt. Taxa	Qual. Taxa	EPT Taxa Ql./ Total	Sensitive Taxa Ql./ Total	CW Taxa	Qual. Tol. Taxa	Relative Density Ql. Qt.[1]	Predominant Organisms on the Natural Substrates with Tolerance Category(ies)	ICI[a]	Narrative Evaluation
Little Chickamauga Creek (09-039-000)													
W03S19	0.16	5.9	30	-	30	7 / 7	2 / 2	0	6	M - L	Hydropsychid caddisflies (F), *Chimarra obscura* (MI)	-	Fair

[A] WAP Ecoregional Macroinvertebrate Biocriteria. ICI = Invertebrate Community Index scores (range = 0 to 60). Exceptional = 46–60. Very Good = 42–44. Good = 36–40. Marginally Good = 32-34.Fair = 14-30. Poor = 8-12. Very Poor = 0-6.

[1] Quant. or Qt.: Quantitative sample collected on Hester-Dendy artificial substrates. Relative density is expressed as number of organisms per square foot.

Qual. or Ql.: Qualitative sample collected sampling all available natural habitats with indicated presence and predominance where relative density was listed as: L=Low, M=Moderate, H=High.

[a] ICI values in parentheses are invalidated due to insufficient current speed over artificial substrates (< 0.3 ft/second (fps) (X15) or 0 fps (X8)), by disturbance/vandalism (X13) or could not be retrieved – Suspected High Water (X12) (e.g., buried by sand or gravel – not collected). Lab accident – Quant. (X17). The assessment at these sites is based on the qualitative narrative assessment: Exceptional, Very Good, Good, Marginally Good, Fair, Poor, or Very Poor.

EPT taxa are the total taxa collected from the mayfly family (Ephemeroptera), the stonefly family (Plecoptera), and the caddisfly family (Trichoptera) combined.

Sensitive Taxa: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).

CW: Taxa listed on the Ohio EPA Macroinvertebrate Taxa List as Coldwater organisms.

Tol.: Tolerant – Tolerance categories in Ohio EPA Macroinvertebrate Taxa List with VT=Very Tolerant, T=Tolerant, MT=Moderately Tolerant. F=Facultative, MI=Moderately Intolerant, I=Intolerant.

[b] St. E. – State Endangered.

Symmes Creek Watershed

During the 2016-2017 Symmes Creek watershed survey, nine macroinvertebrate survey sites were sampled in the mainstem and 49 sites were sampled on 36 different subwatershed tributaries. The largest tributaries to Symmes Creek included Black Fork, Sand Fork, and Buffalo Creek. Intermediate size streams sampled included Huntingcamp Creek, Dirtyface Creek, Johns Creek, and Long Creek. A total of 49 of 58 (84.5 percent) of the Symmes Creek watershed sample sites performed at or above assigned ALU biocriteria standards and 15.5 percent were in non-attainment.

ICI scores were in the good range in the headwaters of Symmes Creek upstream from Black Fork (RM 60 to 70) but increased into the very good to exceptional range from the Black Fork confluence at RM 60.32 to the mouth (Figure 21). The headwaters of Symmes Creek was influenced by historic mining activity and had elevated levels of specific conductivity, total dissolved solids, sulfates, manganese and magnesium found upstream from Black Fork during the 2016-2017 survey (Figure 11). As water quality improved downstream from Black Fork, the macroinvertebrate community also improved into the exceptional range and was recommended EWH from Black Fork to the mouth.

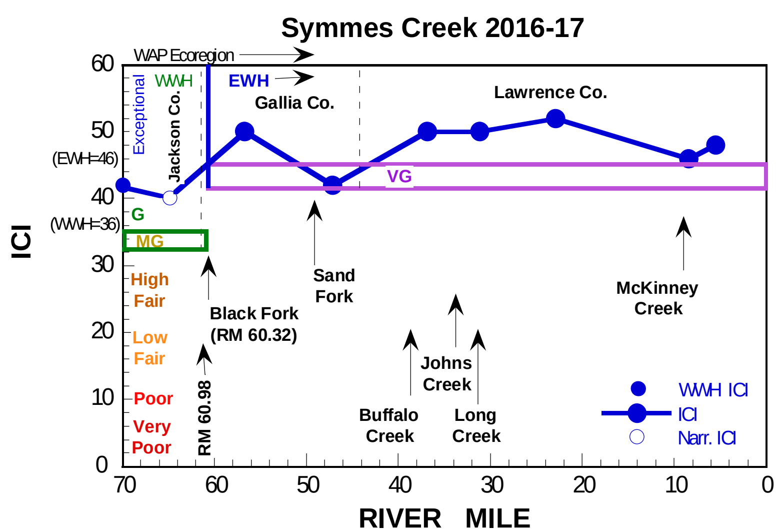


Figure 21—Longitudinal trend of invertebrate community index (ICI) scores for Symmes Creek, 2016-17.

Black Fork Symmes Creek has a drainage area of 62.7 mi.[2] and was sampled at four locations during the 2016 biological assessment. A large portion of the stream flows through low gradient forested reaches with wetlands inputs, like the middle and lower reaches of Huntingcamp Creek, Dicks Creek, and Clear Creek. Inputs from Cambria Creek and Dirtyface Creek (two higher quality streams) likely added to the diversity in the lower reaches of Black Fork (Figure 22). The Jackson Lake dam caused an increase in temperature and organic enrichment and also decreased the natural flow and D.O. causing fair macroinvertebrate scores. Water quality improved at the three downstream locations with more consistent stream flow and lower stream temperatures. Macroinvertebrate assemblages improved and met or exceeded WWH ALU expectations at the lower three sites. The Black Fork sample site near the mouth (RM 0.2) scored an ICI of

52 (exceptional) with high community diversity and quality (totals of 20 EPT and 17 sensitive taxa). Increased mayfly and, caddisfly taxa diversity buoyed assemblages to an exceptional level (Figure 22).

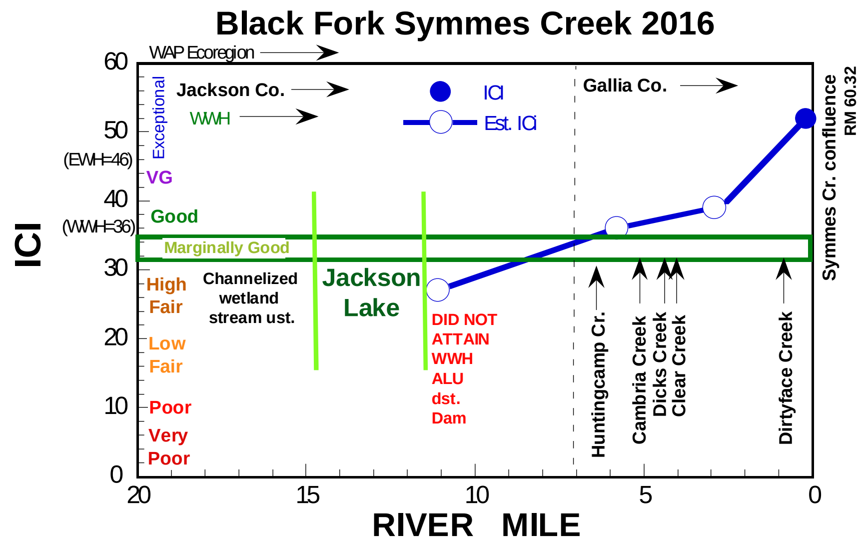


Figure 22—Longitudinal trend of ICI scores for Black Fork Symmes Creek, 2016-2017 survey.

Indian Guyan Creek Watershed

During the 2016-2017 survey, seven macroinvertebrate survey sites were sampled in the mainstem of Indian Guyan Creek. All macroinvertebrate sampling locations on the mainstem of Indian Guyan Creek were in the exceptional range and fully met the EWH ALU biocriterion (Figure 23). Additionally, 14 tributaries to Indian Guyan Creek were sampled at 17 locations. Slate Run was the only location that did not meet the assigned biocriterion with a narrative of poor.

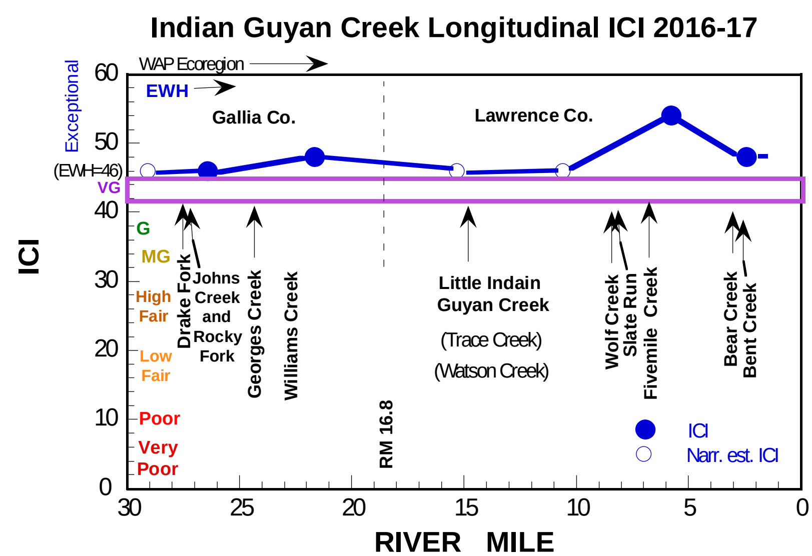


Figure 23—Longitudinal ICI plot of samples sites on Indian Guyan Creek, June-September of 2016.

Ohio River Direct Tributaries

Fourteen direct Ohio River tributaries were sampled during the 2016-2017 survey in southern Ohio from the Ohio River @ RM 711.28 (Chickamauga Creek) to the Ohio River @ RM 670.71 (Buffalo Creek). A total of fifteen sites were sampled with 87 percent (13 of 15) in attainment of the confirmed or recommended ALU. Both Twomile Creek and Little Chickamauga Creek contained fair quality macroinvertebrate communities and did not meet WWH biological performance standards due to organic enrichment from unsewered areas (and failing HSTS issues for Little Chickamauga Creek).

Three sampled streams, Swan Creek, Little Swan Creek, and Teens Run, had very good to exceptional macroinvertebrate communities and were recommended EWH. Macrobenthic communities in Swan Creek and Little Swan Creek were very good, and the Teens Run community was exceptional. Teens Run, Swan Creek and Little Swan Creek had the highest combined EPT, sensitive taxa, and cold water (CW) taxa (Figure 24).

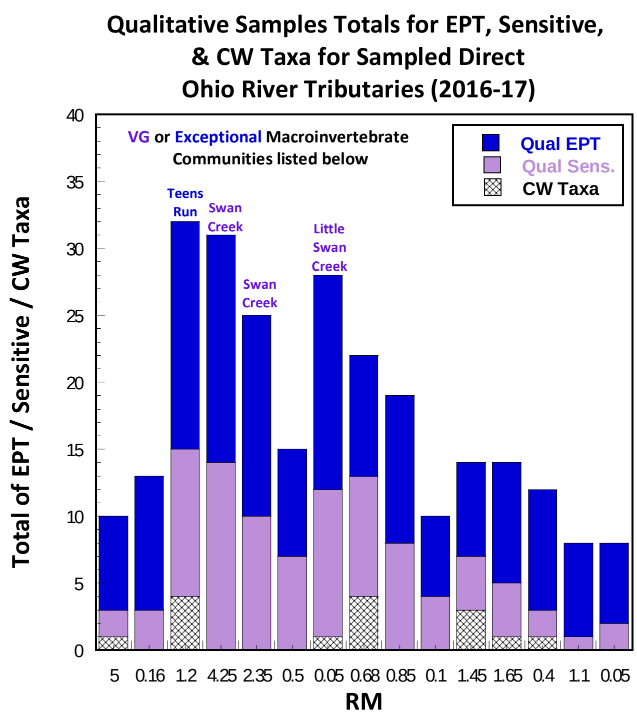


Figure 24—Qualitative EPT, Sensitive, and CW taxa totals for direct Ohio River tributary sample sites, June-Sept. 2016-17.

Aquatic Life Use Discussion

Statistical methods described in Appendix N were used to evaluate and group survey sites based on similarities of the biological assemblages and environmental stressors. This adds an additional weight of evidence to determine the most likely causative stressors for streams in partial or non-attainment of their assigned ALU. The attainment status of Symmes Creek, Indian Guyan Creek and the direct Ohio River tributaries are summarized in Table 1with causes and sources listed. The fish and macroinvertebrate communities in streams throughout the survey area were generally high quality with both groups performing very well (Figure 20, Figure 22, and Table 18). This is not surprising given the high percentage of forest cover (Figure 5), relatively few sources of recent anthropogenic stressors (i.e. mining, silviculture and point sources), and proximity and connections to high quality source waters (i.e. no dams or barriers on the mainstems). Fish and macrobenthic community performance were routinely in the very good or exceptional range both in the mainstems and tributary streams throughout the study area (Table 16 and Table 18).

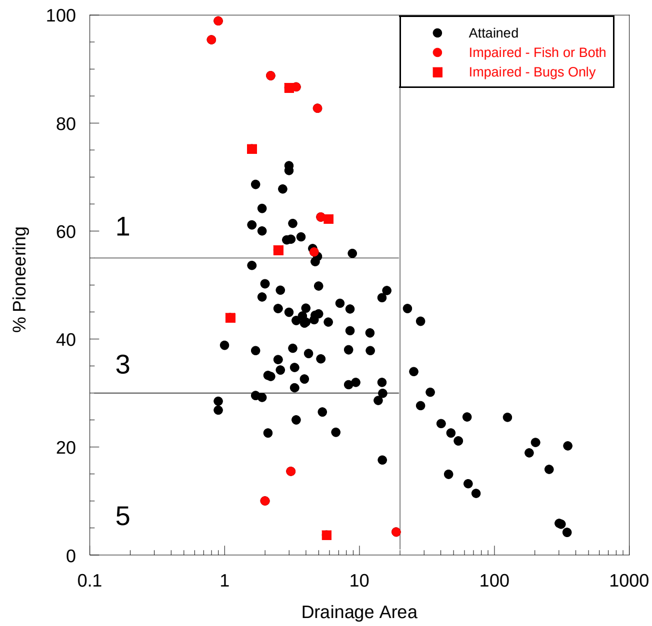


Figure 25—Scatter plot displaying the proportion of the fish community comprised by pioneering individuals as a function of drainage area parsed into attainment categories, 2016/17. Locations in red are those that displayed biological impairment during the current survey. IBI scoring cutoff thresholds (1,3, or 5) for the percent pioneering species metric are also displayed (Ohio EPA, 1987b).

In the Symmes Creek watershed, a total of 59 locations were sampled with 47 in full attainment, 5 in partial attainment and 7 in non-attainment. In the Indian Guyan Creek basin, a total of 26 locations were sampled with 25 in full attainment and one location in partial attainment. For the other fourteen direct Ohio River tributary locations sampled, 12 were in full attainment and two were in in partial attainment. Sites with a drainage area greater than 20 square miles were always in attainment for both fish and macroinvertebrates and typically in the very good to exceptional range with a low percentage of pioneering species (Figure 27). In areas where fish communities were impaired, the proportion of pioneering fish individuals seemed to be useful when trying to interpret information and coarsely elucidate some of the aquatic life impairments observed during the survey. "Pioneering" fish species are those that will be the first to reinvade portions of headwater streams that have been desiccated by prolonged periods of dry weather. These species can also predominate in unstable environments affected by temporal desiccation or other anthropogenic stressors. Thus, a high proportion of these individuals can be an indication of temporal habitat unavailability or generally stressful conditions overall. Several "pioneering" species collected during the survey are also considered highly tolerant (of pollution), including the bluntnose and fathead minnow, creek chub, and green sunfish.

Most impaired stream reaches tended to have fish communities that fell into the group of sites that had the highest proportions of pioneering individuals (i.e., received a "1" for this IBI scoring metric). Many of these impaired reaches also had fish communities with notably higher proportions of pioneering species (>75 percent) compared to other locations in this group. All locations with 75 percent or more of pioneering individuals displayed impairment that was related to either low flow conditions or a source of anthropogenic stress (Figure 27, Table 1).

Black Fork RM 11.05, Clear Fork RM 0.3, Sweetbit Creek RM 0.3, and Tributary to Symmes Creek (73.07) RM 0.1. in upper Symmes Creek were impaired but contained relatively low abundances of pioneering species (Figure 27). Fish communities in this subset of streams were skewed toward more lentic and wetland type environments (i.e. sunfishes, lake chubsucker, bullhead catfish). The lake chubsuckers in the upper Symmes Creek watershed are the only population known to occur in the unglaciated WAP ecoregion in Ohio (Rice & Zimmerman, 2019). All other lake chubsucker populations occur in glaciated Ohio mostly associated with remnant glacial lakes and wetlands.

Streams in the unglaciated WAP ecoregion are typically high gradient streams draining from steep hills with narrow valleys and ridges. The habitat in upper Symmes Creek is not typical for the WAP and is characterized by wetlands and low gradient streams. The wetlands and low gradient streams in the upper Symmes Creek are remnants of the large glacial lakes created when glaciers dammed the Teays River system then receded leaving behind habitat similar to the Huron Erie Lake Plain (HELP) ecoregion in north west Ohio. In the upper portion of Symmes Creek there are over four-square miles of emergent wetlands and forested/shrub wetlands. Cackley Swamp in Pyro is over 200 acres of wetlands and is now a nature preserve.

<u>Site/System Specific Aquatic Life & Impairment Discussion</u>

Biological community performance in all larger stream segments (>20mi^2 drainage) was consistent with existing or recommended aquatic life use expectations. Aquatic life use impairment documented during the survey was limited to stream segments in the headwater drainage class category (<20mi^2) (Table 1, Figure 20). About 80 percent, of all stream segments (81 of 101) evaluated during this survey were in the headwater drainage category range.

Biological community impairment of both organism groups, or non-attainment, was noted in Black Fork RM 11.0 (303576), Hewitt Run RM 0.75 (303636), Huntingcamp Creek RM 1.2 (W02S03), Dicks Creek RM 0.3 (303573), Clear Fork RM 0.3 (303572), and Wolf Run RM 0.1 (303570).

Fish community impairment was noted in Sweetbit Creek RM 0.3 (303637), Peters Cave Creek RM 0.2 (303565), Indian Creek RM 0.1 (303560), and Paddy Creek RM 1.65 (303591). Additionally, macroinvertebrate community impairment was documented in the Tributary to Symmes Creek (73.03) RM 0.10 (303577), Cherry Fork RM 0.4 (303705), Huntingcamp Creek RM 1.71 (W02S06), Slate Run RM 0.4 (303647), Twomile Creek RM 1.45 (303645), and Little Chickamauga Creek RM 0.16 (W03S19). These sites were only partially attaining the aquatic life beneficial use.

Symmes Creek

The Symmes Creek watershed Group 1 sample sites were mostly large DA sites with generally good substrates and developed riffles and pools that met WWH or EWH biocriteria. These Group 1 sites included the Symmes Creek mainstem, the lowest Black Fork Symmes Creek site (RM 0.3 = 62.6 mi.^{2}), and the most downstream Long Creek (RM 0.86) and Sand Fork site (RM 3.3) (Table 1, Table 18, Figure 26).

Group 2 sample sites were small, stable headwater streams (range of 1 to 4.6 $mi.^2$ + one $8.3mi.^2$ stream) with generally a good substrate mix that were more forested (cooler) with less sediment, nutrient, or NPS mining inputs (some were in national forest lands). These streams generally drained between hills, were at the edge of forested boundaries and/or had good forested canopy shading. Group 2 streams included Buffalo Creek, Little Buffalo Creek, Leatherwood Creek, Bear Creek, McKinney Creek, Rankin Creek, Venisonham Creek, Sharps Creek, Elkins Creek, Aaron Creek, Buckeye Creek (Trib. to Long Cr. @ SR 775), Slab Fork, Pigeon Creek, and Miller Creek (Table 1, Table 18, Figure 26).

Group 3 streams were valley streams that were influenced by agriculture (reduced riparian corridor and shading or cattle), mining NPS runoff (sand bedload primarily with some chemistry), forest removal, sedimentation wetland inputs, and/or entrenched conditions with less habitat diversity. The Group 3 streams met WWH biocriteria but could improve with some enhancements with riparian width/thickness, closed pastures, and a lessening of habitat/mining issues with time. Group 3 streams included Cambria Creek, Johns Creek (RMs 5.35 and 0.07), Dirtyface Creek (RMs 4.7 and 1.82), upper Symmes Creek at Jenkins Albin Rd., Black Fork Symmes Creek (RMs 5.77 and 2.4), Long Creek (RM 4.3), Buck Creek, Johns Creek (RMs 5.35 and 0.07), Camp Creek, Peter Caves Creek, and Sand Fork (upper four sites) (Table 1, Table 18, Figure 26).

The Group 4 sample sites were foremost grouped primarily in the upper Symes Creek watershed (Jackson and upper Gallia counties). These streams were either more characteristic of: 1) wetland stream influences (sluggish/low flow velocity or softer substrates (clay or sediment)), limited riffles and rocky substrates; and/or 2) higher metals (Dicks Creek)/ TSS inputs; 3) raw sewage or poorly treated effluent impacts (Huntingcamp Creek); and/or 4) little or no flow (Wolf Run and Black Fork downstream of Jackson Lake spillway). Other Group 4 streams included: Clear Fork, Tributary to Symmes Creek @ C H & D Rd., Hewett Run, Sweetbit Creek, Buckeye Creek (Tributary to Johns Creek), and Trace Creek. Most of the impairment in this survey was contained in these sample sites in this area of the Symmes Creek sub-watershed (Table 1, Table 18, Figure 26).

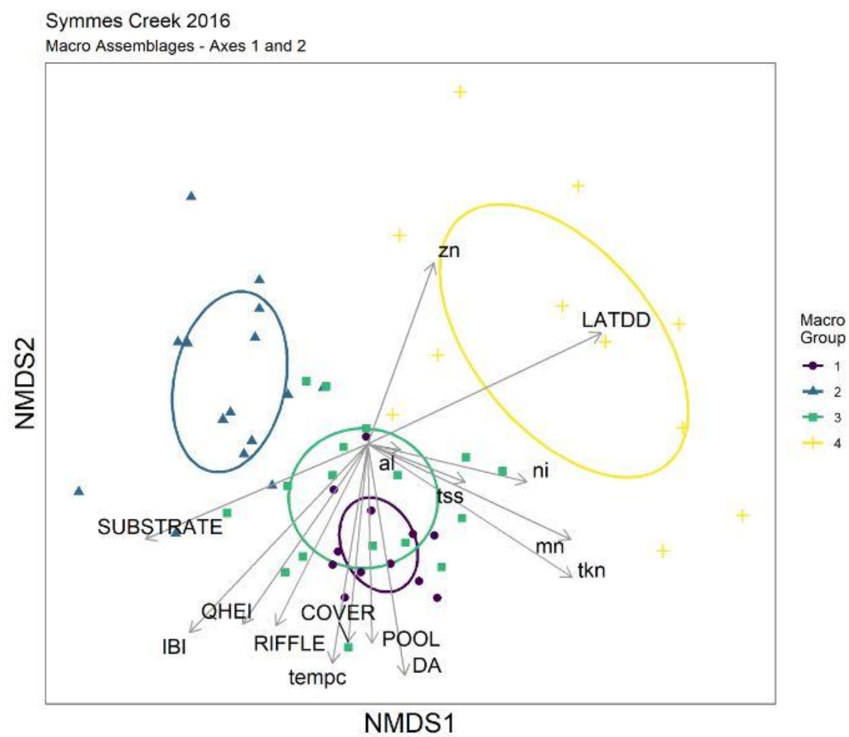


Figure 26—Symmes Creek 2016 macroinvertebrate groupings which correlate to drainage area and habitat characteristics.

Black Fork Symmes Creek Sub-basin

Black Fork Symmes Creek

Black Fork is the largest tributary system to Symmes Creek and drains just over 62 mi² at the confluence. Black Fork was sampled at four locations, while five tributary streams were sampled at six locations (Table 2). Numerous wetland areas are scattered throughout the Black Fork sub-basin. Many streams in this sub-watershed exhibit physical (i.e. slower and less diverse flow velocities, generally reduced stream development, finer substrates and more siltation, etc.), and related chemical properties (i.e. generally reduced conditions) reflective of the physical conditions. Thus, streams in this watershed are naturally more prone to experience episodes of low D.O., or higher ammonia and metals concentrations. Streams in this sub-watershed tended to display more naturally limiting habitat features associated with wetland and lentic habitats compared to other traditional, free-flowing (lotic) streams in this ecoregion.

Impaired stream segments in the Black Fork sub-watershed included Black Fork RM 11.0 (303576), Hewitt Run RM 0.75 (303636), Huntingcamp Creek RMs 1.74 and 1.2 (W02S06, W02S03), Dicks Creek RM 0.3 (303573), Clear Fork RM 0.3 (303572). Six of the 12 impaired stream reaches (50 percent) in the Symmes Creek watershed occurred within this sub-basin (see Figure 19).

Biological communities in Black Fork fully met WWH criteria at three of the four reaches evaluated (Figure 19, Figure 22). Sampling at Black Fork RM 11.0 occurred immediately downstream from the Jackson Lake dam. The flow regime here was heavily influenced by this impoundment causing poor water quality conditions (high temperature, low D.O., elevated ammonia) that impacted both fish and macroinvertebrate communities. This reach was observed to lack any functional flow periodically throughout mid-late summer, following seasonal fluctuations in water levels and discharge over the Jackson Lake dam. Precipitation events in mid-late summer 2016 supplied pulsed flow events throughout this reach. Biological performance here was also naturally limited somewhat by the pervasiveness of wetlands in the vicinity; Black Fork Symmes Creek flows through extensive wetland complexes between the sampling locations at RM 11.0 and RM 5.77. The pervasiveness of wetland areas throughout Black Fork and the modified flow regime at RM 11.0 likely make this reach of Black Fork (and Black Fork as a whole) more prone to experience periods of low D.O, such as those observed (Table 9, Table 10). The macroinvertebrate community here consisted mainly of lentic/pool and margin species, with few lotic taxa collected. The fish community was also heavily skewed toward lentic taxa and species composition was substantially reduced compared to other Black Fork locations. Though still a wetland-type stream system, biological communities throughout the remainder of Black Fork suggest a generally lotic and continuously flowing stream environment overall. The flow regime alterations coupled with the natural background wetland conditions encountered throughout this reach of Black Fork likely drove biological impairment observed downstream from Jackson Lake dam.

Huntingcamp Creek

Huntingcamp Creek is a relatively small tributary stream just over 3.0 mi^2 at its confluence with Black Fork. The Huntingcamp Creek sub-watershed is one of the more heavily developed streams in the study area draining the majority of the village of Oak Hill. Around 22 percent of its drainage area is comprised of various types of developed land (high, medium, low, open space) (NLCD 2011, USGS 2016). The Oak Hill WWTP discharges to Huntingcamp Creek at approximately RM 1.7 and there are also several other NPDES permitted industrial outfalls from that discharge to Huntingcamp Creek. There are both active and inactive industrial mineral mining operations located in this small sub-watershed. Huntingcamp Creek was sampled at two locations, one each up and downstream from the Oak Hill WWTP at RMs 1.8 (W02S06) and 1.4 (W02S03), respectively. The two sampling locations on Huntingcamp Creek drain the majority of village of Oak Hill and encompassed about 36 percent developed land, overall (NLCD 2011, USGS 2016).

Fish community performance marginally met WWH criteria upstream at RM 1.8, while impairment was noted downstream at RM 1.4 (Table 16). The proportion of highly tolerant individuals increased from 60 percent at RM 1.8 to 92 percent at RM 1.4. There were also corresponding decreases in both the abundances of simple lithophilic (intolerant to excessive siltation) and headwater species between the up and downstream sampling locations. The highly tolerant creek chub increased from 49.5 percent of the fish community at RM 1.80 to 81.8 percent at RM 1.4. Other species such as the johnny darter, southern redbelly dace (headwater, simple lithophil), and the western blacknose dace (headwater, simple lithophil) decreased, collectively, from about 36.1 percent to 3.6 percent of the overall fish community (Appendix E). The IBI score at RM 1.4 was one of the lowest from the entire survey area (Figure 20, Table 1).

Macroinvertebrate communities did not meet WWH expectations either up or downstream from the facility. Performance decreased from fair (ICI = 26) to poor between the upstream and downstream sampling locations. Only two EPT taxa, specifically two caddisfly taxa, were collected at RM 1.8, with no mayfly or sensitive taxa present (Table 18). Some caddisflies were present in the small rocky riffle at RM 1.4, but the community here was predominated by highly tolerant midges.

Habitat quality in Huntingcamp Creek upstream from the Oak Hill WWTP at RM 1.8 (QHEI=61.5) was sufficient to support fish communities consistent with WWH expectations. Poor habitat quality noted at RM 1.40 (W02S03) stemmed primarily from pervasive, knee-high siltation that was up to 3 ft. in areas and undoubtedly limited biological community performance. The reach of Huntingcamp Creek immediately downstream from State Route 93 was decidedly siltier compared to the reaches immediately upstream from this highway and other reaches evaluated in Huntingcamp Creek. Additionally, riparian removal/maintenance activities just upstream from RM 1.8 occurred over the 2016 sampling season and may have contributed to sedimentation noted in Huntingcamp Creek and impairment at RM 1.8.

The downstream reaches of Huntingcamp Creek also experienced inconsistent effluent treatment and subsequent episodes of degraded water quality. Water chemistry issues in Huntingcamp Creek were well documented during the survey. Five D.O. exceedances from individual grab samples were noted at RM 1.4. This location also had one of the lowest D.O. grab-sample averages from the entire survey (3.81 mg/L). Additionally, diel sonde monitoring at RM 1.4 recorded multiple minimum and average D.O. exceedances, with individual concentrations as low as 0.98 mg/L noted during a 2017 sonde deployment (Table 10). An ammonia exceedance occurred at RM 1.4, with instream concentrations as high as 7.95 mg/L. Huntingcamp Creek at RM 1.4 also had the highest nutrient concentrations of the entire study area including total phosphorus (average=1.7mg/L, maximum=2.05mg/L) TKN (average = 1.57mg/L, maximum =8.17 mg/L, and nitrate-nitrite (average = 8.22mg/L, maximum = 14.5mg/L). No water quality exceedances for any parameters were noted upstream at RM 1.8 in either surface water grab samples or diel sonde monitoring (Table 9, Table 10). Signatures from historical mining activities, including elevated TDS and manganese were noted throughout this sub-watershed, though no exceedances were noted. Additionally, other spills/overflows were noted upstream from the Oak Hill WWTP due to clogged sewers and sewer line breaks during late spring 2016 while field staff were conducting field reconnaissance and canvassing for access at survey locations. (Table 7).

The Village of Oak Hill significantly reduced SSOs in 2017 and conducted a major upgrade of the WWTP in 2018 (see Appendix K for details). Follow up biological and chemical monitoring should be conducted to determine if the upgrades have improved water quality in Huntingcamp Creek. NOVs were issued in 2019 for not implementing the I/I reduction plan and for noncompliance with the NPDES permit compliance schedule.

Non-attainment of the aquatic life use documented at RM 1.4 was likely a direct result of *both* poor water quality stemming chiefly from poorly treated effluent *and* poor habitat quality, specifically excessive siltation/sedimentation. Biological community performance improved somewhat upstream at RM 1.8, though still only partially attained the aquatic life use. Macroinvertebrate community performance was likely limited by a combination of excessive siltation/channelization activities and water chemistry issues related to mining activities and spills noted throughout the Huntingcamp Creek sub-watershed. The general urbanized character of this small sub-watershed may also "cap" biological performance to an extent compared to other small streams that drain more forested and less developed areas, even before the "additions" of the other sources of pollution identified above. Ultimately, Huntingcamp Creek drains into a portion of Black Fork surrounded by extensive wetlands, offering a degree of natural attenuation of both the identified habitat and water chemistry stressors. Water quality issues documented in Huntingcamp Creek did not appear to negatively impact biological communities in Black Fork downstream from Huntingcamp Creek (Figure 19, Figure 22).

Dicks Creek

Dicks Creek is a small tributary to Black Fork and drains about 3.0 mi² at the confluence. Wetland areas were common throughout Dicks Creek and Black Fork in this vicinity. Consistent with these conditions, macrohabitat data indicated fair to poor overall habitat quality (QHEI=46.0). Heavy and pervasive siltation/sedimentation was noted, and the sampling reach only received a score of "1" for the QHEI substrate metric. This reach of Dicks Creek had one of the lowest substrate quality scores of the entire survey, second to only Huntingcamp Creek RM 1.4 (Table 13, Table 14). Detritus and silt were noted as dominant substrate types and "wetlands" were noted as the substrate origins at this location. "Swamp" was specifically noted as one of the floodplain quality types and QHEI sheet comments also indicated the sampling location was surrounded by wetlands. Additionally, the biological sampling reach in Dicks Creek was located downstream from Sardis Rd., in the formerly channelized reaches just before joining Black Fork. As such, this particular reach of Dicks Creek was very shallow overall and never exceeded 0.4 meters. Pool habitats were also generally limited throughout this reach.

Both historical and active areas of mining are present within this small sub-watershed and, relative to size, covered a proportionally larger area compared to other tributary stream networks in the survey (Figure 6). Signatures from mining operations in this sub-watershed were evident with elevated metals including aluminum, iron, manganese, pH levels below the WQS of 6.5 S.U., elevated ammonia, and occasional pulses of acidity.

Fish and macroinvertebrate community performance fell short of WWH expectations resulting in non-attainment of the aquatic life criteria at the one location evaluated (RM 0.1, 303573). The macroinvertebrate community was poor and had no EPT taxa with very low diversity (21 taxa). Fish community quality was in the very poor range and was among the worst performing locations of the entire survey area (Figure 20). Fish community composition was rudimentary and consisted of 4 species, totaling only *15 individuals* (Appendix E). The johnny darter was the most abundant fish species here, totaling 11 individuals. Pioneering species dominated the overall community (86 percent), though percent tolerant individuals were low compared to other locations that had such high proportions of pioneering individuals (Figure 27, Figure 29). Pool species such as sunfish and chubsuckers were absent from this sampling reach in appreciable numbers (Appendix E), reflective of the lack of suitable

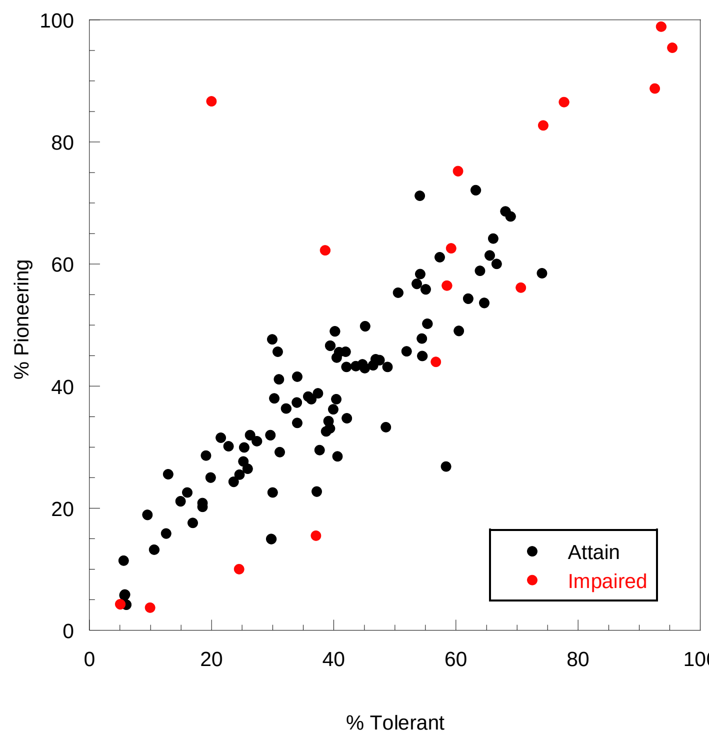


Figure 27—Scatter plot displaying the proportions of the overall fish community comprised by pioneering and tolerant individuals from sampling locations in the survey area, 2016. Impaired locations are displayed in red

pool here. Historical fish community samples collected by Dan Rice (ODNR) in 2005 near RM 1.0 indicated a fish community reflective of wetland type conditions upstream from Sardis Rd., including predominance of various sunfish species, bullhead, and chubsuckers. Historical samples suggest an overall wetland-type nature of this small sub-watershed, despite the shallow and desiccated conditions observed at RM 0.1. Field impressions during fish community sampling suggested low overall flows and siltation as factors limiting fish community performance.

Despite the presence of mining signatures and attendant water chemistry issues, biological impairments at this location are likely most *directly* related to the general desiccation and habitat limitations of this sampling reach. As with Huntingcamp Creek, the extensive wetland conditions in Black Fork offer a degree of natural attenuation from the identified water chemistry issues. Ultimately, biological performance in Black Fork downstream from Dicks Creek did not appear to be impacted by inputs from this stream (Figure 19, Figure 22).

Clear Fork

The biological sampling reaches in Clear Fork were surrounded by extensive wetland areas. The fish sampling zone was actually shortened somewhat because of the presence of impassible beaver dams. Similar to other impaired and relatively unimpacted wetland-type streams, the proportion of pioneering individuals was low (Figure 27) and the fish community was skewed toward a lentic or wetland adapted fauna (i.e. sunfishes, golden shiner, lake chubsucker, bullhead). The macroinvertebrate community was also reflective of the generally lentic conditions here. Wetland-type stream conditions in and surrounding Clear Fork naturally limited biological performance in this stream.

Hewitt Run

Wetland type conditions in Hewitt Run also likely naturally limited biological performance. Mining occurred in the headwaters of Hewitt Run in 2010 by the Waterloo Coal Company. Elevated levels of manganese, ammonia and conductivity were indications that non-acidic mine drainage could also be impacting Hewitt Run. The absence of somewhat common species found downstream from the impoundment in Black Fork (i.e. johnny darter, longear sunfish, northern hog sucker, bluntnose minnow) suggests that the fish community in Hewitt Run is additionally limited by the Jackson Lake dam (Figure 19). Despite impairment noted in these two streams, these areas are still high-quality wetland type streams and lake chubsuckers were collected both here and in Clear Fork.

Sand Fork sub-watershed

Sand Fork is the second largest tributary system to Symmes Creek, draining just over 45 mi^2 at the confluence. This winding valley stream courses through the hills of Lawrence and Gallia County with flow supplemented by numerous small headwater streams from small hollows over its length. Biological communities were sampled at five locations in Sand Fork and one location in the largest tributary stream in this sub-watershed, Peters Cave Creek at RM0.2 (303565) (Table 1).

Along with the Black Fork sub-watershed and the uppermost portions of Symmes Creek, the upstream reaches of Sand Fork are among the most impacted areas by mining activities in the study area. Despite this, water and macrohabitat quality throughout Sand Fork were sufficient to support biological communities consistent with WWH expectations. Biological community performance throughout the lower several miles of Sand Fork even exceeded WWH expectations and was consistent with EWH criterion.

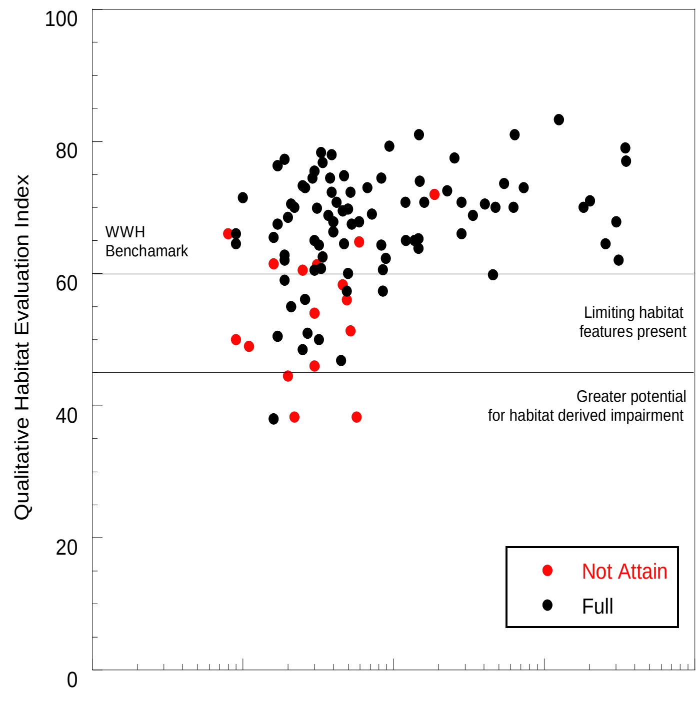


Figure 28 – Box plot displaying aggregated QHEI scores from all survey sites with a drainage area between 4.0 mi² and 7.0 mi², 2016.

Biological communities in Peters Cave Creek were only partially attaining WWH criteria. Macroinvertebrate community performance was very good and met WWH expectations, while fish community performance fell just short of the WWH criterion. Macrohabitat quality at this location (QHEI = 51.25) indicated that there may be habitat components limiting biological performance throughout this reach. The QHEI score in Peters Cave Creek was lower than other survey streams with similar drainage areas (Figure 30). The habitat evaluation indicated open pasture throughout the sampling reach, resulting in somewhat localized areas of habitat disturbance, including false banks, excessive siltation and sedimentation, disturbed stream substrates, and increased turbidity. Historic surface and underground mines are located in the headwaters of Peters Cave Creek and could be contributing additional sediment bedloads from disturbed and unreclaimed areas. No water quality exceedances were noted in Peters Cave Creek. Fish community impairments in Peters Cave Creek most likely resulted from the areas of open pasture and subsequent habitat disturbances. Ultimately, the impairment in Peters Cave Creek was relatively minor and did not have noticeable impacts on biological communities downstream in Sand Fork.

<u>*Other Symmes Creek Tributary Streams*</u>

Cherry Fork at RM 0.4 (303705) is a relatively small tributary (DA=2.7 mi²) in the very uppermost reaches of Symmes Creek, joining near RM 64.6. Biological communities were in partial attainment of the aquatic life use at the one location. The fish community marginally met WWH criterion, while macroinvertebrate community performance was in the fair range and fell just short of WWH expectations. Despite a fish community marginally meeting WWH expectations, the most abundant fish species collected in Cherry Fork included the creek chub (32.8 percent), green sunfish (12.8 percent), yellow bullhead (10.7 percent), johnny darter (7.8 percent), and redfin pickerel (7.8 percent). All but the redfin pickerel are either highly tolerant and/or pioneering species (Figure 27). Overall, macrohabitat quality was in the good range

(QHEI=60.5) but was evaluated quite early during the summer sampling season on June 30, 2016, coinciding with the fish community collection. The QHEI evaluation early in the summer already indicated only slow flows, and shallow riffles with borderline functionality. Narrative descriptions recorded while evaluating macrohabitat quality noted "relatively deep pools separated by very shallow, non-functional, sandy-glide type habitats". Macroinvertebrate community sampling occurred on September 6, 2016 and the sample collector noted interstitial flow conditions while collecting the sample. Similar to many streams in this study area, the water table dropped over the course of a relatively dry summer (Figure 9, Figure 15) resulting in the interstitial condition observed by macroinvertebrate biologists in late summer. No water chemistry samples were collected at this location. It is likely that the naturally occurring low flow conditions that arose over the course of the summer sampling reason resulted in macroinvertebrate communities that fell just short of WWH expectations.

Habitat evaluations and general field notes indicated wetland type stream conditions throughout both Sweetbit Creek at RM 0.3 (303637) and the Tributary to Symmes Creek (73.07) (303577). The fish community in each stream was skewed toward a lentic or wetland adapted fauna. The macroinvertebrate communities were also skewed toward lentic taxa, with limited numbers of taxa associated with lotic habitats. No water quality exceedances were observed in either stream (Table 9). Natural, wetland type stream conditions were likely the primary driver of biological impairment in these two streams.

Both Indian Creek at RM 0.1 (303560) and Wolf Run at RM 0.1 (303570) have drainage areas under 1.0 mi^2 and were the smallest sub-watersheds sampled during the 2016 survey. Habitat evaluations in both streams indicated low overall flows throughout each sampling reach. IBI scores from these two streams corresponded to poor narrative evaluations and were among the lowest recorded during the survey (Figure 20, Table 16). Fish community composition in each stream was rudimentary, consisting of only two and three species, respectively (Appendix E). Creek chubs comprised over 90 percent of the fish community in each stream and pioneering species comprised 95 percent and 99 percent, respectively (Figure 27). Creek chubs are often one of the last species to "drop out" of a relatively unimpacted fish community as stream size begins to decrease and are often one of the last fish species to be found in a stream. Macroinvertebrate community performance in Wolf Run was in the fair range and fell short of WWH expectations. Macroinvertebrate community samples were not collected from Indian Creek. No water chemistry exceedances were documented in either stream. The impairments in these two streams most likely result from the combination of very small stream size and natural low stream flows throughout the sampling reaches.

Indian Guyan Creek & Tributaries

Indian Guyan Creek was sampled at seven locations along its length. Biological communities at all seven locations generally exceeded WWH expectations and were consistent with EWH criteria. Biological community performance in many of the tributaries solidly met or exceeded EWH expectations (Figure 18, Figure 20, Figure 23). *Both* fish *and* macroinvertebrate communities fully met EWH criteria in Georges Creek, Fivemile Creek, and Little Indian Guyan Creek. Aside from some historical mining areas in the western portion of the watershed (Figure 6) and some localized agricultural activities typically confined to floodplain areas with suitable relief (Figure 5), the Indian Guyan Creek watershed remains relatively unimpacted by recent anthropogenic disturbance and, overall, supports high quality biological communities.

Of all tributary sampling locations in the Indian Guyan watershed, only Slate Run RM 0.4 (303647) displayed biological impairment. Slate Run is a very small tributary (1.3mi^2) that joins Indian Guyan Creek near RM 8.3. Fish community performance was in the very good range, while macroinvertebrate community performance fell short of expectations and was in the fair range. Habitat evaluations indicated interstitial flows throughout much of this sampling reach later during the summer in 2016 and a single D.O. exceedance was also noted on 9/6/16 (Table 9). The average ammonia value (0.095, n=5) was above the 90th percentile reference value of 0.06 mg/L. Additionally, biologists noted the presence of localized algal mats and grey water, both indicating possible inputs from underperforming home sewage treatment systems (HSTS). It is likely that in the relatively minor and localized impairments observed in Slate Run resulted from the combination of naturally occurring low/interstitial streamflows here, coupled with HSTS inputs to this small stream during low flow periods.

Direct Ohio River Tributaries

Biological communities in the remaining 14 direct Ohio River tributary streams were assessed at 15 locations (Table 1). Of all direct tributary streams assessed, the Swan Creek sub-basin, collectively, had the highest overall biological performance. Both fish and macroinvertebrate community performance exceeded WWH criteria and were consistent with EWH at three of four locations in the Swan Creek sub-basin. Biological communities in Teens Run were also consistent with EWH expectations, despite desiccated conditions observed in late summer.

Biological community performance at one of two locations in the Paddy Creek sub-basin fell short of WWH expectations. Fish community performance fell short of the WWH criterion in Paddy Creek RM 1.65 (303591), resulting in partial attainment of the aquatic life use. Highly interstitial conditions were noted during the fish sampling event. Field staff walked several hundred meters downstream from the sampling location and encountered dry streambed conditions, with the only areas of water and limited flow being in the hundred or so meters near the bridge crossing and sampling location. The "beginning" of the 150m electrofishing zone was functionally dry, with a deeper pools and riffles occurring more toward the middle and end of the sampling zone. The high proportion of pioneering individuals (82 percent) (Figure 29), coupled with the generally desiccated conditions observed while sampling suggest that interstitial flows were the most obvious factor limiting fish community performance. Despite an impaired community, 16 fish species were still recorded here, including two sensitive species and two headwater species. Good quality macroinvertebrate communities at RM 1.65 despite fish community impairment suggests sufficient hyporheic flow to support WWH macroinvertebrate communities. The single DO exceedance noted here was unsurprising given the vast swaths of dry stream surrounding this sampling reach, limiting the re-aeration potential.

Biological communities were consistent with WWH expectations in Chickamauga Creek upstream from Little Chickamauga Creek, but only partially attained aquatic life use criteria at the one location in Little Chickamauga Creek (RM 0.16, W03S19). Macroinvertebrate communities in Little Chickamauga Creek were in the fair range and fell just short of WWH expectations (Table 18). Fish community performance was very similar between the two locations. The proportion of tolerant individuals was very similar between the two locations, but the proportion of pioneering species was comparatively higher in Little Chickamauga Creek (62.2 percent) than Chickamauga Creek (37.8 percent), suggesting more stressed conditions in the former. Macrohabitat quality alone was very similar between both locations and, alone, should not have precluded biological communities consistent with WWH expectations In Little Chickamauga Creek. A single D.O.

exceedance was noted in 2016 (Table 9). Follow-up diel sonde monitoring in 2017 additionally noted very large D.O. swings (>9.0 mg/L) in the late August deployment, suggesting over-enrichment. Given the similar habitat quality between these two streams and full attainment recorded in Chickamauga Creek, impaired macroinvertebrate communities in Little Chickamauga Creek were most likely related to the over-enriched conditions documented here.

Partial attainment of the WWH aquatic life use was also observed in Twomile Creek. Similar to Little Chickamauga Creek, macroinvertebrate community performance fell short of WWH expectations, while fish community performance marginally met. Despite meeting WWH criterion, the fish community here displayed signs of stress. The community displayed a relatively high proportion of both highly tolerant (77.7 percent) and pioneering (86.5 percent) individuals (Figure 29). The relative number of individuals minus highly tolerant species (86.0/0.3km) was the lowest of all other direct Ohio River tributary reaches sampled during the survey. The highly tolerant creek chub comprised over 62 percent of the fish sample here, with the next two closest species also being highly tolerant and/or pioneering species, including the green sunfish (12.4 percent) and johnny darter (10.8 percent). Aside from the herbivorous central stoneroller (5.1 percent), all remaining fish species were found in very low abundances (one or two individuals) and each comprised around one percent of the overall community. While limiting habitat features may have been present in Twomile Creek, habitat quality alone should not have precluded full attainment of the aquatic life use and higher fish community performance (Figure 16). Biological communities at other sampling locations of similar drainage area and habitat quality were able to support biological communities fully consistent with WWH expectations. Though no water chemistry exceedances were recorded, average total ammonia concentrations in Twomile Creek were high compared to other direct Ohio River tributaries. Macroinvertebrate field staff also noted sewage odors at the location and observed sewage fungus on rocks while collecting samples. It is most likely that aquatic life impairments in Twomile Creek are the result of localized organic enrichment in this small stream stemming from unsewered areas in the vicinity.

Aquatic Life Trends

For many streams in this study area, this survey represented the first major, comprehensive effort to assess ambient water quality and concurrent biological condition. As such, there is a general paucity of existing historical data from streams that might otherwise be present for other survey areas. Historical fish and macroinvertebrate community data was limited to smaller collection efforts over the decades preceding this survey. Where present, historical fish community index scores are presented in Table 19. There were only four previous historical macroinvertebrate samples: Symmes Creek mainstem at RM 8.4 (1990), Buffalo Creek at RM 1.90 (1990), and Caulley Creek at RM 0.2 in 1984 and 1990.

IBI scores from the single reach historically evaluated in Symmes Creek were higher than that recorded in 1990, while though the MIwb was substantially higher in 2016. The higher MIwb score in 2016 can partially be explained by the differences in sampling gear used to collect each sample: wading methods (Type D) were used in 1990, while boat methods (Type A) were used in 2016. Boat sampling methods will typically yield comparatively higher MIwb scores than wading sampling, though the differences in collection types are not likely to fully account for such a drastic increase in MIwb scores. There were likely overall increases in fish community performance throughout this reach of Symmes Creek. Only one macroinvertebrate sampling location at RM 8.4 was collected in 1990 and while the ICI scores were similar in 2016, the diversity of EPT and sensitive taxa greatly increased since 1990. More mayflies, stoneflies, a rare caddisfly (Brachycentrus numerosus) and live Pistolgrip mussels (Tritogonia verrucosa) were among the increased EPT and sensitive taxa collected at RM 8.4 in 2016 compared to 1990

Black Fork RM 5.77 is located downstream from Huntingcamp Creek (and the Oak Hill WWTP). Fish community performance at Black Fork RM 5.77 has improved since the late 1980s. IBI scores have remained similar between 1995 and 2016, while MIwb scores have increased.

Fish community performance throughout Huntingcamp Creek has improved somewhat through time since the 1980s, both up and downstream from the Oak Hill WWTP. IBI scores still failed to meet WWH criterion at the lower location in 2016. IBI scores, both historically and in 2016, have been higher upstream from this facility than downstream from it.

Both IBI and MIwb scores also have increased substantially throughout the lower reaches of Indian Guyan Creek. Fish community performance was also similar or has improved in Sugar Run, Sand Fork, and Caulley Creek. Caulley Creek, a regional reference site, was historically sampled for macroinvertebrates in 1984 and in 1999. The majority of the subwatershed upstream was located within the national forest. In years past, much lower historical taxa totals were collected at Co. Rd. 46 (RM 0.15), as Caulley Creek crossed private property with more intense land use downstream near the mouth. Eight EPT and 3 sensitive taxa with 38 total taxa were collected in 1984 with corn fields in the valley adjacent the stream by Co. Rd. 46. In 1999, an extreme drought year, only two EPT with no sensitive taxa collected. The instream habitat improved generally through time with QHEIs increasing from 57.0 in 1984 to 73.5 in 2016 (less silt and more instream substrates/cover). In 2016, the adjacent stream property consisted of mostly grass fields in secondary succession and more natural habitat with a more intact wooded riparian corridor.

Declines in IBI scores were noted in the upper reaches of Buffalo Creek compared to 1990 (RM 5.0, 200752), while scores were similar or slightly higher in the lower reaches of this same stream. Almost the entire area upstream from the sampling location at RM 5.0 in encompassed by portions of the Wayne National Forest and are almost entirely forested. The macroinvertebrate community in Buffalo Creek at RM 1.9 (8.5 mi.^{2}) was very much improved compared to the historical sample in 1990. The exceptional quality community collected in 2016 contained 18 EPT taxa and 14 sensitive taxa compared to seven EPT and three sensitive taxa (Good quality) in 1990 at RM 1.90. Hydropsychid caddisflies, *Helichus* sp. beetles, and MI *Isonychia* sp. mayflies were predominant in the stable riffle habitat and three very rare taxa were collected at RM 1.90 in 2016.

IBI scores from the singular location in Leatherwood Creek decreased modestly from 1998 to 2016, but still met WWH criterion.

Table 19—Historical IBI and MIwb scores from streams within the study area for the indicated years. IBI and MIwb scores are unique to each individual sampling event; if multiple sampling event occurred within a given year, an average of scores was taken. Scores followed by an asterisk (*) indicate significant departure from (not achieving) applicable biocriteria, while scores followed by a *NS* indicate nonsignificant departure from (achieving) applicable biocriteria. Determinations of significant and non-significant departure for historical data is based off current or recommended Aquatic Life Uses. Scores indicated by [brackets] were collected by Ohio Department of Natural Resources.

River	Station	1984	1987	1990	1991	1995	1998	1999	2010	2016/17
Symmes Creek (09-700-000)										
11.0	200746			50/8.2*						
9.7	200746									54/10.5
Sugar Run (09-741-000)										
1.5	303899				[30*]					
0.1	200756				[20*]					42^{NS}
Black Fork (09-730-000)										
5.77	W02S02		32*			50/8.5				49/9.1
Huntingcamp Creek (09-735-000)										
2.3	200755		20*							
1.8	W02S06					29*				40^{NS}
1.6	W02S04					25*				
1.4	W02S03									30*
1.2	W02S03		12*			25*				
Sand Fork (09-727-000)										
16.5	301801								[32*]	
16.3	301799								[30*]	
15.1	303569									40^{NS}
14.85	303568									44
13.4	301798								[46]	52
10.25	303567									42^{NS}
Buffalo Creek (09-719-000)										
5.0	200752			50						42^{NS}
5.0	200752									36*
1.9	W02S09									46
1.1	W02S09			42^{NS}						
Caulley Creek (09-720-000)										
0.15	W02S1	46		43^{NS}				44		52
Leatherwood Creek (09-704-000)										
0.8	200747						50			46
Indian Guyan Creek (09-100-000)										
5.76	W02S08			44/8.7						52/9.9
2.95	609150									53/9.1
0.7	W02K03			30*/5.6*						

Recreation Use

Water quality criteria for determining attainment of recreation uses are established in the Ohio Water Quality Standards (Table 37-2 in OAC 3745-1-37) based upon the presence or absence of bacteria indicators (*Escherichia coli*) in the water column. *Escherichia coli* (*E. coli*) bacteria are microscopic organisms that are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufor, 1977), but there is currently no simple way to differentiate between human and animal sources of coliform bacteria in surface waters, although methodologies for this type of analysis are becoming more practicable. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes or may enter water bodies along with runoff from soils where these wastes have been deposited.

Pathogenic (disease causing) organisms are typically present in the environment in such small amounts that it is impractical to monitor them directly. Fecal indicator bacteria by themselves, including *E. coli*, are usually not pathogenic. However, some strains of *E. coli* can be pathogenic, capable of causing serious illness. Although not necessarily agents of disease, fecal indicator bacteria such as *E. coli* may indicate the potential presence of pathogenic organisms that enter the environment through the same pathways. When *E. coli* are present in high numbers in a water sample, it invariably means that the water has received fecal matter from one source or another. Swimming or other recreational-based contact with water having a high fecal coliform or *E. coli* count may result in ear, nose, and throat infections, as well as stomach upsets, skin rashes, and diarrhea. Young children, the elderly, and those with depressed immune systems are most susceptible to infection.

The streams of the Symmes Creek, Indian Guyan Creek and direct Ohio River tributaries evaluated in this survey are designated with the Primary Contact Recreation (PCR) recreational use in OAC Rule 3745-1-16. Water bodies with a designated recreational use of PCR "...are waters that, during the recreation season, are suitable for one or more full-body contact recreation activities such as, but not limited to, wading, swimming, boating, water skiing, canoeing, kayaking and scuba diving" [OAC 3745-1-07 (B)(3)(b)].

Recreation use attainment status is determined by comparing the geomean of samples collected within a 90-day period of the larger recreation season, which extends from May 1 through October 31, to the geometric mean criterion of 126 cfu/100 ml and to the statistical threshold value (STV) of 410 cfu/100 ml, which should not be exceeded by more than 10 percent of individual samples.

Summarized bacteria results are listed in Table 20, and the complete dataset is reported in Appendix K. Five to 10 *E. coli* samples were collected from 19 locations in the Symmes Creek, Indian Guyan Creek and the direct Ohio River tributary study area from June 6 through August 16, 2016. Seventeen (17) locations, or 89 percent, of the sampling locations failed to meet both the applicable geometric mean criterion and the statistical threshold value, and thus were in *non-attainment* of the recreation use.

Indian Guyan Creek RM 14.7 had the highest geomean *E. coli* concentration, 1578 cfu/100 ml, followed closely by Long Creek RM 0.86 with a geomean of 1545 cfu/100 ml. Little Indian Creek at RM 0.13 and Symmes Creek RMs 31.7 and 2.85 also had *E. coli* geomean concentrations higher than 1,000 cfu/100 ml. Two tributary locations, Dirtyface Creek RM 1.82 (geomean 69 cfu/100 ml) and Black Fork RM 2.40 (geomean 126 cfu/100 ml), were in full attainment of recreation use (see Table 20).

Sources of elevated bacteria concentrations were ubiquitous and most likely due to a variety of inputs and land use conditions in the watershed. The watershed is rural and has very few centralized wastewater treatment facilities. Inadequately functioning home sewage treatment systems (HSTS) in unsewered areas and agricultural activities are the most probable sources of bacteria to streams in the study area. Agricultural activities include land application of manure and biosolids as well as livestock pasture and production.

The highest concentrations of *E. coli* were evident during or shortly following heavy rain events, such as a storm event on 7/5/2016 that coincided with sample collection; however bacterial contamination in most streams was present to some extent during both wet and dry weather events. This indicates that strategies to reduce bacteria levels in streams should include both non-point source and point source measures. Summarized *E. coli* bacteria results are presented in Table 20. Some of the sources of bacterial contamination throughout the study area are indicated in Table 20. At the time of this study, the sources listed have not necessarily been confirmed as a source of impairment nor are they exclusive of other possible sources.

Table 20—A summary of E. coli data for the 19 locations in Symmes Creek and Indian Guyan Creek sampled June through August 2016. Recreation Use Attainment Status is determined by comparing samples collected within a 90-day period during the recreation season to the geometric mean criterion of 126 cfu/100 ml and to the statistical threshold value (STV) of 410 cfu/100 ml (for PCR). The STV is not be exceeded by more than 10 percent of individual samples.

Station ID	Location	River Mile	# Samples	Geometric Mean	% > STV	Maximum Value	Attainment Status	Possible Source(s)[1] of Bacteria
05090101 07 03 – Swan Creek								
303527	Swan Creek at Swan Creek Rd	2.35	5	891	80%	4,200	NON	HSTS, Ag
05090101 07 06 – Little Indian Guyan Creek								
303532	Little Indian Guyan Creek at St. Rt. 217	0.13	5	1435	100%	9,800	NON	HSTS, Ag
05090101 07 07 – Johns Creek – Indian Guyan Creek								
W02K04	Indian Guyan Creek at County Road 67	15.3	5	1578	100%	6,500	NON	HSTS, Ag
05090101 07 08 – Wolf Creek – Indian Guyan Creek								
W02S08	Indian Guyan Creek at County Road 69	5.76	10	675	70%	5,600	NON	HSTS, Ag
05090101 08 01 – Dirtyface Creek								
300156	Dirtyface Creek at CH&D Road	1.82	10	69	10%	5,400	**FULL**	
0509101 08 02 – Black Fork								
303501	Black Fork at State Route 233	2.40	10	126	10%	480	**FULL**	
0509101 08 03 – Headwaters Symmes Creek								
300158	Symmes Creek at Jenkins Alben Road	62.76	10	820	90%	7,500	NON	HSTS, Ag
0509101 09 01 – Sand Fork								
301798	Sand Fork at State Route 775	13.4	10	298	20%	610	NON	HSTS, Ag
300154	Sand Fork @ Patriot-Cadmus Rd.	2.7	10	664	50%	5,900	NON	HSTS, Ag
0509101 09 02 – Buffalo Creek								
W02S09	Buffalo Creek @ County Road 14	1.91	5	87	20%	550	NON	HSTS, Ag
0509101 09 03 – Camp Creek – Symmes Creek								
200754	Symmes Creek @ Symmes Creek Road	56.7	10	155	10%	2,400	NON	HSTS, Ag
303500	Symmes Creek at Waterloo-Mt. Vernon Rd.	38.7	10	545	50%	6,300	NON	HSTS, Ag
0509101 10 01 – Johns Creek								
300153	Johns Creek @ St. Rt. 141	0.07	10	438	40%	1,400	NON	HSTS, Ag
0509101 10 02 – Long Creek								
303536	Long Creek at Zalmon Rd SE of Arabia	0.86	5	1545	60%	20,000	NON	HSTS, Ag
0509101 10 03 – Pigeon Creek – Symmes Creek								
303533	Symmes Creek at St. Rt. 141	31.7	5	1003	60%	21,000	NON	HSTS, Ag

Station ID	Location	River Mile	# Samples	Geometric Mean	% > STV	Maximum Value	Attainment Status	Possible Source(s)[1] of Bacteria
0509101 10 04 – Aaron Creek – Symmes Creek								
300151	Symmes Creek at Aid St. T. 141 USGS gage station	22.6	10	519	50%	3,300	NON	HSTS, Ag
303534	Symmes Creek at State Route 217 - Linnville	17.53	5	616	60%	6,100	NON	HSTS, Ag
0509101 10 05 – McKinney Creek – Symmes Creek								
303535	Symmes Creek at County Road 104 Boothe Eaton Rd	2.85	5	1200	60%	8,700	NON	HSTS, Ag
0509101 10 07 – Buffalo Creek – Ohio River								
303531	Buffalo Creek at Buffalo Creek Rd	1.10	5	982	80%	6,000	NON	HSTS, Ag

[1] Possible Sources:
AG – Agriculture
HSTS – Home Sewage Treatment Systems

Fish Tissue

Ohio has been sampling streams annually for sport fish contamination since 1993. Fish are analyzed for contaminants that bioaccumulate in fish and that could pose a threat to human health if consumed in excessive amounts. Contaminants analyzed in Ohio sport fish include mercury, PCBs, DDT, mirex, hexachlorobenzene, lead, selenium, and several other metals and pesticides. Other contaminants are sometimes analyzed if indicated by site-specific current or historic sources. For more information about the chemicals analyzed, how fish are collected, or the history of the fish contaminant program, see State Of Ohio Cooperative Fish Tissue Monitoring Program Sport Fish Tissue Consumption Advisory Program, Ohio EPA, January 2010.

Fish contaminant data are primarily used for three purposes: 1) to determine fish advisories; 2) to determine attainment with the water quality standards; and 3) to examine trends in fish contaminants over time.

Fish Advisories

Fish contaminant data are used to determine a meal frequency that is safe for people to consume (e.g., two meals a week, one meal a month, do not eat), and a fish advisory is issued for applicable species and locations. Because mercury mostly comes from nonpoint sources, primarily aerial deposition, Ohio has had a statewide one meal per week advisory for most fish since 2001. Most fish are assumed to be safe to eat once a week unless specified otherwise in the fish advisory, which can be viewed at ***http://www.epa.state.oh.us/dsw/fishadvisory/index.aspx***.

The first advisory for Symmes Creek was issued in 1998, with "one meal per month" advisories for freshwater drum and sauger due to mercury concentrations.

The minimum data requirement for issuing a fish advisory is three samples of a single species from within the past 10 years. For Symmes Creek, data had been collected in 2012, 2014, and 2016, which were pooled together for the advisory calculated and published in 2017. The following species had sufficient samples to calculate advisories: channel catfish, common carp, freshwater drum, rock bass, and sauger. Golden redhorse, silver redhorse, smallmouth bass, spotted bass, and white crappie were also collected, but under three samples per species. Both 1998 advisories for freshwater drum and sauger were confirmed and retained; channel catfish was also added to the "one meal per month" advisory due to mercury. All other species caught in Symmes Creek should follow the statewide advice of two meals a week for sunfish and yellow perch, one meal a week for most other fish, and one meal a month for flathead catfish ≥ 23" and northern pike ≥ 23".

For a listing of fish tissue data collected from Symmes Creek in support of the advisory program, and how the data compare to advisory thresholds, see Table 22 and Table 23 at the end of the section.

Fish Tissue/Human Health Use Attainment

In addition to determining safe meal frequencies, fish contaminant data are also used to determine attainment with the human health water quality criteria pursuant to OAC Rules 3745-1-33 and 3745-1-34. The human health water quality criteria are presented in water column concentrations of μg/L and are then translated into fish tissue concentrations in mg/kg. [See Ohio's 2018 Integrated Report, Section E (***https://www.epa.ohio.gov/Portals/35/tmdl/2018intreport/SectionE.pdf***) for further details.]

In order to be considered in attainment of the water quality standards, the sport fish caught within a HUC12 must have a weighted average concentration of the geometric means for all species below 1.0 mg/kg for mercury, and below 0.054 mg/kg for PCBs.

Within the Symmes Creek study area, fish tissue data were adequate to determine attainment status in three assessment units: Camp Creek (HUC12 050901010903), Pigeon Creek (HUC12 050901011003), and Aaron Creek (HUC12 050901011004). At least 2 samples from each trophic level, 3 and 4, are needed. There were not adequate data to assess impairment of McKinney Creek (HUC12 050901011005).

No PCBs were detected in fish (reporting limit of 0.05 mg/kg from 1974-2014; 0.02 mg/kg from 2015 to present) from Camp Creek and Pigeon Creek. PCBs were detected in two channel catfish, one each in Aaron Creek and McKinney Creek, but the average PCB concentration in trophic level three fish was below the 0.054 mg/kg criterion. No fish had mercury levels above the criterion of 1.0 mg/kg (reporting limit of 0.024 mg/kg). Therefore, Camp Creek, Pigeon Creek, and Aaron Creek HUCs are considered in attainment of the fish tissue use. There has been no change in impairment between the current and previous analysis cycles (Table 21).

Table 21—Assessment Units (AUs) in Symmes Creek. Three of the four AUs have no impairment (category 1); the other has insufficient data (category 3i).

Assessment Unit (AU)	Previous status (2016)	Current status (2018)	AU Name
05090101 09 03	1	1	Camp Creek-Symmes Creek
05090101 10 03	1	1	Pigeon Creek-Symmes Creek
05090101 10 04	1	1	Aaron Creek-Symmes Creek
05090101 10 05	3i	3i	McKinney Creek-Symmes Creek

Fish Contaminant Trends

Fish contaminant levels can be used as an indicator of pollution in the water column at levels lower than laboratory reporting limits for water concentrations but high enough to pose a threat to human health from eating fish. Most bioaccumulative contaminant concentrations are decreasing in the environment because of bans on certain types of chemicals like PCBs, and because of stricter permitting limits on dischargers for other chemicals. However, data show that PCBs continue to pose a risk to humans who consume fish, and mercury concentrations have been increasing in some locations because of increases in certain types of industries for which mercury is a byproduct that is released to air and/or surface water.

For this reason, it is useful to compare the results from the survey presented in this TSD with the results of the previous survey(s) done in the study area. Recent data can be compared against historical data to determine whether contaminant concentrations in fish tissue appear to be increasing, decreasing, or staying the same in a water body or watershed.

Because mercury tends to increase with increasing position within the food web (that is, predator fish have higher mercury levels than herbivores and insectivores), all sample results within a trophic level (TL) can be calculated as a yearly average and compared between years, making for an informative assessment while remaining concise.

However, this analysis technique does not fare well for PCBs, which are more affected by the fat content and foraging habitat of fish species rather than their TL (Lopes, Perga, Roger, & Babut, 2011). For example, TL three fish (insectivores) often include both some of the most-contaminated species for PCBs (such as catfish and carp), as well as some of the least-contaminated species for PCBs (such as bluegill and other panfish). If the same species have been consistently collected across years at a given site, then species PCB concentration trends can be evaluated directly, but if different species have been collected across years, then other approaches must be considered. Therefore, PCB contamination trends are often evaluated on a case-by-case basis to ensure the most reliable conclusions.

Mercury

Fish tissue had previously been collected from Symmes Creek in 1974, 1996, 2012, and 2014. Including the 2016 samples, a total of fourteen species (ten TL 3, four TL4) were collected at least once. Mercury concentrations often fluctuate substantially between years, with such normal fluctuations observed in Symmes Creek (Figure 29, Figure 30). Species already under a one meal/month advisory – channel catfish, freshwater drum, sauger – contributed to the elevated average TL concentrations (Figure 29). White crappie also had concentrations within one meal/month from single samples each from 1974 and 2016 (Figure 30); protocol requires three samples within a ten-year period, so the species has been flagged for follow-up sampling in coming years.

Total PCBs

PCB concentrations in Symmes Creek were generally low and of minimal concern. All species except channel catfish and sauger had concentrations below detection limits (0.05 mg/kg until 2015, 0.02 mg/kg after 2015) (Figure 31). These measurements result in consumption advisories in the unrestricted and one meal per week advisories, though mercury concentrations have stricter advisories (one meal per month).

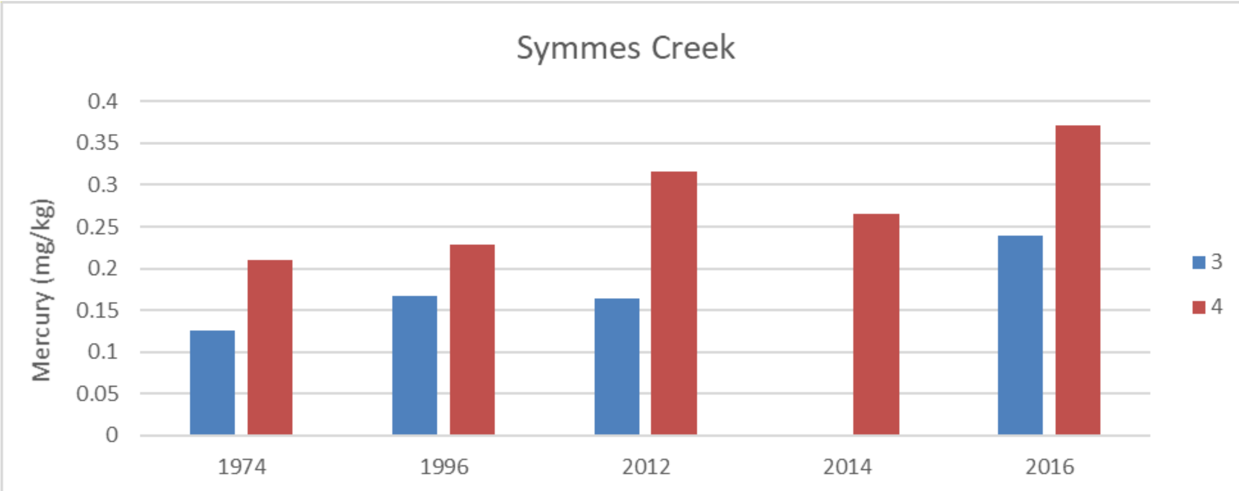


Figure 29—Average mercury concentrations of trophic levels 3 and 4 in Symmes Creek. Observed inter-annual fluctuations were consistent with expected natural variation, though there seems to be a slight increase in concentration for both TLs across years.

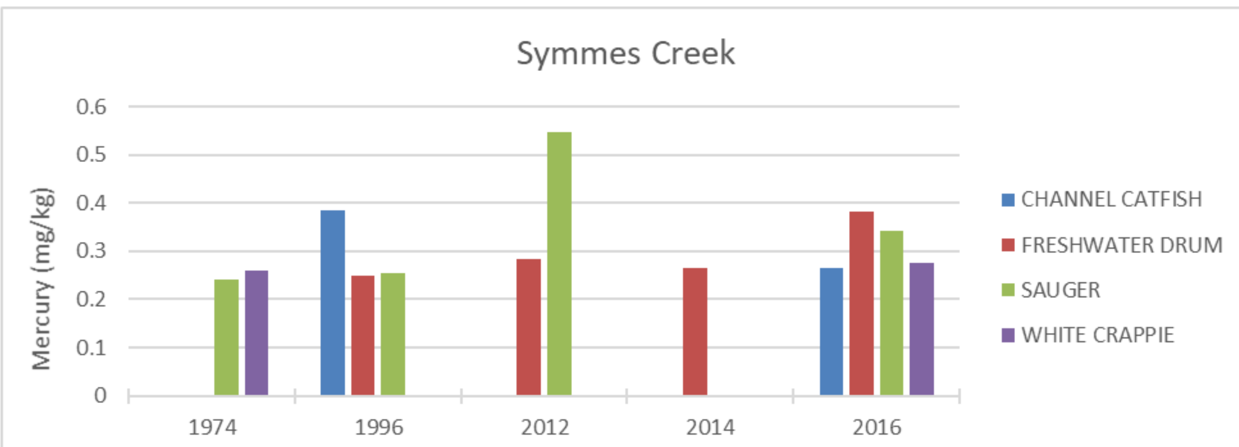


Figure 30—Average mercury concentrations of select species in Symmes Creek. The average mercury concentration of sauger in 2012 was markedly higher (0.548 mg/kg), though all concentrations throughout the years are within the one meal/month advisory level of 0.220-1

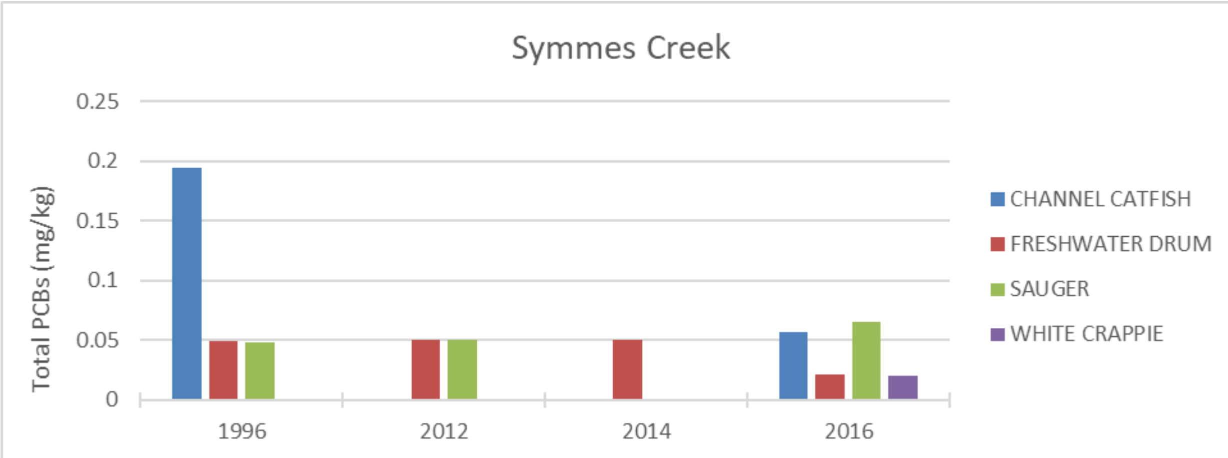


Figure 31—Average total PCBs concentrations of select species in Symmes Creek. Except for channel catfish and sauger, all concentrations were below detection limits. Those measurements above detection limit were within the state-wide advisory of one meal/week (0.220 mg.kg tissue).

Table 22—Select fish tissue mercury concentrations from 2012, 2014, and 2016 Symmes Creek. Cell shading in the Results colun indicates the advisory category that apply: green = two meals per week, yellow = one meal per week, orange = one meal per month.

Station	Site Name	Species	Year	River	Sample	Result
303535	SYMMES CREEK @ CR104 BOOTHE EATON RD	CHANNEL CATFISH	2016	2.85	Fillet	0.363
303534	SYMMES CREEK SR 217 @ LINNVILLE	CHANNEL CATFISH	2016	17.53	Fillet	0.528
303534	SYMMES CREEK SR 217 @ LINNVILLE	CHANNEL CATFISH	2016	17.53	Fillet	0.118
300151	SYMMES CREEK AT AID @ ST. RT. 141	CHANNEL CATFISH	2016	22.6	Fillet	0.055
200748	SYMMES CREEK ADJ. TWP. RD. 114	FRESHWATER DRUM	2012	14.3	Fillet	0.435
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2012	29.3	Fillet	0.122
200751	SYMMES CREEK DST. WATERLOO, UPST. PIGEON CREEK	FRESHWATER DRUM	2012	35.1	Fillet	0.457
200753	SYMMES CREEK AT CADMUS @ ST. RT. 141	FRESHWATER DRUM	2012	47.1	Fillet	0.118
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2014	29.3	Fillet	0.216
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2014	29.3	Fillet	0.127
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2014	29.3	Fillet	0.096
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2014	29.3	Fillet	0.845
200753	SYMMES CREEK AT CADMUS @ ST. RT. 141	FRESHWATER DRUM	2014	47.1	Fillet	0.172
200753	SYMMES CREEK AT CADMUS @ ST. RT. 141	FRESHWATER DRUM	2014	47.1	Fillet	0.133
303535	SYMMES CREEK @ CR104 BOOTHE EATON RD	FRESHWATER DRUM	2016	2.85	Fillet	0.236
303534	SYMMES CREEK SR 217 @ LINNVILLE	FRESHWATER DRUM	2016	17.53	Fillet	0.557
300151	SYMMES CREEK AT AID @ ST. RT. 141	FRESHWATER DRUM	2016	22.6	Fillet	0.265
300151	SYMMES CREEK AT AID @ ST. RT. 141	FRESHWATER DRUM	2016	22.6	Fillet	0.378
300151	SYMMES CREEK AT AID @ ST. RT. 141	FRESHWATER DRUM	2016	22.6	Fillet	0.479
200748	SYMMES CREEK ADJ. TWP. RD. 114	SAUGER	2012	14.3	Fillet	0.581
200751	SYMMES CREEK DST. WATERLOO, UPST. PIGEON CREEK	SAUGER	2012	35.1	Fillet	0.515
303534	SYMMES CREEK SR 217 @ LINNVILLE	SAUGER	2016	17.53	Fillet	0.466
300151	SYMMES CREEK AT AID @ ST. RT. 141	SAUGER	2016	22.6	Fillet	0.217

Table 23—Select fish tissue total PCBs concentrations from 2012, 2014, and 2016 Symmes Creek. Cell shading in the Results column indicates the advisory category that apply: yellow = one meal per week. Cells shaded blue represent no advisory.

Station	Station Name	Species	Year	River	Sample	Result	Detected
303535	SYMMES CREEK @ CR104 BOOTHE EATON RD	CHANNEL CATFISH	2016	2.85	Fillet	0.126	Yes
303534	SYMMES CREEK SR 217 @ LINNVILLE	CHANNEL CATFISH	2016	17.53	Fillet	0.0594	Yes
303534	SYMMES CREEK SR 217 @ LINNVILLE	CHANNEL CATFISH	2016	17.53	Fillet	0.0199	No
300151	SYMMES CREEK AT AID @ ST. RT. 141	CHANNEL CATFISH	2016	22.6	Fillet	0.02	No
200748	SYMMES CREEK ADJ. TWP. RD. 114	FRESHWATER DRUM	2012	14.3	Fillet	0.0498	No
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2012	29.3	Fillet	0.0496	No
200751	SYMMES CREEK DST. WATERLOO, UPST. PIGEON CREEK	FRESHWATER DRUM	2012	35.1	Fillet	0.05	No
200753	SYMMES CREEK AT CADMUS @ ST. RT. 141	FRESHWATER DRUM	2012	47.1	Fillet	0.0496	No
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2014	29.3	Fillet	0.0497	No
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2014	29.3	Fillet	0.0496	No
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2014	29.3	Fillet	0.0498	No
200749	SYMMES CREEK SW OF ARABIA, ADJ. CO. RD. 5	FRESHWATER DRUM	2014	29.3	Fillet	0.0499	No
200753	SYMMES CREEK AT CADMUS @ ST. RT. 141	FRESHWATER DRUM	2014	47.1	Fillet	0.0499	No
200753	SYMMES CREEK AT CADMUS @ ST. RT. 141	FRESHWATER DRUM	2014	47.1	Fillet	0.0499	No
303535	SYMMES CREEK @ CR104 BOOTHE EATON RD N OF	FRESHWATER DRUM	2016	2.85	Fillet	0.0199	Yes
303534	SYMMES CREEK SR 217 @ LINNVILLE	FRESHWATER DRUM	2016	17.53	Fillet	0.0231	Yes
300151	SYMMES CREEK AT AID @ ST. RT. 141	FRESHWATER DRUM	2016	22.6	Fillet	0.0199	No
300151	SYMMES CREEK AT AID @ ST. RT. 141	FRESHWATER DRUM	2016	22.6	Fillet	0.02	No
300151	SYMMES CREEK AT AID @ ST. RT. 141	FRESHWATER DRUM	2016	22.6	Fillet	0.0199	No
200748	SYMMES CREEK ADJ. TWP. RD. 114	SAUGER	2012	14.3	Fillet	0.0496	No
200751	SYMMES CREEK DST. WATERLOO, UPST. PIGEON CREEK	SAUGER	2012	35.1	Fillet	0.05	No
303534	SYMMES CREEK SR 217 @ LINNVILLE	SAUGER	2016	17.53	Fillet	0.1099	Yes
300151	SYMMES CREEK AT AID @ ST. RT. 141	SAUGER	2016	22.6	Fillet	0.0198	No

Fish contaminant data are used to determine a meal frequency that is safe for people to consume (for example, two meals a week, one meal a month, do not eat), and a fish advisory is issued for any species with an average contaminant concentration above advisory threshold concentrations.

Recommendations

Aquatic Life Use

All streams within the Symmes Creek, Indian Guyan Creek, and direct Ohio River tributaries study area currently listed in the Ohio Water Quality Standards (WQS) are either assigned the warmwater habitat (WWH) aquatic life beneficial use (ALU) or are currently undesignated (i.e. not listed in WQS). As this is the first major comprehensive and integrated water quality survey conducted in many of these stream systems, ALU designations for nearly all streams evaluated during this survey have not been previously verified using standardized biological field collections. Many streams in Ohio were originally designated an aquatic life use in the 1978 Ohio WQS, but the techniques used then did not include standardized approaches to the collection of instream biological data or numerical biological criteria. This study used biological field data to assess current condition to either verify the existing ALU or recommend an appropriate ALU(Table 24).

Sixty-eight streams were evaluated for aquatic life use potential in 2016 and 2017. Significant findings from this survey include the following:

- The mainstem of Symmes Creek is just over 73 river miles in length and was evaluated at 10 sampling locations. The Symmes Creek mainstem was previously verified WWH aquatic life use with limited biological samples in 1990 and 1995. Much of the uppermost reaches of Symmes Creek and many tributaries in the upper reaches are sluggish, low gradient, and display other characteristics similar to wetlands. Swamp and wetlands frequently dot the landscape in the upper reaches of this watershed and the nexus between "wetlands" and "streams" can be blurred. Because of these conditions, biological community performance is naturally limited in upper Symmes Creek mainstem and many other tributaries in the upper portions of the watershed. The lower reaches of Symmes Creek still maintain some of these wetland characteristics but begins to support biological communities more typical of flowing environments, though reaches of sluggish flow are still present.

  Biological communities largely meet or exceed WWH criteria in the uppermost reaches of Symmes Creek from the headwaters to the confluence of Black Fork. Locations evaluated downstream from the confluence of Black Fork meet or exceed EWH expectations throughout the lower 56 miles evaluated. Eighteen species of mussels have been documented in this reach including species that are state endangered or of special concern. Biological community performance at eight locations throughout the lower 56 miles of Symmes Creek was consistent with EWH expectations. It is therefore recommended that from the headwaters of Symmes Creek to its confluence with Black Fork (RM 60.3) retain the WWH designations and the lower reaches from RM 60.3 to the mouth be assigned the EWH aquatic life use.

- Sand Fork is a direct tributary to Symmes Creek and was evaluated at five sampling locations along its length. All five locations assessed fully met ecoregional WWH expectations. Biological performance in the lower several miles exceeded WWH criteria and was consistent with EWH expectations. The current survey confirmed the WWH aquatic life use is appropriate much of Sand Fork. The EWH aquatic life use designation is recommended for the lower reaches of Sand Fork, beginning at the unnamed tributary at RM 4.55 and extending downstream to its confluence with Symmes Creek.

- Indian Guyan Creek is a relatively sizable, direct Ohio River tributary and was previously verified WWH aquatic life use with limited biological monitoring data collected in 1990. This survey represents the first major, comprehensive sampling effort conducted in Indian Guyan Creek. Biological performance at the seven locations assessed largely exceeded WWH criteria and was consistent with EWH expectations. The entirety of Indian Guyan Creek is therefore recommended the EWH aquatic life use.

- The current survey confirmed the WWH aquatic life use was appropriate for 40 streams that were previously designated WWH but were unverified with field biological collections. These streams included:
  - Symmes Creek watershed – Sugar Run, Cherry Fork, upper Black Fork, Hewitt Run, Huntingcamp Creek, Cambria Creek, Dicks Creek, Clear Fork, lower Dirtyface Creek, Wolf Run, Peters Cave Creek, Trace Creek, Camp Creek, Indian Creek, Pigeon Creek, Johns Creek, Buckeye Creek (Trib. to John's Ck.), Brushy Buckeye Creek, Long Creek, Aaron Creek, Elkins Creek, Venisonham Creek, Leatherwood Creek, McKinney Creek, Big Branch Creek
  - Indian Guyan Creek watershed – Drake Fork, Johns Creek, Rocky Fork, Lanes Branch, Slate Run, Bear Creek, Bent Creek
  - Direct Ohio River tributaries – Buffalo Creek, Paddy Creek, Twomile Creek, Federal Creek, Clean Fork, Chickamauga Creek, Little Chickamauga Creek.

- Buffalo Creek (Trib. to Symmes Creek at RM 38.58) was previously verified WWH with biological data collected in 1990. The lower segment of Buffalo Creek is recommended for an EWH designation from RM 1.9 to the mouth based on full attainment of the EWH biocriteria and its continuity with other exceptional segments present both upstream and downstream. The headwaters of Buffalo Creek to RM 1.9 is verified WWH.

- Eleven other streams evaluated during the survey currently maintain an unverified WWH or undesignated aquatic life use designation. Biological community performance in these streams exceeded ecoregional WWH criteria and was consistent with EWH expectations. The current survey represented the first biological community collections from all these streams. Thus, the following streams are recommended the EWH aquatic life use designation.
  - Symmes Creek watershed – lower Black Fork, upper Dirtyface Creek, Slab Fork, Buckeye Creek (Trib. to Long Creek), Sharps Creek, Rankin Creek, Buck Creek
  - Indian Guyan Creek watershed – Georges Creek, Little Indian Guyan Creek, Wolf Creek, Fivemile Creek, Trace Creek
  - Direct Ohio River tributaries – Swan Creek, Little Swan Creek, Teens Run

Additionally, Caulley Creek (Tributary to Buffalo Creek at RM 1.7) was desiginated WWH aquatic life use based on biological data collected from 1984, 1990 and 1999. Biological community performance from the survey exceeded WWH criteria and was consistent with EWH expectations. Caulley Creek is recommended for an EWH aquatic life use designation.

- Ten streams previously undesignated in the WQS evaluated during the current survey either displayed biological community performance consistent with ecoregional WWH expectations or had biological communities consistent with expectations but were naturally limited by low-flows or wetland-influenced stream habitat conditions. The WWH aquatic life use is recommended for the following streams:
  - Symmes Creek watershed – Tributary to Symmes Creek (73.03), Sweetbit Creek, Handley Branch
  - Indian Guyan Creek watershed – Tributary to Drake Fork (0.55), Williams Creek, Watson Creek
  - Direct Ohio River tributaries – Scarey Creek, Tributary to Swan Creek (5.95), Little Paddy Creek

- The presence of cold-water biological indicators was documented in substantial numbers during the Agency's first-ever survey of four tributaries: Big Creek, Miller Creek, Little Buffalo Creek and Perigen Creek. This biological signature suggests the presence of a coldwater thermal regime. The CWH aquatic life use designation is recommended to protect the fauna documented in these streams during the survey.

- Little Buffalo Creek was also meeting EWH aquatic life use expectations is recommended a duel use of CWH and EWH.

- Three streams in the Buffalo Creek sub-watershed (Bakers fork, Beech Creek, and Asbury Creek) were not sampled during the survey and were not listed in the WQS. Attempts were made to obtain access to sample Asbury Creek, but were unable to make contact with necessary landowners. The drainage network of the Buffalo Creek sub-watershed was updated in Table 24 to reflect proper ordering. These three streams are recommended to receive the baseline CWA beneficial use goals until biological and water quality data are collected to confirm their uses.

Recreation Beneficial Use

All streams or stream segments within the study area should have the Primary Contact Recreation beneficial use confirmed, retained, or assigned.

Water Supply Beneficial Use

All streams in the study area should have the Agricultural Water Supply and Industrial Water Supply uses confirmed, retained, or assigned. No Public Drinking Water surface intakes are present on streams evaluated as part of the survey.

Anti-Degradation Categories

Numerous streams in Table 24 are currently listed as a State Resource Water (SRW). The SRW is an outdated antidegradation category being phased out as described in OAC 3745-1-05(A)(25) and replaced with the modern antidegradation categories as described in OAC 3745-1-05. The SRW listing for all the streams listed above are recommended to be removed and replaced with the General High-Quality Waters (GHQW) category.

Table 24—Beneficial use designations for water bodies in the Symmes Creek, Indian Guyan Creek, Chickamauga Creek watershed and direct Ohio River tributaries. Shaded streams were sampled during the current survey; darker shading indicates a stream segment being recommended either the EWH or CWH aquatic life beneficial use. Beneficial use designations for all waterbodies in the southeast Ohio tributaries drainage basin can be found in Ohio Administrative code 3745-1-16 (Table 16-1).

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Buffalo creek		*/+							*/+	*/+		*/+		
Scarey Creek		Δ							Δ	Δ		Δ		Formerly undesignated.
Symmes creek – headwaters to Black Fork confluence (RM 60.3)	~~*~~	+							+	+		+		
RM 60.3 – mouth			Δ						+	+		+		
Big Branch creek		*/+							*/+	*/+		*/+		
McKinney creek		*/+							*/+	*/+		*/+		
Rankin creek		~~*~~	Δ						*/+	*/+		*/+		
Leatherwood creek		*/+							*/+	*/+		*/+		
Venisonham creek		*/+							*/+	*/+		*/+		
Dicks creek		*							*	*		*		
Yellow creek		*							*	*		*		
Sharps creek		~~*~~	Δ						*/+	*/+		*/+		
Elkins creek	~~*~~	*/+							*/+	*/+		*/+		
Aaron creek		*/+							*/+	*/+		*/+		
Long creek		*/+							*/+	*/+		*/+		
Buckeye creek		~~*~~	Δ						*/+	*/+		*/+		
Buck creek		~~*~~	Δ						*/+	*/+		*/+		
Handley Branch		Δ							Δ	Δ		Δ		Formerly undesignated.
Johns creek	~~*~~	*/+							*/+	*/+		*/+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
| | | | | | | |														
Buckeye creek	~~*~~	*/+							*/+	*/+		*/+		
Brushy Buckeye creek	~~*~~	*/+							*/+	*/+		*/+		
Slab fork	~~*~~	~~*~~	Δ						*/+	*/+		*/+		
Pigeon creek		*/+							*/+	*/+		*/+		
Buffalo creek - headwaters to RM 1.9 (Twp. Hwy. 154)	~~*~~	+							+	+		+		
- RM 1.9 to mouth			Δ						+	+		+		
Bakers fork		*							*	*		*		Currently undesignated. Add to WQS with baseline CWA beneficial use goals.
Caulley Creek	~~*~~	~~+~~	Δ						+	+		+		
Miller creek	~~*~~	~~*~~				Δ			*/+	*/+		*/+		
Beech Fork		*							*	*		*		Currently undesignated. Add to WQS with baseline CWA beneficial use goals.
Asbury Creek		*							*	*		*		Currently undesignated. Add to WQS with baseline CWA beneficial use goals.
Indian creek	~~*~~	*/+							*/+	*/+		*/+		
Little Buffalo creek	~~*~~	~~+~~	Δ			Δ			*/+	*/+		*/+		
Camp creek	~~*~~	*/+							*/+	*/+		*/+		
Trace creek	~~*~~	*/+							*/+	*/+		*/+		
Sand fork – headwaters to RM 2.7 (Patriot-Cadmus Rd.)		*/+							*/+	*/+		*/+		
RM 2.7 – mouth			Δ						*/+	*/+		*/+		
Peter Cave creek		*/+							*/+	*/+		*/+		
Wolf creek	~~*~~	*/+							*/+	*/+		*/+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
| | | | | | | |														
Sweetbit Creek		Δ							Δ	Δ		Δ		Formerly undesignated.
Black fork – headwaters to Dirtyface Creek (RM 0.9)	~~*~~	*/+							*/+	*/+		*/+		
RM 0.9 to mouth			Δ						*/+	*/+		*/+		
Dirtyface creek – headwaters to C-H-D Rd. (RM 4.7)	~~*~~		Δ						*/+	*/+		*/+		
RM 4.7 to mouth		*/+							*/+	*/+		*/+		
Clear fork	~~*~~	*/+							*/+	*/+		*/+		
Dicks creek		*/+							*/+	*/+		*/+		
Lefthand fork (A.K.A. Cambria creek)	~~*~~	*/+							*/+	*/+		*/+		
Huntingcamp creek		*/+							*/+	*/+		*/+		
Cub run		*							*	*		*		
Mackley run		*							*	*		*		
Hewitt run	~~*~~	*/+							*/+	*/+		*/+		
Cherry fork	~~*~~	*/+							*/+	*/+		*/+		
Sugar run	~~*~~	*/+							*/+	*/+		*/+		
Tributary to Symmes creek (73.03)		Δ							Δ	Δ		Δ		Formerly undesignated.
Indian Guyan creek		~~+~~	Δ						+	+		+		
Bent creek		*/+							*/+	*/+		*/+		
Bear creek		*/+							*/+	*/+		*/+		
Fourmile creek		*							*	*		*		
Fivemile creek		~~*~~	Δ						*/+	*/+		*/+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Slate run		*/+							*/+	*/+		*/+		
Wolf creek		~~*~~	Δ						*/+	*/+		*/+		
Wagner branch		*							*	*		*		
Trace creek			Δ						Δ	Δ		Δ		Formerly undesignated.
Watson run		Δ							Δ	Δ		Δ		Formerly undesignated.
Little Indian Guyan creek		~~*~~	Δ						*/+	*/+		*/+		
Spring branch		*							*	*		*		
Williams creek		Δ							Δ	Δ		Δ		Formerly undesignated.
Georges creek		~~*~~	Δ						*/+	*/+		*/+		
Lanes branch		*/+							*/+	*/+		*/+		
Johns Creek		*/+							*/+	*/+		*/+		
Rocky fork		*/+							*/+	*/+		*/+		
Drake fork		*/+							*/+	*/+		*/+		
Tributary to Drake fork (0.55)		Δ							Δ	Δ		Δ		Formerly undesignated.
Perigen creek		~~*~~				Δ			*/+	*/+		*/+		
Paddy creek		*/+							*/+	*/+		*/+		
Little Paddy creek		Δ							Δ	Δ		Δ		Formerly undesignated.
Twomile creek		*/+							*/+	*/+		*/+		
Federal creek		*/+							*/+	*/+		*/+		

Water Body Segment	Use Designations													Comments
		Aquatic Life Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
Clean fork		*/+							*/+	*/+		*/+		
Dirty fork		*							*	*		*		
Big Creek						Δ			Δ	Δ		Δ		Formerly undesignated.
Stillhouse branch		*							*	*		*		
Swan creek		~~*~~	Δ						*/+	*/+		*/+		
Little Swan creek		~~*~~	Δ						*/+	*/+		*/+		
Peters branch		*							*	*		*		
Tributary to Swan Creek (5.95)		Δ							Δ	Δ		Δ		
Hildebrand run		*							*	*		*		
Teens run		~~*~~	Δ						*/+	*/+		*/+		
Chickamauga creek		*/+							*/+	*/+		*/+		
Paint creek		*							*	*		*		
Little Chickamauga creek		*/+							*/+	*/+		*/+		

* Designated use based on the 1978 water quality standards
\+ Designated use based on the results of a biological field assessment performed by the Ohio EPA
*/+ Designated use confirmed based on the results of a biological field assessment performed by the Ohio EPA
▲ New beneficial use recommended based on the results of a biological field assessment performed by the Ohio EPA

SRW = state resource water; WWH = warmwater habitat; EWH = exceptional warmwater habitat; MWH = modified warmwater habitat; SSH = seasonal salmonid habitat; CWH = coldwater habitat; LRW = limited resource water; PWS = public water supply; AWS = agricultural water supply; IWS = industrial water supply; BW = bathing water; PCR = primary contact recreation; SCR = secondary contact recreation.

Acknowledgements

The following Ohio EPA staff provided technical expertise for this project in 2016 & 2017.

Report Preparation and Analysis	Andrew Phillips, Ed Moore, Mohammed Assasi Mariah Hood, Kelly Capuzzi and Randy Spencer
Reviewers	Marianne Piekutowski, Jeff Bohne, Rachel Taulbee, Sarah Becker, Cathryn Allen and Kathryn Hamilton
Data Collection	**Stream, Sediment and Lake Sampling** Kelly Capuzzi and Randy Spencer with interns Carson Calhoun, Michael Crowe and Sarah Maj **Macroinvertebrate Community** Ed Moore with interns Jillian Tesny, Abby Bowman, Abby Costilow and Austin Galbraith **Fish Community** Andrew Phillips with interns Brin Kessinger, Ben Foster, Connor Dahn and Neil Hamrick **Water Quality Sonde Monitoring** Mohammed Assasi with interns Nick Doarn, Quinn Harnett, Mitch Skinner, Mikaela Tardivo and Eva Rezek

Ohio EPA appreciates the generosity of the many landowners within the basin who allowed water quality staff access to the project area.

References

Alexander, R. B., Elizabeth, B. M., Richard, S. A., Gregory, E. S., & Richard, M. B. (2007). The role of headwater streams in downstream water quality. *Journal of the American Water Resources Association, 43*(1), 41 - 59. doi:10.1111/j.1752-1688.2007.00005.x

Auch, T. (2014, November 17). *The water-energy nexus in Ohio, part II*. Retrieved 2016, from Fractracker Alliance: https://www.fractracker.org/2014/11/water-energy-nexus-ohio-pt2/

Auch, T. (2015, September 29). *The curious case of the shrinking Utica shale play*. Retrieved 2016, from Fractracker Alliance: https://www.fractracker.org/2015/09/shrinking-utica-shale-play/

Becker, G. C. (1983). Muskellunge. In *Fishes of Wisconsin* (pp. 405-414). Madison, Wisconsin: University of WIsconsin Press. Retrieved from http://digital.library.wisc.edu/1711.dl/EcoNatRes.FishesWI

Camp, M. J. (2006). *Roadside Geology of Ohio.* Missoula, Montana: Mountain Press Publishing Co.

De Caceres, M., & Legendre, P. (2009). Associations between species and groups of sites: indices and statistical inference. *Ecology*. Retrieved from http://sites.google.com/site/miqueldecaceres/

Dodds, W. (2007). Trophic State, Eutrophication and Nutrient Criteria in Streams. . *Trends in Ecology and Evolution. 22(12)*, 669-676.

Dodds, W. K. (2006). Eutrophication and trophic state in rivers and streams. *Limnology and Oceanography, 51(1, part 2)*, 671–680.

Dufor, A. (1977). Escherichia Coli: The Fecal Coliform. In A. W. Hoadley, *Bacterial Indicators/health Hazards Associated with Water* (pp. 48-58). ASTM.

Farley, M. (2018). ODNR-MRM. (R. Spencer, Interviewer)

Heiskary, S., & Markus, H. (2003). *Establishing Relationships Among In-Stream Nutrient Concentrations, Phytoplankton Abundance and Composition, Fish IBI and Biochemical Oxygen Demand in Minnesota USA Rivers Final Report to USEPA Region V.* St. Paul: Minnesota Pollution Control Agency - Environmental Outcomes Division.

Hoggarth, M. A., Kimberly, D. A., & Allan, G. V. (2007). A Study of the Mussels (Mollusca: Bivalvia: Unionidae) of Symmes Creek and Tributaries in Jackson, Gallia and Lawrence Counties, Ohio. *Ohio Journal of Science*, 107 (4): 57-62.

Karr, J. R. (1991). Biological integrity: a long-neglected aspect of water resources managment. . *Ecological Applications*, 1(1):66-84.

Karr, J. R., Fausch, K. D., Angermeier, P. L., Yant, P. R., & Schlosser, I. J. (1986). *Assessing biological integrity in running waters. A method and its rationale.* Champaign: Illinois Natural History Survey, Special Pulbickation 5.

Kennard, M. J., Arthington, A. H., Pusey, B. J., & Harch, B. D. (2005). Are alien fish a reliable indicator of river health? *Freshwater Biology, 50*, 174-193.

Lopes, C., Perga, M., Roger, M., & Babut, M. (2011). Is PCBs concentration variability between and within freshwater fish species by their contamination pathways? *Chemosphere, 85(3)*, 502-508.

MacDonald, D., Ingersoll, C., & Berger, T. (2000). Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. *Archives of Environmental Contamination and Toxicology, 39*(1), 20-31.

MacDonald, D., Ingersoll, C., & Berger, T. (2000). Development and Evaluation of Consensus-Based Sediment Quality Guidelines for Freshwater Ecosystems. *Archives of Environmental Contamination and Toxicology, 39*, 20-31.

Miller, W. E. (1943). Petroleum in southeastern Ohio. *The Ohio Journal of Science*, 121-134.

Miltner, R. J. (2010). A Method and Rationale for Deriving Nutrient Criteria for Small Rivers and Streams in Ohio. *Environmental Management*, 45:842-855.

Miltner, R. J. (2018). Eutrophication endpoints for large rivers in Ohio, USA. *Environmental Monitoring and Assessment*, 190: 55.

Minor, R., & Borton, D. (1991). Considerations in the development and implementation of biocriteria. *Water Quality Standards for the 21st Century* (p. 115 pp). Washington D.C.: U.S. EPA office of Science and Technology.

Norling, D. L. (1958). *Geology and mineral resources of Morgan County.* Columbus: Ohio Division of Geological Survey.

ODNR. (2001). *Gazetter of Ohio Streams, Second Edition, Water Inventory Report 29.* Columbus: Division of Water.

ODNR. (2011). *A Citizen's Guide to Mining and Reclemation in Ohio.* Columbus: Division of Mineral Resources Managment.

ODNR. (2012). *Lake Chubsucker - Erimyzon suecetta.* . Retrieved from Division of Wildlife: http://wildlife.ohiodnr.gov/species-and-habitats/species-guide-index/fish/lake-chubsucker

Ohio Department of Natural Resources. (2014, June 1). Oil and gas well locations of Ohio. Columbus, Ohio. Retrieved 2016

Ohio Department of Natural Resources. (2015). *Water withdrawal regulations for oil and gas drilling.* Columbus: State of Ohio.

Ohio Environmental Protection Agency. (2008). *Sediment reference values.* Columbus: Divison of Environmental Remediation and Response.

Ohio Environmental Protection Agency. (2010). *Guidance on Evaluating Sediment Contaminant Results .* Ohio EPA.

Ohio Environmental Protection Agency. (2012). *Sediment sampling guide and methodologies, 3rd edition.* Division of Surface Water, Columbus.

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

Ohio EPA. (1987a). *Biological criteria for the protection of aquatic life: Volume I. The Role of Biological Data in Water Quality Assessment.* Columbus: Div. Water Quality Monitoring and Assessment, Surface Water Section.

Ohio EPA. (1987b). *Biological Criteria for the Protection of Aquatic Life: Volume II: Users Manual for Biological Field Assessment of Ohio Surface Waters.* Columbus: Ohio EPA - Ecological Assessment Section.

Ohio EPA. (1989a). *Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. .* Columbus: Div. Water Qual. Plan. & Assess., Ecological Assessment Section.

Ohio EPA. (1989b). *Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities.* Columbus: Div. Water Quality Plan & Assess. Sect.

Ohio EPA. (1999). *Appendices to the the Association Between Nutrients and the Aquatic Bioto of Ohio River and Streams.* Columbus: Division of Surface Water.

Ohio EPA. (2006). *Methods for assessing habitat in flowing waters: Using the Qualitative Habitat Evaluation Index (QHEI).* Columbus: Div. Water Quality Monitoring and Assessment, Surface Water Section.

Ohio EPA. (2008). *Ecological Risk Assessment Guidance Document.* Columbus: Division of Environmental Response and Revitalization.

Ohio EPA. (2010). *Guidance on Evaluating Sediment Contaminant Results.* Columbus: Division of Surface Water.

Ohio EPA. (2014). *Preamble: Proposed Stream Nutrient Assessment Procedure. Ohio EPA Nutrients Technical Advisory Group - Assessment Procedure Subgroup.* Columbus: DSW.

Ohio EPA. (2015). *Sediment Sampling Guide and Methodologies (3rd Edition).* Columbus: Division of Surface Water.

Ohio EPA. (2015). *Surface Water Field Sampling Manual for water quality and flows.* Columbus: Division of Surface Water.

Ohio EPA. (2015a). *Surface Water Field Sampling Manual for water quality parameters and flows.* Columbus: Division of Surface Water.

Ohio EPA. (2015b). *Biological criteria for the protection of aquatic life: Volume III. Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities.* Columbus: Div. Water Quality Monitoring and Assessment, Surface Water Section.

Ohio EPA. (2015b.). *Surface Water Field Sampling Manual - Appendix III - Sediment Sampling.* Columbus: Division of Surface Water.

Oksanen, J. F., Blanchet, G., Fiendly, M., Kindt, R., Legendre, P., McGlinn, D., & Minchin, P. R. (2017). *vegan: Community Ecology Package. R*. Retrieved from https://CRAN.R-project.org/package=vegan.

Omernik, J. M. (1987). *Ecoregions of the conterminous United States. .* Annals of the Association of American Geographers.

Omernik, J., & Griffith, G. (2008, December 11). *Ecoregions of Indiana and Ohio (EPA)*. Retrieved 2015, from The Encyclopedia of Earth: http://www.eoearth.org/view/article/152069

R Core Team. (2016). R: A language and environment for statistical computing. Vienna, Austria: R Foundation for Statistical Computing. Retrieved from https://www.R-project.org/

Rankin, E. T. (1989). *The qualitative habitat evaluation index (QHEI): rationale, methods, and application. .* Columbus: Division of Water Quality Planning and Assessment.

Rankin, E. T. (1995). *Habitat Indices in Water Resource Quality Assessments, in W.S. Davis and T. Simons (eds).Biological assessment and criteria: tools for rish-based planning adn decision making. .* Ann Arbor: CRC Press/Lewis Publisher.

Schumacher, G. A., Mott, B. E., & Angle, M. P. (2013). *Ohio's geology in core and outcrop: A field guide for citizens and environmental and geotechnical investigators.* Columbus: ODNR, Division of Geological Survey.

Soil Survey Staff. (2004, January 20). Soil Survey Geographic Database. Fort Worth, Texas: U.S. Department of Agriculture, Natural Resources Conservation Service.

Trautman, M. B. (1981). Ohio Lamprey. In *The Fishes of Ohio* (pp. 151-153). Columbus, Ohio: Ohio State University Press.

U.S. Environmental Protection Agency. (2012, May 12). Level IV Ecoregions of Ohio. Corvallis, Oregon.

U.S. EPA. (2003). *Region 5, final technical approach for developing ecological screening levels for RCRA Appendix IX constituents and other significant contaminants of ecological concern.* Chicago: Region 5.

U.S. EPA. (2015). *State Development of Numeric Criteria for Nitrogen and Phosphorus Pollution.* Nutrient Policy and Data.

USDA. (1998). *Soil Survey of Lawrence County.* Soil Survey, Natural Resources Conservation Service. United States Department of Agriculture.

USGS. (2014). *USGS*. Retrieved from Nutrients and Eutrophication.: https://www.usgs.gov/mission-areas/water-resources/science/nutrients-and-eutrophication?qt-science_center_objects=0#qt-science_center_objects

Vengosh, A., Jackson, R. B., Warner, N., Darrah, T. H., & Kondash, A. (2014, March 7). A critical review of the risks to water resources from unconventional shale gas development and hydraulic fracturing in the United States. *Environmental Science & Technology, 48*, 8334 - 8348. doi:dx.doi.org/10.1021/es40511

Wright, C. E., & Stucker, J. D. (2018). *2017 Report on Ohio Mineral Industries: An Annual Summary of the State's Economic Geology.* Columbus: ODNR Division of Geological Survey.

Yoder, C. O. (1989). The development and use of bilogical criteria for Ohio surface waters. *Water Quality Standards for the 21st Century* (pp. 139-146). U.S. EPA, Criteria and Standards Div., Water Quality Standards.

Yoder, C. O. (1991). Answering some concerns about biological criteria based on experiences in Ohio, in G. H. Flock (ed.) Water quality standards for the 21st century. *Water quality standards for the 21st century.* Washington, D.C.: U.S. EPA Office of Water.

Yoder, C. O. (1995). Policy issues and management applications of biological criteria. In W. D. Simon, *Biological Assessment and Criteria: Tools for Water Resource Planning and Decision Making.* (pp. 327-343 (Chapter 21)). Boca Raton: Lewis Publishers.

Yoder, C. O., & Rankin, E. T. (1995a). Biological criteria program development and implementation in Ohio. In W. S. Simon, *Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making.* Ann Arbor: CRC Press.

Yoder, C. O., & Rankin, E. T. (1995b.). Biological Response Signatures and the Area of Degradation Value: New Tools for Interpreting Multimetric Data. In W. D. Simon, *Biological Assessment and Criteria: Tools for Risk-based Planning and Decision Making* (pp. 263-286). Boca Raton: Lewis Publication.

Yoder, C. O., & Rankin, E. T. (1995c). *The role of biological criteria in water quality monitoring, assessment and regulation.* Columbus: Ohio EPA technical report MAS/1995-1-3.