Biological and Water Quality Study of Selected Southeastern Ohio River Tributaries (Shade, Kyger, Little Hocking), 2015

Athens, Gallia, Meigs and Washington Counties

Ohio EPA Technical Report AMS/2015-SHADE-2

Division of Surface Water
Assessment and Modeling Section
August 2019

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(Little Hocking River, Shade River, Kyger Creek, Champaign Creek)

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List of Acronyms

ALU	aquatic life use
CFR	Code of Federal regulations
cfs	cubic feet per second
cfu	colony forming units
CSO	combined sewer overflow
CWA	Clean Water Act
DC	direct current
DELT	deformities, erosions, lesions, tumors
D.O.	dissolved oxygen
ECBP	Eastern Corn Belt Plains
EPT	Ephemeroptera, Plecoptera, Trichoptera
EWH	exceptional warmwater habitat
GIS	geographic information system
GPS	global positioning system
HHEI	headwater habitat evaluation index
HUC	hydrologic unit code
IBI	index of biotic integrity
ICI	invertebrate community index
IP	Interior Plateau
IPS	integrated prioritization system
LRAU	large river assessment unit
LRW	limited resource water
MGD	million gallons per day
MIwb	Modified Index of well-being
NPDES	National Pollutant Discharge Elimination System
OAC	Ohio Administrative Code
ODNR	Ohio Department of Natural Resources
ORC	Ohio Revised Code
PAH	polycyclic aromatic hydrocarbons
PCR	primary contact recreation
PEC	probable effects concentration
QHEI	Qualitative Habitat Evaluation Index
RM	river mile
SCR	secondary contact recreation
SRV	sediment reference value

SSO	sanitary sewer overflow
TALU	tiered aquatic life use
TDS	total dissolved solids
TEC	threshold effects concentration
TKN	total Kjeldahl nitrogen
TMDL	total maximum daily load
TSS	total suspended solids
UAA	use attainability analysis
VOC	volatile organic compound
WAU	watershed assessment unit
WQS	water quality standards
WWH	warmwater habitat
WWTP	wastewater treatment plant

Executive Summary

The 2015 biological and water quality survey of the southeast Ohio River tributaries (SEORT) study area included the entire Shade River drainage, the Little Hocking River catchment, the Campaign Creek watershed and the lower reach of Kyger Creek and Little Kyger Creek (Figure 2). The survey also included several small, direct tributaries to the Ohio River. For the Shade and Little Hocking catchments, this is the first comprehensive biological survey conducted by Ohio EPA.

Of the 55 stations included in the survey, 39 were in full attainment of existing or recommended aquatic life uses, eight were in partial attainment (one biological indicator passed, one failed), seven stations did not attain (both biological indicators failed) and one site remained unassessed (Figure 1 and Figure 3). The most pervasive cause of aquatic life impairment was excessive sedimentation due to channel incision. This cause of impairment is largely a legacy of deforestation. High levels of manganese and sulfate indicated that chemical stressors from alkaline mine drainage (non-acidic mine drainage) was the principal cause of impairment to four sites but contributed stress to streams draining the western flank of the Shade River drainage, notably Kingsbury Creek and the West Branch Shade River. Organic enrichment from livestock contributed to impairment at two sites. Table 1 provides the condition status of all the survey sites, and lists causes and sources of impairment for sites with compromised status.

Figure 1 — Sampling locations in the SEORT - 2015 survey largely met their existing or recommended aquatic life use.

Of general note, the survey found nothing remarkable in terms of biology; no rare or noteworthy species were recorded. However, the Shade River mainstem and the lower reaches of its three branches harbored large freshwater drum, sauger and an occasional channel and flathead catfish. In this regard, the Shade River is a resource for local anglers. The most remarkable aspect of the system uncovered by the survey is the amount of sand entrained in the stream channels, as detailed in the physical habitat quality section (***Physical Habitat***). This condition will persist until the geomorphic stability is restored through erosion, widening and eventual degradation of sediment in the channel.

In 2015, Ohio EPA sampled 24 locations in the Shade River and Little Hocking River study areas for *E. coli*. All sites sampled failed to attain the applicable geometric mean criterion or exceeded more than 10 percent the allowable single sample maximum value, indicating impairment of the recreation use on a watershed-wide scale. Most sampling locations in the Shade River and Little Hocking River watersheds are in areas without centralized sewage treatment. Non-attainment is likely due to unsanitary conditions from poorly treated sewage treatment due to failing home sewage treatment systems (HSTS). Another likely source of non-attainment is pasture and cropland runoff, as well as other agricultural activities including land application of manure and biosolids as well as livestock production.

Ohio EPA collected surficial sediment samples at six locations, co-located with biological sampling sites. Samples were analyzed for metals, nutrients and semivolatile organic compounds. Organic chemical parameters were tested at all six sampling locations and were reported as not detected. Arsenic concentrations were above the threshold effect concentration (TEC) in Kyger Creek, but below the probable effect concentration (PEC) and are unlikely to cause any harmful effects. All other sediment metals sampled were below Ohio Sediment Reference Values, TEC values and PEC values.

During the 2015 – 2016 lakes survey, Ohio EPA sampled two recreational lakes (Forked Run and Veto) to determine the use attainment for each. Both lakes are man-made in-stream impoundments and were found in full attainment of the recreation use. However, as a result of a Lake Habitat Use (LHU) assessment (proposed criteria), Veto Lake warrants a watch list designation due to secchi disk and total phosphorus values exceeding the target value. Furthermore, Veto Lake is considered in non-support due to dissolved oxygen (D.O.) and median chlorophyll-*a* exceedances. Forked Run Lake is in full support of the metals and total dissolved solids criteria. The proposed LHU of Forked Run Lake warrants a watch list designation due to secchi disk and total nitrogen values exceeding target values. However, Forked Run Lake was considered in full support of the proposed use based on chlorophyll-*a*, total phosphorus, ammonia, pH and D.O. results.

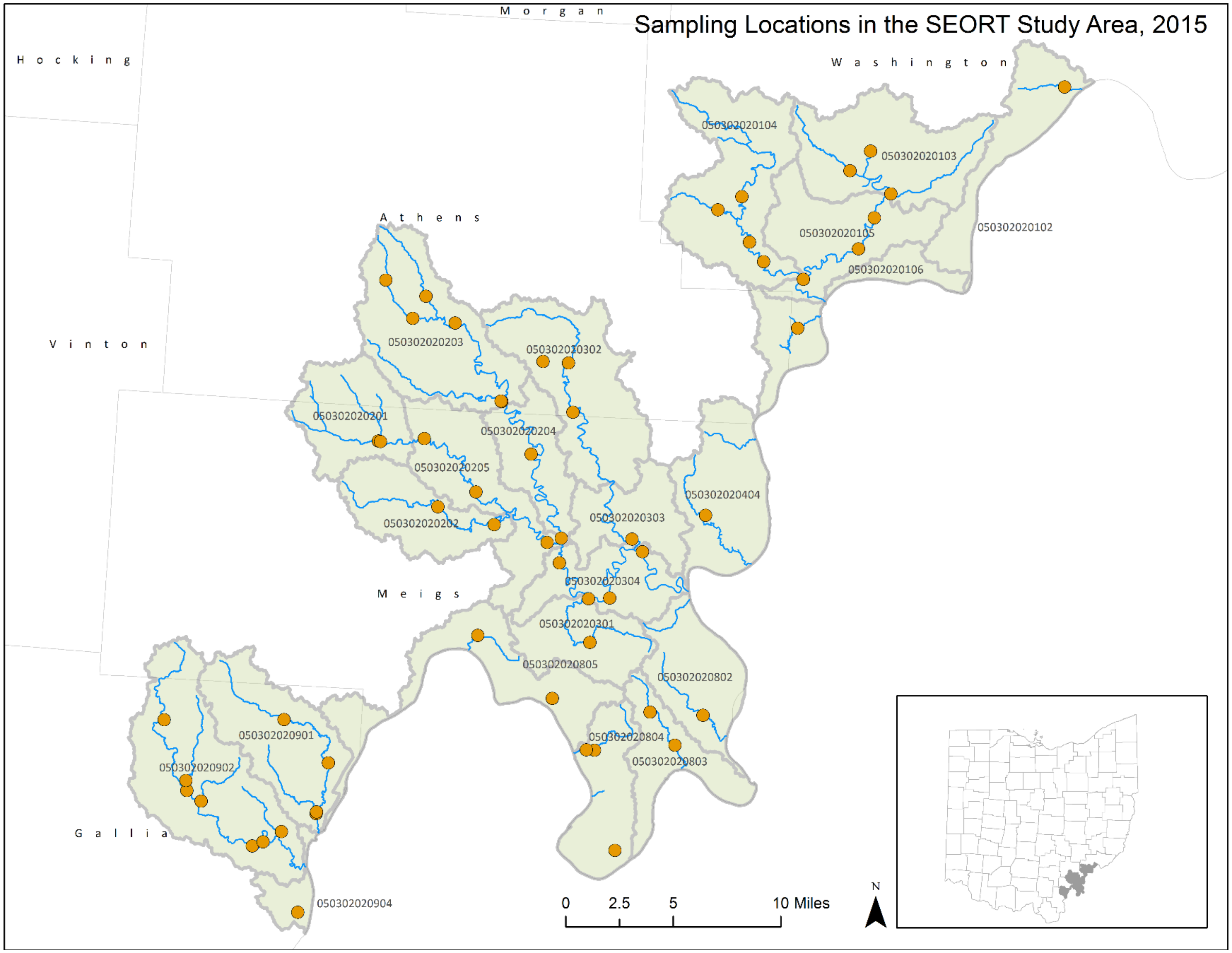

Figure 2 — Sampling locations in the SEORT study area, 2015.

Recommendations

Status of Non-Aquatic Life Uses

All non-aquatic life uses should remain as presently designated in the Ohio Water Quality Standards for all waters surveyed within the hydrologic unit. For those not presently designated, industrial water supply, agricultural water supply and recreation use are appropriate designations.

Campaign Creek, Little Campaign Creek, White Oak Creek and Little White Oak Creek [050302020902]

Status of Aquatic Life Uses

Campaign Creek has a verified Warmwater Habitat (WWH) aquatic life use. This use was fully met at all four sampling locations. Little Campaign, White Oak and Little White Oak have unverified WWH designations. Although biological communities failed to fully meet applicable biological criteria for WWH for each of these streams, the WWH use is appropriate given that existing habitat quality possesses the necessary attributes to support viable assemblages, and abatable, limiting stressors were present. Specifically, these stressors included mine drainage and organic enrichment from livestock.

Other Recommendations and Future Monitoring Concerns

Restricting and managing livestock access to White Oak Creek and Little White Oak Creek would result in an immediate positive water quality benefit. Identifying and treating mine seeps draining to Little Campaign Creek and Little White Oak Creek would likely result in full biological recovery.

Kyger Creek and Little Kyger Creek [050302020901]

Status of Aquatic Life Uses

Little Kyger Creek is designated Limited Resource Waters (LRW) due to mine drainage. Kyger Creek is recommended to be Modified Warmwater Habitat–Mine Affected (MWH-MA) downstream from Jesse Creek to its confluence with the Ohio River. Upstream from Jesse Creek, Kyger Creek has a verified WWH designation. Biological communities in the MWH-MA sections of Kyger Creek and Little Kyger Creek did not show evidence of acute toxicity. The one site sampled in the WWH section of the Kyger Creek did not attain the aquatic life use because of an impaired fish community. The cause of the impairment was chemical stressors from mine drainage.

Other Recommendations and Future Monitoring Concerns

Identifying and treating mine seeps draining to Kyger Creek is likely necessary to affect full biological recovery in the WWH section.

Georges Creek [050302020209]

Status of Aquatic Life Uses

Georges Creek has an unverified WWH designation. At the location sampled (RM 1.20), Georges Creek is a losing stream (the surface water runs into the ground/hyporheic zone) and went dry during the course of the summer. The total drainage area for the catchment puts the stream in the transition between primary headwaters and headwaters that can support typical WWH faunas. Therefore, the existing WWH remains unconfirmed.

Forest Run and Bowman Run [050302020805]

Status of Aquatic Life Uses

Forest Run and Bowman Run have unverified WWH designations. Biological assemblages assessed in Bowman Run fully met the WWH biological criteria, thereby substantiating the use. In Forest Run, both biological indicators were impaired by mine drainage and organic enrichment of unknown origin. The habitat quality in Forest Run would suggest that in the absence of the stressors present, the stream would support WWH faunas. Therefore, the appropriate and verified use is WWH.

Other Recommendations and Future Monitoring Concerns

The sources of mine drainage and organic enrichment to Forest Run should be identified and remediated.

Yellowbush Creek and Johns Run [050302020804]

Status of Aquatic Life Uses

Yellowbush Creek is presently undesignated for aquatic life use. Yellowbush Creek possesses the physical habitat capable of supporting typical WWH biological assemblages, and biological scores that demonstrate the WWH use. Johns Run has an unverified WWH use. The location sampled on Johns Run (RM 1.4) flows through an area of silt-rich, pre-Illinoian lacustrine deposits. These deposits do not produce the coarse substrates more typical of Western Alleghany Plateau (WAP) streams, a natural habitat limitation to expected biological communities typical of WAP streams. Chemical water quality, however, appeared unperturbed.

Other Recommendations and Future Monitoring Concerns

A biological sampling station upstream of the area of lacustrine deposits on Johns Run (RM 1.4) is recommended to determine the appropriate aquatic life use.

Oldtown Creek [050302020803]

Status of Aquatic Life Uses

Oldtown Creek currently possesses an unverified WWH use. Habitat quality and biological scores demonstrate that a WWH designation is appropriate and confirmed.

Other Recommendations and Future Monitoring Concerns

A trash dump adjacent to Sharon Hollow Rd. under the U.S. 33 overpass may be contaminating Oldtown Creek with lead. Oldtown Creek at RM 1.65 had a surface water exceedance of the aquatic life Outside Mixing Zone Average water quality criterion for lead at 64.6 µg/L.

Groundhog Creek [050302020802]

Status of Aquatic Life Uses

Groundhog Creek has an unverified WWH designation. The habitat quality and biological scores from the location sampled confirm that a WWH use is appropriate.

Forked Run [050302020404]

Status of Aquatic Life Uses

Forked Run has both an unverified Exceptional Warmwater Habitat (EWH) aquatic life use designation, and an unverified State Resource Water (SRW) listing. The extant habitat was excellent, possessing all the attributes necessary to support faunas typical for the region, and the macroinvertebrate assemblage certainly reflected this. The WWH use is recommended.

Other Recommendations and Future Monitoring Concerns

The SRW use is not supported.

Shade River [050302020304]

Status of Aquatic Life Uses

The mainstem of the Shade River has a verified WWH use. This use was fully supported by both biological assemblages.

Other Recommendations and Future Monitoring Concerns
A boat electrofishing sample from the lower reach of the river should be conducted to complete the inventory of the resource.

East Branch Shade River and Dog Hollow Run [050302020303 & 050302020302]

Status of Aquatic Life Uses
The East Branch Shade River has unverified EWH and SRW uses. Habitat quality and biological index scores demonstrate that a WWH use is appropriate and fully attained. Dog Hollow Run has an unverified WWH use. That use is confirmed based on observed habitat quality and biological index scores.

Other Recommendations and Future Monitoring Concerns
The SRW use is not supported.

Horse Cave Creek [050302020301]

Status of Aquatic Life Uses
Prior to the survey, Horse Cave Creek was designated unverified WWH use. Habitat quality and biological performance clearly confirms and fully supports the use.

West Branch Shade River [050302020205 & 050302020201] and Kingsbury Creek [050302020202]

Status of Aquatic Life Uses
The West Branch Shade River and Kingsbury Creek have unverified WWH designations. The unnamed tributary to the West Branch (RM 16.35) is undesignated. All three waterbodies are impaired by excessive levels of sand entrained in the channel, and chemical stressors from mine drainage appear to contribute stress to those systems. The overall quality of physical habitat observed in each stream suggests that without the added stress of mine drainage, biological assemblages should meet expectations for a WWH stream. An additional line of evidence supporting WWH as an appropriate use is reflected by macroinvertebrate scores in each stream meeting the WWH biocriterion.

Other Recommendations and Future Monitoring Concerns
Mine seeps discharging to these systems should be identified and remediated. Portions of Kingsbury Creek have been channelized, exacerbating the problems caused by sedimentation.

Middle Branch Shade River [050302020203 & 050302020204] including Pratts Fork and Long Run

Status of Aquatic Life Uses
The Middle Branch Shade River is designated as an unverified EWH use. Two major tributaries to Middle Branch, Pratts Fork and Long Run, have unverified WWH designations. For the Middle Branch, habitat quality is not sufficient to support an EWH use, but more than sufficient to support a WWH use. Biological index scores confirm and fully support the WWH use at five of the six sampling sites on the Middle Branch. One site downstream from Pratts Forks was impaired by excessive levels of sand accumulated on the stream bottom. Pratts Fork also experienced severe sedimentation and generally lacked the physical properties necessary to support WWH assemblages. However, the sampling location (RM 0.02) may not have been representative of the stream. Habitat quality and biological scores confirmed and fully supported the WWH designation for Long Run.

Other Recommendations and Future Monitoring Concerns
A follow-up sample from a different location on Pratts Fork is needed to assign the appropriate use and determine condition status.

Little Hocking River and Tributaries [050302020103, 050302020104 & 050302020105]

Status of Aquatic Life Uses

The mainstem of the Little Hocking River is a verified WWH use stream. The West Branch, East Branch, Gilbert Run and Tupper Creek tributaries all have unverified WWH designations. Little Hocking River biological index scores demonstrated full support of the WWH use. Furthermore, habitat quality and biological performance in the tributaries demonstrated that the WWH use is appropriate, fully supported and confirmed.

Dunfee Run [050302020106] and Mile Run [050302020102]

Status of Aquatic Life Uses

Dunfee Run and Mile Run are direct tributaries to the Ohio River, both of which are unverified WWH streams. Habitat quality and biological index scores from both streams indicated that the WWH use is an appropriate designation.

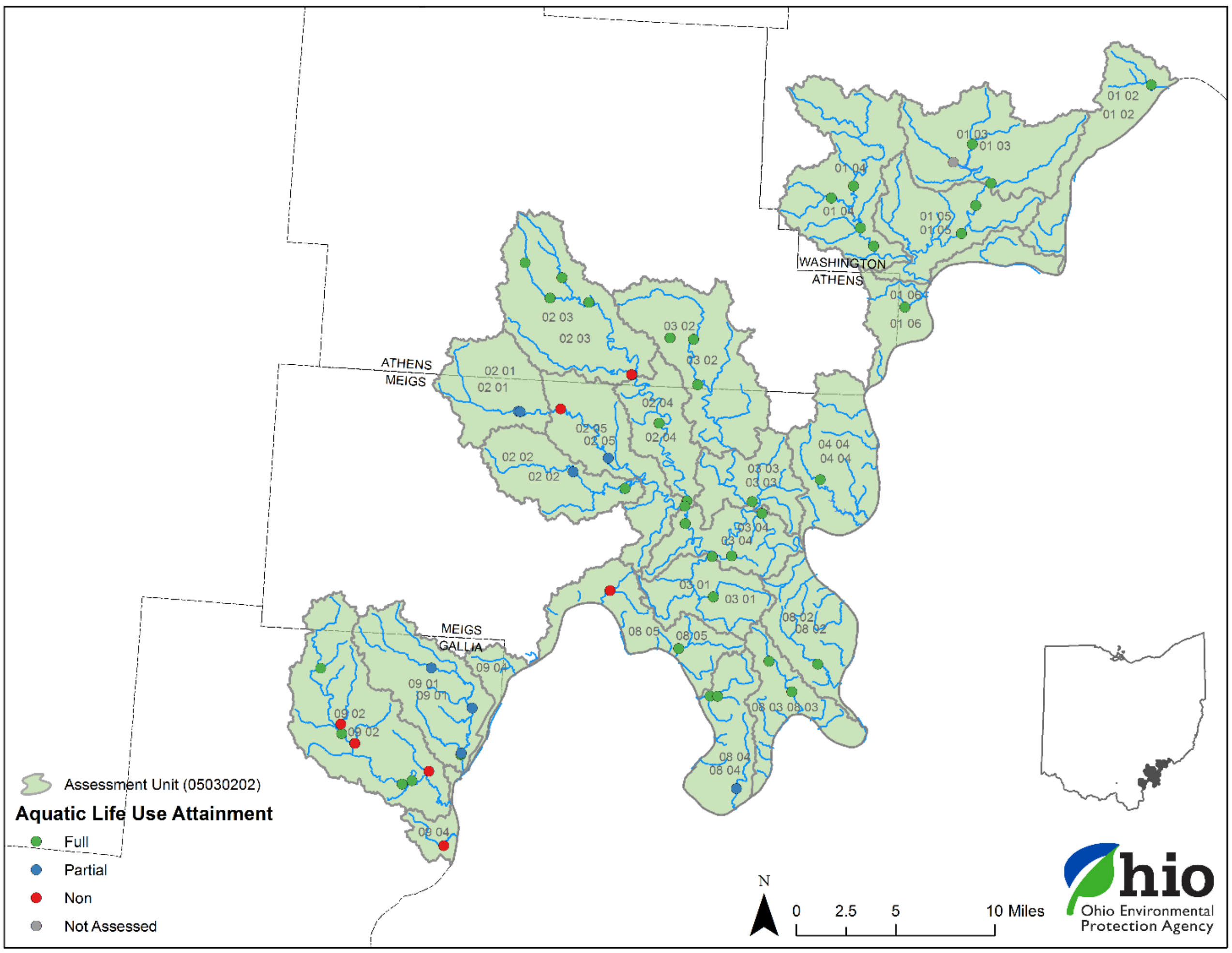

Figure 3 — A map of the Shade River study area with sampling locations color-coded to condition status. The major watershed divisions are labeled.

Table 1 — Site-level aquatic life use assessments based on biological indicators for locations sampled in the SEORT study area, 2015. Where the biological indicators demonstrate less than full attainment of the beneficial aquatic life use, causes and sources are noted. For a given site, the most proximate cause is listed first. Sites where the current aquatic life use has been verified are denoted with "(v)".

Station	RM	IBI	MIwb	ICI[a]	QHEI	Status	Cause(s)	Source(s)
Campaign Creek (09-051-000)						**WWH (v)**		
W03K05	16.60	52	-	VG	59.8	Full		
301794	11.50	49	9.1	48	69.4	Full		
303029	6.25	42^{ns}	8.3^{ns}	G	57.0	Full		
W03S28	5.56	44	9.1	50	58.5	Full		
Little Campaign Creek (09-051-000)						**WWH (v)**		
301795	0.37	38*	-	LF*	60.0	Non	Metals[‡]	Coal Mining
Little Whiteoak Creek (09-055-000)						**WWH (v)**		
301796	0.33	34*	-	P*	58.0	Non	Metals[‡]; Organic Enrich.	Coal Mining; Livestock
Whiteoak Creek (09-055-000)						**WWH (v)**		
303121	0.38	38*	-	P*	72.0	Non	Organic Enrichment	Livestock
Kyger Creek (09-057-000)						**WWH (v)**		
W03S13	8.42	38*	-	G	67.3	Partial	Metals[‡]	Coal Mining
Kyger Creek (09-057-000)						**MWH-MA – Recommended**		
300593	4.00	27*	5.0	46	71.3	Partial	Metals[‡]	Coal Mining
W03S26	1.00	25	6.8	MG	61.3	Full		
Little Kyger Creek (09-058-000)						**MWH-MA – Recommended**		
W03P51	0.01	34*	-	P	69.8	Partial	Metals[‡]	Coal Mining
Forest Run (09-065-000)						**WWH (v)**		
301805	1.10	32*	-	F*	58.5	Non	Metals[‡]; Organic Enrich.	Coal Mining; Unknown
Bowman Run (09-068-000)						**WWH (v)**		
303117	0.42	50	-	MG	65.5	Full		
Dunham (Yellowbush) Creek (09-071-000)						**WWH (v)**		
W04W11	1.48	42^{ns}	-	MG^{ns}	60.8	Full		
303120	0.85	49	-	G	63.0	Full		
Johns Run (09-075-000)						**WWH (v)**		
303119	1.40	42^{ns}	-	F*	45.3	Partial	Natural	Natural
Oldtown Creek (09-079-000)						**WWH (v)**		
303116	4.00	50	-	VG	77.8	Full		
W04W12	1.65	42^{ns}	-	VG	74.0	Full		
Groundhog Creek (09-083-000)						**WWH (v)**		
303115	2.30	52	-	VG	73.3	Full		
Forked Run (09-091-000)						**WWH – Recommended**		
303114	4.72	42^{ns}	-	E	79.3	Full		

Station	RM	IBI	MIwb	ICI[a]	QHEI	Status	Cause(s)	Source(s)
Georges Creek (09-110-000)						**WWH (v)**		
303118	1.20	32*	-	-	56.5	Non	Natural	Natural
Shade River (09-600-000)						**WWH (v)**		
W04S01	17.13	48	9.1	44	74.3	Full		
W04S02	11.64	47	8.4	42	85.0	Full		
609170	5.84	54	9.0	52	68.5	Full		
Horse Cave Creek (09-604-000)						**WWH (v)**		
303112	4.88	50	-	VG	78.0	Full		
W04S04	0.35	48	-	G	58.0	Full		
East Branch Shade River (09-610-000)						**WWH – Recommended**		
W04K07	15.00	52	-	VG	71.0	Full		
W04S08	11.84	48	-	E	66.0	Full		
303028	0.87	47	8.4	50	63.5	Full		
Dog Hollow (09-620-000)						**WWH (v)**		
303113	2.50	50	-	VG	64.0	Full		
Middle Branch Shade River (09-630-000)						**WWH – Recommended**		
303105	28.20	50	-	MG[ns]	66.3	Full		
303110	25.80	44	-	E	71.3	Full		
303106	22.50	50	8.1[ns]	42	62.0	Full		
W04K10	14.80	38*	7.5*	E	63.8	Partial	Sediment	Incision
W04K09	8.10	47	8.5	E	69.8	Full		
W04S06	0.42	53	9.2	46	67.3	Full		
Pratts Fork (09-633-000)						**WWH (v)**		
W04S09	0.02	38*	-	F*	48.0	Non	Sediment	Incision
Long Run (09-634-000)						**WWH (v)**		
303109	1.40	46	-	VG	71.3	Full		
West Branch Shade River (09-640-000)						**WWH (v)**		
303104	16.50	30*	-	VG	59.3	Partial	Sediment; Metals[‡]	Incision; Coal Mining
303111	13.80	31*	4.8*	38	61.8	Non	Sediment; Metals[‡]	Incision; Coal Mining
W04K11	7.80	38*	7.9[ns]	40	51.8	Partial	Sediment; Metals[‡]	Incision; Coal Mining
W04S05	0.16	51	9.0	54	55.0	Full		
Tributary to West Branch Shade River (09-640-001)						**WWH – Recommended**		
303103	0.10	34*	-	G	59.3	Partial	Sediment; Metals[‡]	Incision; Coal Mining
Kingsbury Creek (09-643-000)						**WWH (v)**		
301809	6.75	28*	-	E	46.5	Partial	Sediment; Metals[‡]	Incision; Coal Mining
W04S10	2.08	44	-	VG	64.0	Full		
Dunfee (Whites) Run (17-025-000)						**WWH (v)**		
303102	1.40	48	-	E	64.0	Full		

Station	RM	IBI	MIwb	ICI[a]	QHEI	Status	Cause(s)	Source(s)
Little Hocking River (17-900-000)						**WWH (v)**		
303098	15.20	-	-	E	-	-		
303026	9.89	47	9.6	E	58.8	Full		
W04S15	7.55	48	8.2[ns]	E	69.5	Full		
Mile Run (17-900-001)						**WWH (v)**		
303096	1.10	48	-	VG	70.8	Full		
West Branch Little Hocking River (17-901-000)						**WWH (v)**		
303100	8.70	54	-	E	76.5	Full		
303099	4.80	49	9.7	42	70.8	Full		
303027	2.87	50	9.0	48	73.0	Full		
Gilbert Run (17-903-000)						**WWH (v)**		
303101	1.30	50	-	VG	76.8	Full		
East Branch Little Hocking River (17-908-000)						**WWH (v)**		
R19P03	0.01	42[ns]	-	VG	59.5	Full		
Tupper Creek (17-910-000)						**WWH (v)**		
303097	1.42	42[ns]	-	VG	63.5	Full		

a Quality rankings based on presence/absence sampling. E=excellent; VG=very good; G=good; MG=marginal; F=fair; LF=low fair; P=poor; VP=very poor.
ns Biological scores within the range of non-significant departure of WWH.
* Biological scores significantly less than the applicable biocriterion.
‡ Manganese is the indicator stressor but is correlated with several other parameters — notably nickel, ammonia and sulfate — indicating alkaline mine drainage.

Index – Site Type	Biological Criteria - WAP		
	EWH	WWH	MWH
IBI — Boat	48	40	24
IBI — Wading	50	44	24
IBI — Headwater	50	44	24
MIwb — Boat	9.6	8.6	5.4
MIwb — Wading	9.4	8.4	5.5
ICI	46	36	30

Table 2 — Use designations for water bodies in the SEORT study area. Designations based on the 1978 and 1985 water quality standards appear as asterisks (*). A plus sign (+) indicates a confirmation of a current designation and a triangle (▲) denotes a new recommended use based on the findings of this study.

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	
Swan Run		*							*	*		*		
Dunfee Run		*/+							*/+	*/+		*/+		
Sawyer Run		*							*	*		*		
Little Hocking River		+							+	+		+		
West Branch		*/+							*/+	*/+		*/+		
Laurel Run		*							*	*		*		
Gilbert Run		*/+							*/+	*/+		*/+		
Burnett Run		*							*	*		*		
Falls Creek		*							*	*		*		
Little West Branch		*							*	*		*		
Mill Branch		*							*	*		*		
East Branch		*/+							*/+	*/+		*/+		
Tupper Creek		*/+							*/+	*/+		*/+		
Davis Creek		*							*	*		*		
Congress Run		*							*	*		*		
Crooked Creek		*							*	*		*		
Mile Run		*							*	*		*		
Dodge Run		*							*	*		*		
Claylick Run		*							*	*		*		
Sardis Run		*							*	*		*		
Long Run		*							*	*		*		
Clark Run		*							*	*		*		
Evans Run		*							*	*		*		
Chickamauga Creek		*							*	*		*		
Paint Creek		*							*	*		*		
Little Chickamauga Creek		*							*	*		*		
Mill Creek		*							*	*		*		
George Creek		*							*	*		*		
Campaign Creek		+							+	+		+		
Little Campaign Creek		*/+							*/+	*/+		*/+		
Flatfork Run		*							*	*		*		

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	
Little Whiteoak Creek		*/+							*/+	*/+		*/+		
Whiteoak Creek		*/+							*/+	*/+		*/+		
Wolf Run		*							*	*		*		
Kyger Creek - confluence with Jessie Creek to the mouth				▲					+	+		+		Mine Drainage
- headwaters to confluence with Jessie Creek		+							+	+		+		
Little Kyger Creek				▲					+	+		*		Mine Drainage
Turkey Run							+		+	+		*		Acid Mine Drainage
Stingy Run							+		+	+		*		Acid Mine Drainage
Jessie Creek							+		+	+		*		Acid Mine Drainage
Bell Lick Run		+							*	*		*		
Stores Run		*							*	*		*		
Silver Run		*							*	*		*		
Leading Creek	+/-	+							+	+		+		
Dirt Creek		*							*	*		*		
Hysell Run		*							*	*		*		
Bailey Run		*							*	*		*		
Thomas Fork		*							*	*		*		
Long Hollow		*							*	*		*		
Little Leading Creek		*							*	*		*		
Malloons Run		*							*	*		*		
Parker Run		*							*	*		*		
Muddy Fork		*							*	*		*		
Dexter Run		*							*	*		*		
Mud Fork		*							*	*		*		
Ogden Run		*							*	*		*		
Sisson Run		*							*	*		*		
Fivemile Run		*							*	*		*		
Forest Run		*/+							*/+	*/+		*/+		
Kerr Run		*							*	*		*		
Jesse Run		*							*	*		*		
Bowman Run		*/+							*/+	*/+		*/+		
German Fork		*							*	*		*		
Wolf Run		*							*	*		*		
Dunham Run		*/+							*/+	*/+		*/+		
Cabin 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	
Jennie Walls Run		*							*	*		*		
Tupper Run		*/+							*/+	*/+		*/+		
Johns Run		*							*	*		*		
Mill Run		*							*	*		*		
Tanner Run		*							*	*		*		
Toms Run		*							*	*		*		
Oldtown Creek		*/+							*/+	*/+		*/+		
Granny Run		*							*	*		*		
Silver Creek		*							*	*		*		
Savers Run		*							*	*		*		
Groundhog Creek		*/+							*/+	*/+		*/+		
Dry Run		*							*	*		*		
Locks Run		*							*	*		*		
Wells Run		*							*	*		*		
Dewitt Run		*							*	*		*		
Perry Run		*							*	*		*		
Long Run		*							*	*		*		
Shade River		+							+	+		+		
Spruce Run		*							*	*		*		
Big Run		*							*	*		*		
East Branch	*/-	▲	*						*/+	*/+		*/+		
Spicer Creek		*							*	*		*		
Barney Fork		*							*	*		*		
Lickskillet Run		*							*	*		*		
Big Run		*							*	*		*		
Joes Creek		*							*	*		*		
Meigs Creek		*							*	*		*		
Kappel Hollow		*							*	*		*		
Guthrie Creek		*							*	*		*		
Palk Hollow		*							*	*		*		
Dog Hollow		*/+							*/+	*/+		*/+		
Sugar Run		*							*	*		*		
Horse Cave Creek		*/+							*/+	*/+		*/+		
Straight Hollow Run		*							*	*		*		
East Horse Cave 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	
Aumiller Creek		*							*	*		*		
Middle Branch	*/-	▲	*						*/+	*/+		*/+		
Elk Run		*							*	*		*		
Wolfpen Run		*							*	*		*		
Pratts Fork		*							*/+	*/+		*/+		
Long Run		*/+							*/+	*/+		*/+		
Spring Branch		*							*	*		*		
West Branch		*/+							*/+	*/+		*/+		
Walker Run		*							*	*		*		
Oliver Run		*							*	*		*		
Kingsbury Creek		*/+							*/+	*/+		*/+		
Peach Fork		*							*	*		*		
Guyan Run		*							*	*		*		
Forked Run – headwaters to Forked Run reservoir	*/-	▲							*/+	*/+		*/+		
– all other segments		*							*	*		*		
Little Forked Run		*							*	*		*		
Sugarcamp Run		*							*	*		*		
Indian Run		*							*	*		*		

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.

Introduction

Ohio EPA sampled 55 stream locations within the SEORT study area in Athens, Gallia, Meigs and Washington counties. Fourteen National Pollutant Discharge Elimination System (NPDES) permitted facilities discharge sanitary wastewater, industrial process water or industrial storm water into the streams of the study area.

In 2015, Ohio EPA conducted a water resource assessment of 30 streams in the SEORT study area using standard Ohio EPA protocols as described in the Notice to Users section of the appendices. Included in this study are assessments of the biological, surface water and recreation condition. A total of 55 biological, 55 water chemistry and 24 bacterial stations were sampled with the following objectives:

1) Systematically sample and assess the principal drainage networks of SEORT in support of the TMDL process.
2) Gather ambient environmental information (biological, chemical and physical) from designated water bodies, to assess current beneficial uses (for example, aquatic life, recreational, water supply).
3) Collect fish tissue samples at selected stations.
4) Validate the appropriateness of existing, verified and unverified beneficial use designations.
5) Establish baseline ambient biological conditions at selected reference stations to evaluate the effectiveness of future pollution abatement efforts.
6) Document any changes in biological, chemical and physical conditions of the study areas where historical information exists, thus expanding Ohio EPA's database for statewide trends analysis (for example, 305[b]).

The findings of this evaluation may factor into regulatory actions taken by Ohio EPA (for example, NPDES permits, Director's Orders or the Ohio Water Quality Standards [OAC 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] report).

Study Area Description

Location and Scope

The SEORT study area is comprised of three larger watersheds, representing 26 HUC-12 units covering 561 mi², including 43 named streams that are direct tributaries to the Ohio River (Table 3). Thirteen of those direct tributaries were of sufficient size to be included in the survey. The significant streams within these four watersheds are Campaign Creek, Kyger Creek, Shade River and the Little Hocking River. The study area was located within Athens, Gallia, Meigs and Washington counties. Large cities like Marietta, Belpre and Athens are on the edges of this sparsely populated rural study area.

Table 3 —The SEORT HUC 12 watersheds.

HUC-12	HUC-12 Name	Area (mi²)
50302020102	Mile Run-Ohio River	21.07
50302020103	Headwaters Little Hocking River	35.53
50302020104	West Branch Little Hocking River	39.43
50302020105	Little West Branch Little Hocking River-LHR	27.29
50302020106	Sandy Creek-Ohio River	18.18
50302020201	Headwaters West Branch Shade River	22.18
50302020202	Kingsbury Creek	21.44
50302020203	Headwaters Middle Branch Shade River	40.07
50302020204	Elk Run-Middle Branch Shade River	17.56
50302020205	Walker Run-West Branch Shade River	27.68
50302020301	Horse Cave Creek	18.39
50302020302	Headwaters East Branch Shade River	37.51
50302020303	Big Run-East Branch Shade River	17.48
50302020304	Spruce Creek-Shade River	18.79
50302020404	Forked Run-Ohio River	27.93
50302020802	Groundhog Creek-Ohio River	21.75
50302020803	Oldtown Creek-Ohio River	17.77
50302020804	West Creek-Ohio River	19.70
50302020805	Broad Run-Ohio River	22.64
50302020901	Kyger Creek	30.48
50302020902	Campaign Creek	46.59
50302020904	Crooked Creek-Ohio River	11.71

Beneficial Uses

The beneficial use designations that apply to these watersheds in Ohio Administrative Codes (OAC) 3745-1-24 and 3745-1-16 include: recreation, water supply, and aquatic life habitat. Aquatic life uses include: EWH, WWH and MWH. The only recreation use that applies to the entire study area is Primary Recreation Contact (PCR) and the water supply uses are Agricultural Water Supply (AWS) and Industrial Water Supply (IWS).

Ecoregion, Geology and Soils

The study area is located within the unglaciated WAP ecoregion (Figure 4). The two sub-ecoregions that comprise the study area are the Permian Hills and the Monongahela Transition Zone (U.S. Environmental Protection Agency, 2012). The Permian Hills ecoregion is a highly dissected plateau with rounded hills and ridges. The existing steep, narrow stream valleys are not conducive to row crops, so most farming is done on the rounded hills and ridges. Stream flow can be low in summer due to a lack of ground water contributions and underlying shale bedrock. Streams are typically high gradient but without large riffle-inhabiting fish populations (Omernik & Griffith, 2008). The soils in the Permian Hills are predominately Gilpin (parent material sandstone), Upshur (parent material red clay), Lowell (parent material limestone) and Vandalia (parent material mixed soil and rock types). These soil types are well drained with moderate to low permeability. The natural fertility is medium, and these soils respond well to lime addition (Soil Survey Staff). The Monongahela Transition Zone (MTZ) has dissected plateaus with rounded hills and ridges but is less rugged than the Permian Hills ecoregion. The streams are mostly high gradient with steep, narrow valleys that are usually forested throughout this region. The soils in the MTZ are predominately Gilpin, Lowell and to a lesser extent Upshur, Guernsey (parent materials shale, siltstone and limestone), Vandalia and Brookside (parent material mixed soil and rock types) which are landslide-prone with high clay content. These are erosion-prone soils and may, in part, account for the heavy bedload in these streams. These soil types are well drained with moderate to low permeability (Soil Survey Staff).

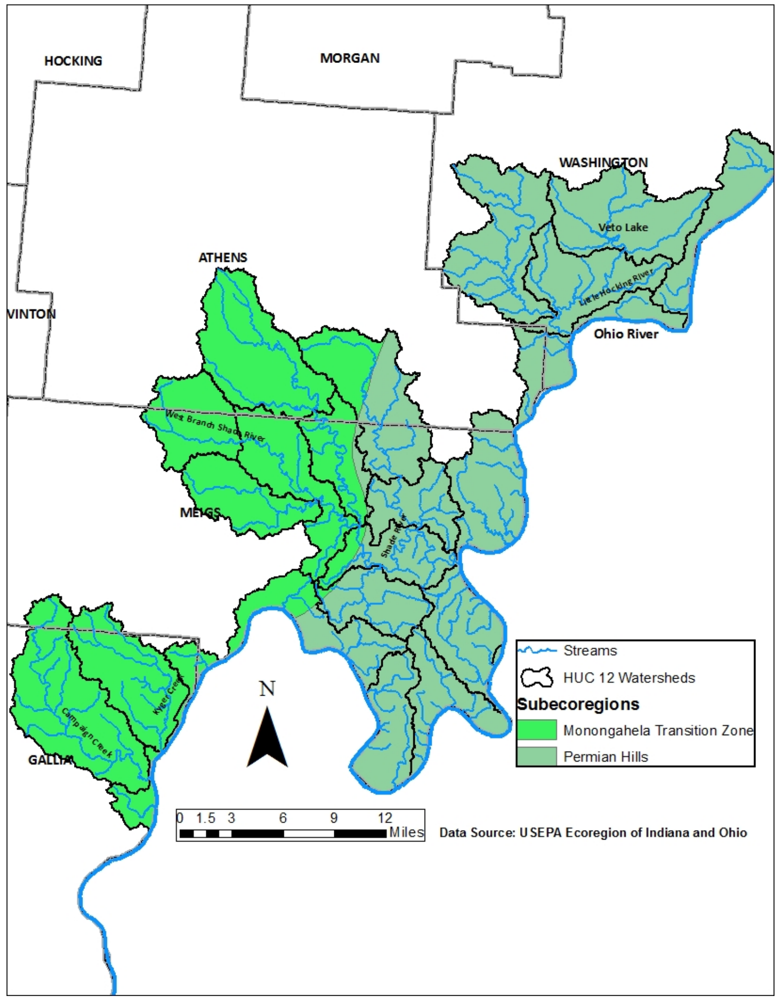

Figure 4 — The Western Allegheny Plateau sub ecoregions in the Southeastern Ohio River Tributaries study area 2015.

The bedrock in this area is Pennsylvanian Conemaugh Group overlying the Monongahela Group which is overlying the Permian Dunkard Group (oldest to youngest). Monongahela and Conemaugh Groups are comprised primarily of shale and siltstone and secondarily mudstone. Sandstone, limestone and coal make up a lesser portion of these groups. Coal in the Conemaugh Group is thin, impure and discontinuous. When coal is found near the surface, locals have mined it for personal use. Sandstone has been quarried in the Conemaugh Group for heavy building stones and foundation stone, as well as for canal locks and bridge piers. When exposed, the sandstone forms cliffs and gorges along streams. The Monongahela Group has bituminous coal beds ranging from thin to a thickness that is of economic value. Surface mines in Campaign Creek, Kyger Creek and West Branch of the Shade Creek and West Branch of the Shade River all fall within this group. Pittsburgh No. 8 and Pomeroy No. 8 coal seams were mined from the surface and underground. In the Dunkard Group, mudstone is the primary rock type and shale is the secondary type. Siltstone, sandstone, limestone and coal make up a lesser portion of this group. Coal is thin, impure and discontinuous in the Dunkard group, so coal mining in the region is typically done using underground mining techniques to reach deeper geologic strata. Shale was quarried to make bricks. Dunkard sandstone was mined to make high-quality grindstones and building stone. Where exposed, the Dunkard sandstone forms gorges, cliffs and natural bridges like Ladd Natural Arch (Schumacher, Mott, & Angle, 2015). In sedimentary rocks, mudstone has the highest median phosphorus content at 1,135 ppm (Porder & Ramachandran, 2012). In the unglaciated portion of Ohio, the parent rock material is the basis for the soils and colluvium.

Land Cover

Little Hocking River and Ohio River Tributaries Watershed

The Little Hocking River and Ohio River Tributaries drainage area is 141.5 mi^2 with the Little Hocking River watershed making up 102 mi^2 of the drainage (Figure 5). Two small Ohio River tributaries originate in Athens County and all other streams originate in Washington County, flowing south into the Ohio River. The landscape consists mostly of steep rolling hills. Agricultural activities predominately occur on the hill tops comprising 22.6 percent of the entire land use. Some farming also occurs in the Ohio River valley, but the valley is mostly developed urban and industrial land use, comprising 11.4 percent of the land use. Large and small industrial facilities dot the Ohio River valley from the Little Hocking River to Marietta. The city of Belpre, population 6,448, is the largest municipality (U.S. Census, 2015). The Ohio River industrial facilities and the city of Belpre all have discharges to the Ohio River that are not a part of the study area. Forested areas make up 64.4 percent of the land use; conservation areas like Veto Lake Wildlife Area (462 acres), Ladd Natural Bridge Nature Preserve (36 acres) and The Nature Conservancy's 290-acre Tefft Memorial Forest are the largest public lands.

Shade River and Ohio River Tributaries Watershed

The Shade River and Ohio River Tributaries watershed drains 330.9 mi^2, including the 221 mi^2 Shade River watershed. The study area is predominately within Meigs County, with the headwaters of the Shade River reaching north into Athens County (Figure 6). Agricultural activities make up 24.3 percent of the land use and are typically confined to the ridge tops due to the numerous, narrow stream valleys. The Ohio River valley in this area is usually about one mile wide where large-scale farming activities take place in the rich river floodplain soils. Forested areas make up 66.9 percent of the land use with conservation areas such as Forked Run State Park and the Shade State Forest being the largest public lands in the watershed. Small communities like Chester, Syracuse (population 826) and Racine (population 625) make up most of the developed areas (U.S. Deparment of Commerce. U.S. Census Bureau, 2010); only 7.5 percent of the study area is considered developed.

Campaign Creek and Kyger Creek watershed

Campaign Creek and Kyger Creek are located mostly in Gallia County with the headwaters of both streams and Story Run partially in Meigs County (Figure 7). This study area totals 77.1 mi^2 with Campaign Creek watershed consisting of 46.6 mi^2 and Kyger Creek consisting of 30.5 mi^2. Agricultural activities take place within some wide stream valleys and along the more rolling hills making up 24.7 percent of the land use. Large coal power generating stations along the Ohio River in Cheshire comprise most of the 7.4 percent developed land use. Open water (1.4 percent) and barren land areas (0.88 percent) are mostly attributed to the ash ponds and residual waste landfills at the power stations. Forested areas account for the majority (65.6 percent) of the land use including Wilson Wetlands (10.9 acres), the largest public conservation area.

Watershed Groups

While there are currently no active watershed groups in the SEORT survey area, Rural Action, in partnership with Ohio University, is currently developing a watershed planning initiative for streams in southeastern Ohio. Information about the watershed planning initiative can be found at ***ruralaction.org/wpi/.***

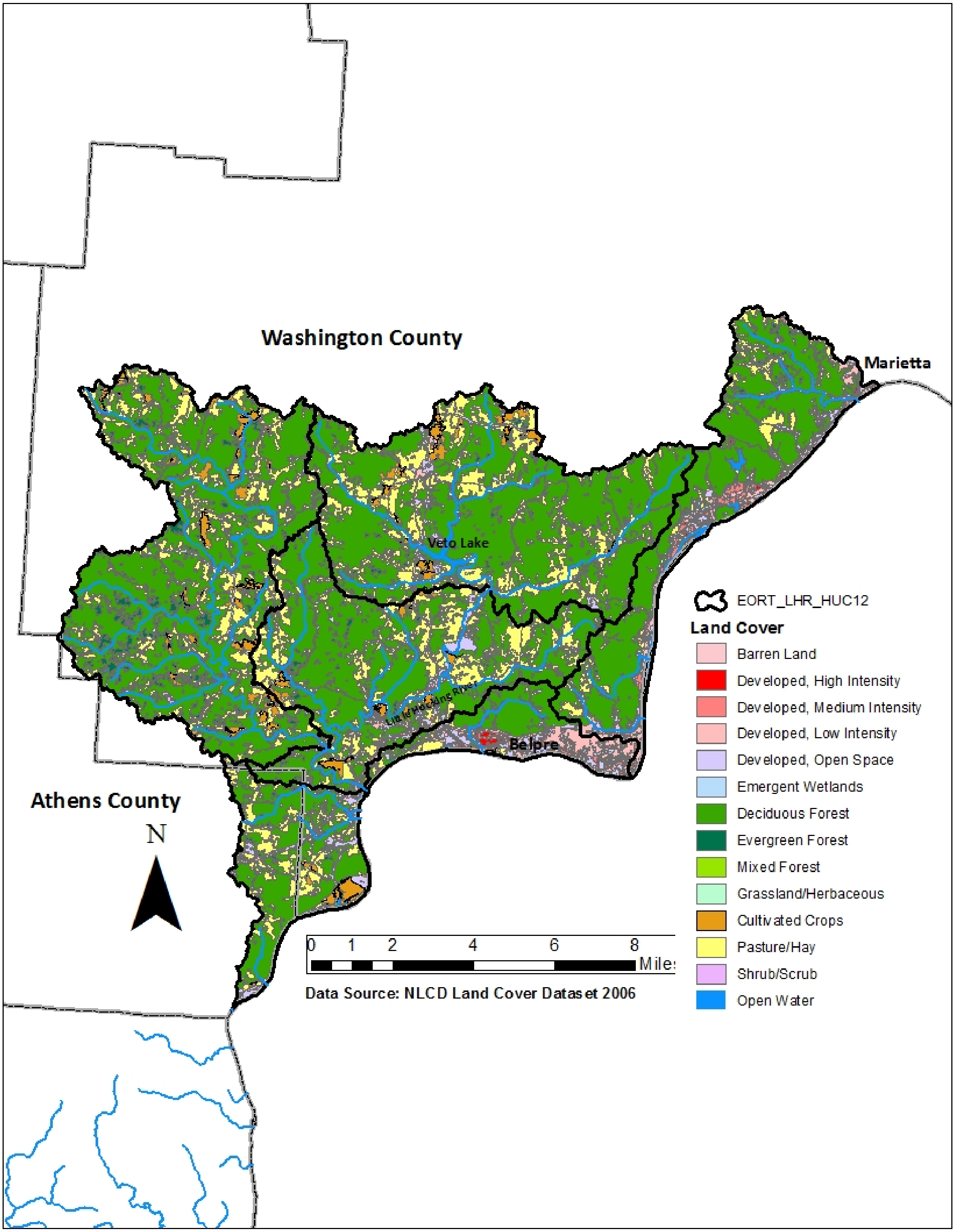

Figure 5 — Little Hocking River and Ohio River Tributaries survey area land use.

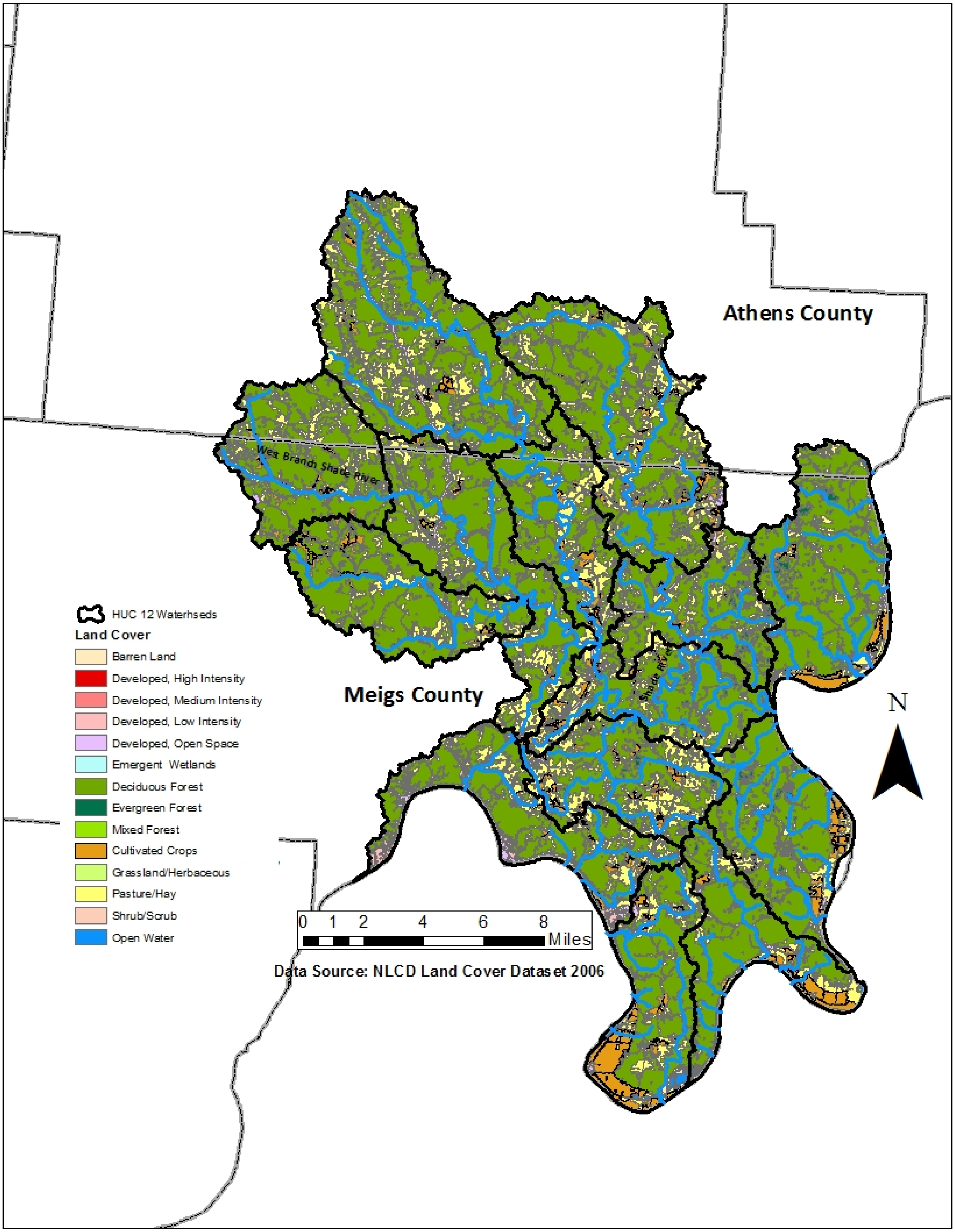

Figure 6 — Shade River and Ohio River Tributaries survey area land use.

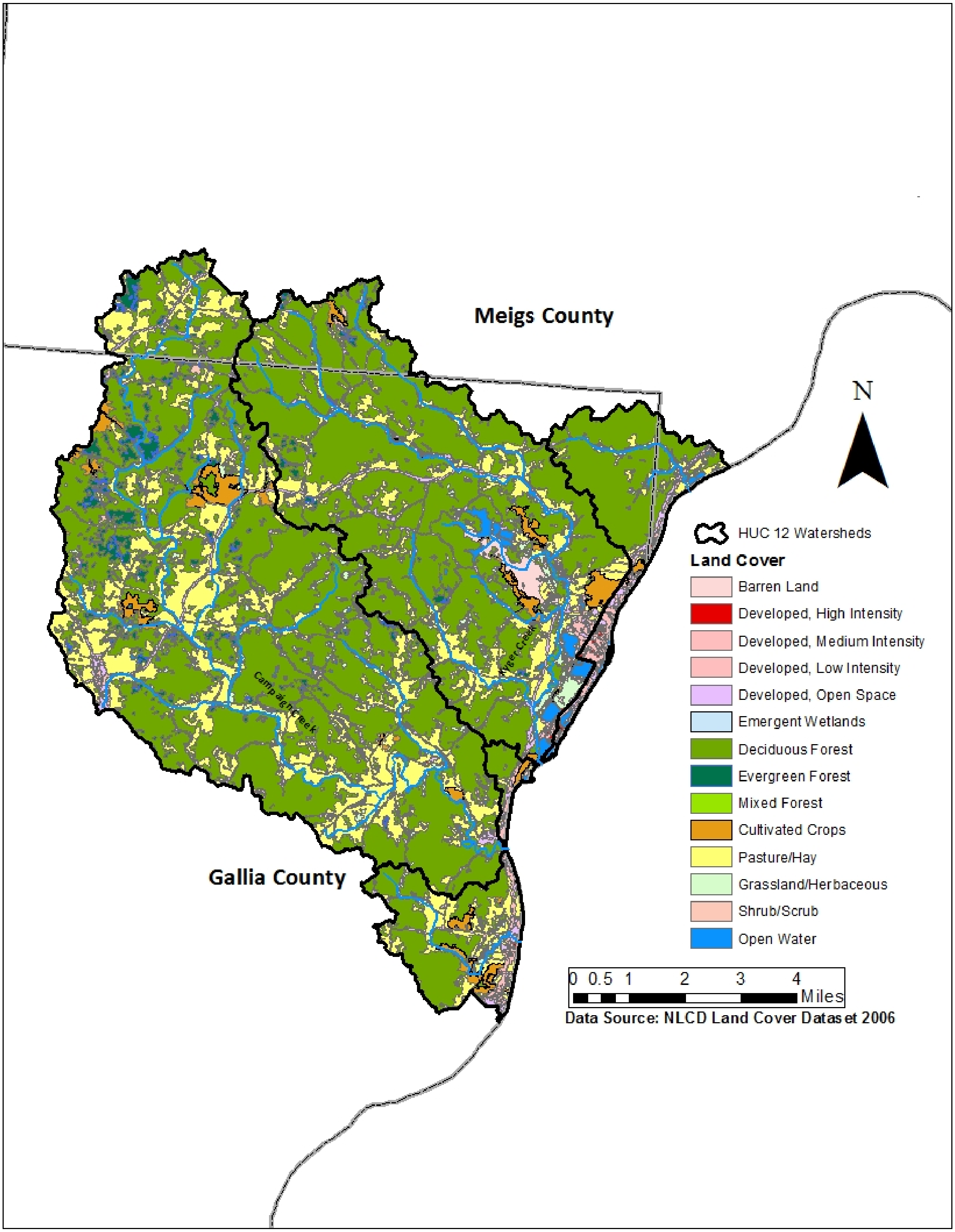

Figure 7 — Campaign Creek and Kyger Creek survey area land use.

Results

Chemical, Habitat and Biological Assessment

Pollution Loadings

0IB00005 Ohio Valley Electric Corporation Kyger Creek Station

The Ohio Valley Electric Corporation Kyger Creek Station has permitted discharges to Kyger Creek and Little Kyger Creek. The discharge to Kyger Creek is listed as outfall 005 and contains treated wastewater from a flue gas desulfurization wastewater treatment plant and a fly ash pond. Little Kyger Creek receives direct or indirect discharges of storm water and pond leachate, primarily from outfalls 026, 028, 030 and 031 based on reported flows. A detailed description of the facility and the various outfalls is available at ***wwwapp.epa.ohio.gov/dsw/permits/doc/0IB00005.fs.pdf***

Flows and suspended sediment concentrations from the 005 outfall to Kyger Creek have been stable from 2009 through 2015 (Figure 8 a and b). Monthly reporting of chloride resulting from the purge stream started in 2012; since that time, median and 75th percentile chloride concentrations range between 90 and 120 mg/L (Figure 8c). The mercury removal equipment serving the fly ash pond appears to have had its intended effect of preventing increased loadings, as mercury concentrations have remained stable through time (Figure 8d).

Concentrations of sulfate, arsenic and selenium (Figure 9) appear to have decreased at the 005 outfall following an initial increase in 2012 when the chloride purge stream used in desulfurization came on line. Concentrations of manganese have trended upward since 2012 (Figure 9b), eventually approaching levels potentially toxic to aquatic life (Reimer 1999, Nagpal 2001) by 2014; however, monitoring for manganese was discontinued in 2015.

Daily flows to Little Kyger Creek from the 026, 028, 030 and 031 outfalls were erratic, ranging from a few hundred gallons to several million gallons (Figure 10a). Similarly, concentrations of mercury, arsenic and selenium varied widely, though all the concentrations were reported when daily flows were less than 20,000 gallons per day. Whether the few high magnitude flow events resulted in significant loadings is undetermined.

0IB00006 Gavin Power, LLC — General James M Gavin Plant

Gavin Power, LLC – General James M. Gavin Plant is an electric generation facility. At the time of the 2015 survey, the facility was owned by The Ohio Power Company (AEP Generation Resources). Since the 2015 survey, Gavin Power, LLC has acquired the plant. Several landfills and their associated leachate ponds that handle flue gas desulfurization (FGD) byproduct from the plant are located adjacent to Kyger Creek and its tributaries. Discharges from the leachate ponds are covered under outfalls 007, 008 and 009. Storm water from a fly ash pond is discharged to Kyger Creek via Stingy Run under outfall 001. A detailed description of the facility and the location of the outfalls can be found at ***wwwapp.epa.ohio.gov/dsw/permits/doc/0IB00006.fs.pdf***

Flows from the 001 discharge were less variable in 2014 and 2015 compared to previous years (Figure 11), reflecting the on-going effort to drain and reclaim the fly ash pond. Reported concentrations of suspended sediment, oil and grease, and zinc were all within permit limits.

Discharge from the FGD leachate ponds showed no appreciable trends (Figure 11), and concentrations of suspended sediment and selenium were within permit limits (Figure 11). However, mercury concentrations near or in excess of the maximum limit of 242 ng/L were noted on two occasions in 2015 (Figure 11).

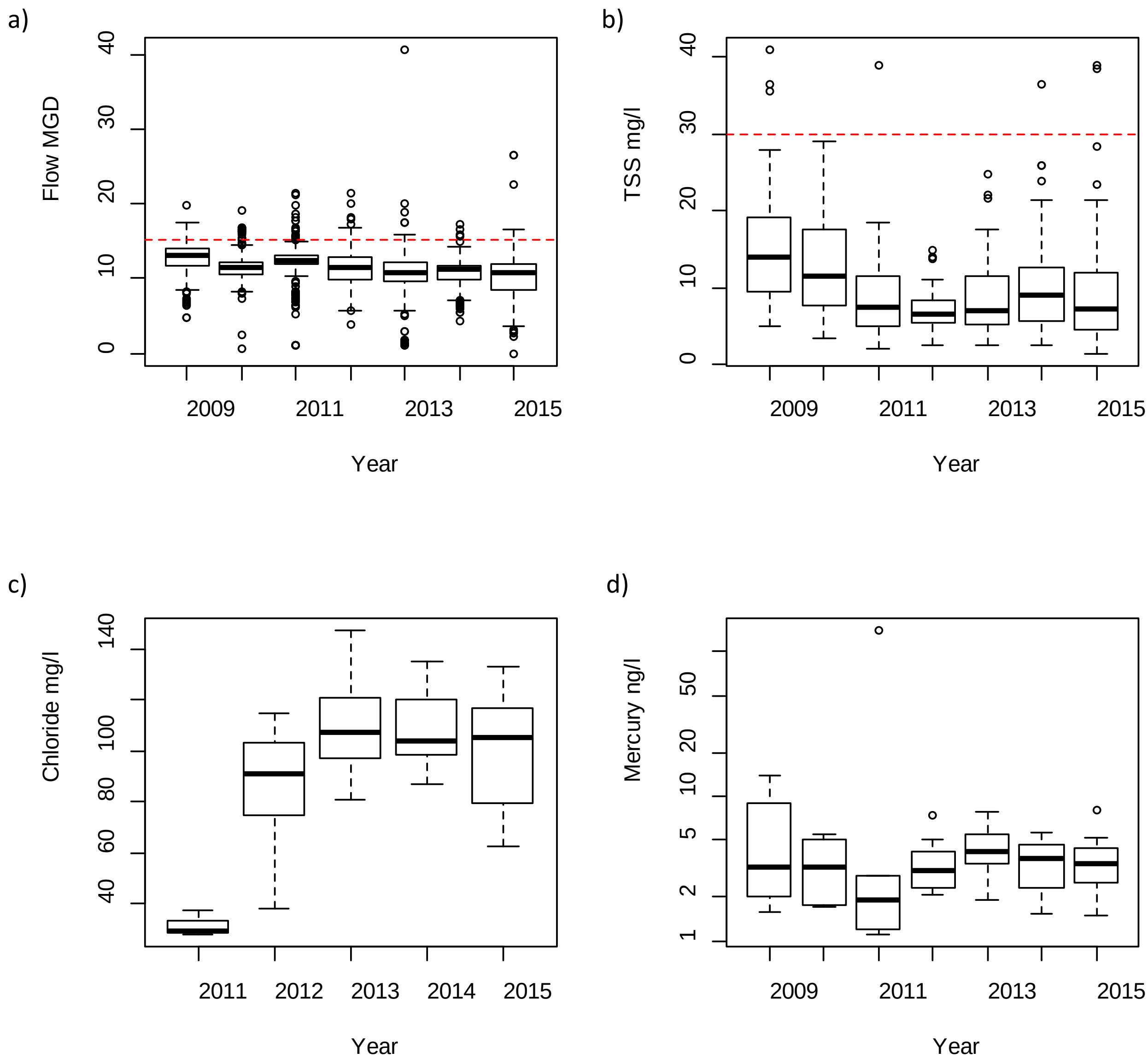

Figure 8 — Distributions of parameters reported under the permit for the Ohio Valley Electric Kyger Creek station, outfall 005. a) Flow in millions of gallons per day (MGD), b) total suspended solids, c) chloride and d) mercury.

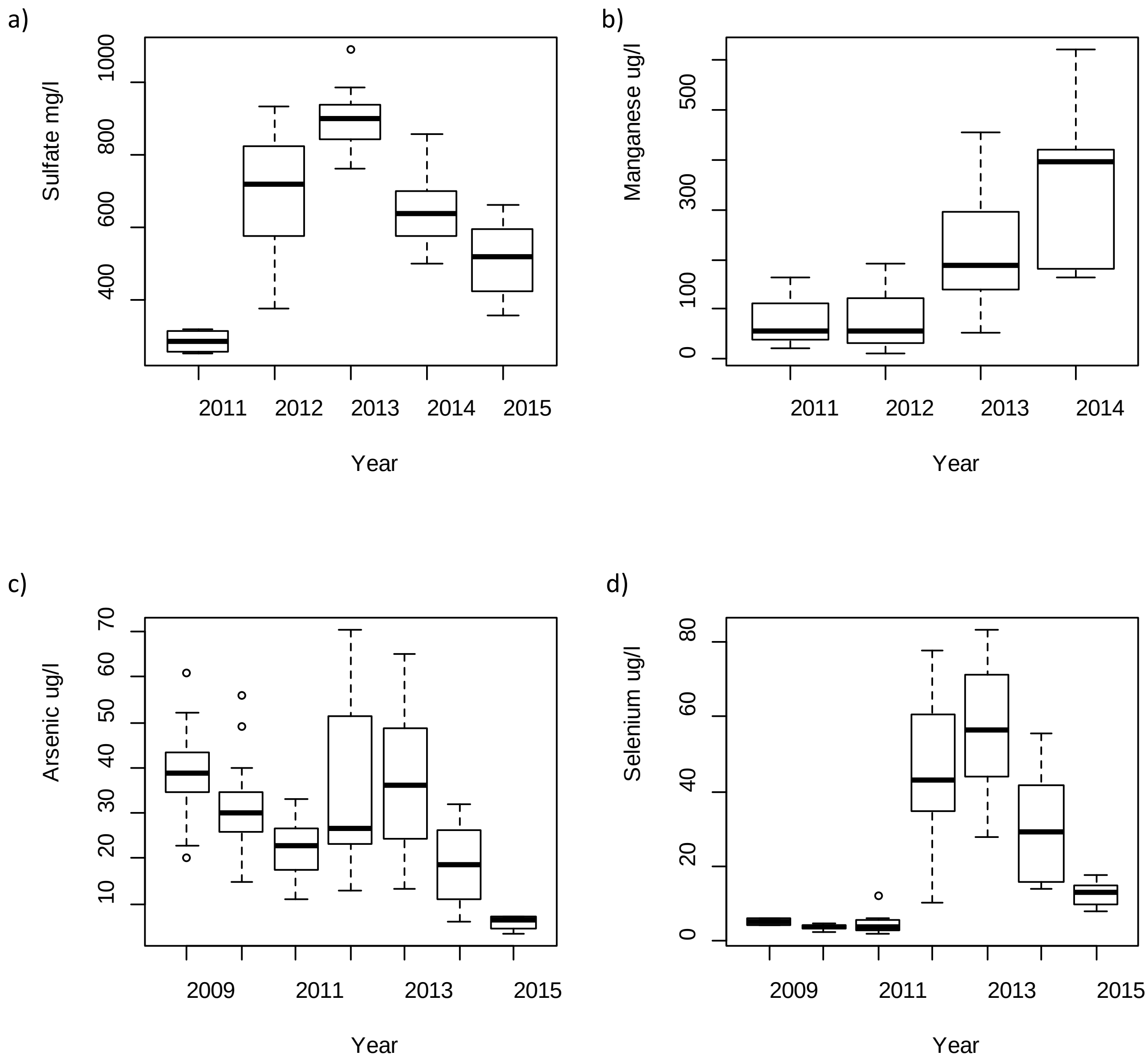

Figure 9 — Distributions of parameters reported under the permit for the Ohio Valley Electric Kyger Creek station, outfall 005. a) Sulfate, b) manganese, c) arsenic and d) selenium.

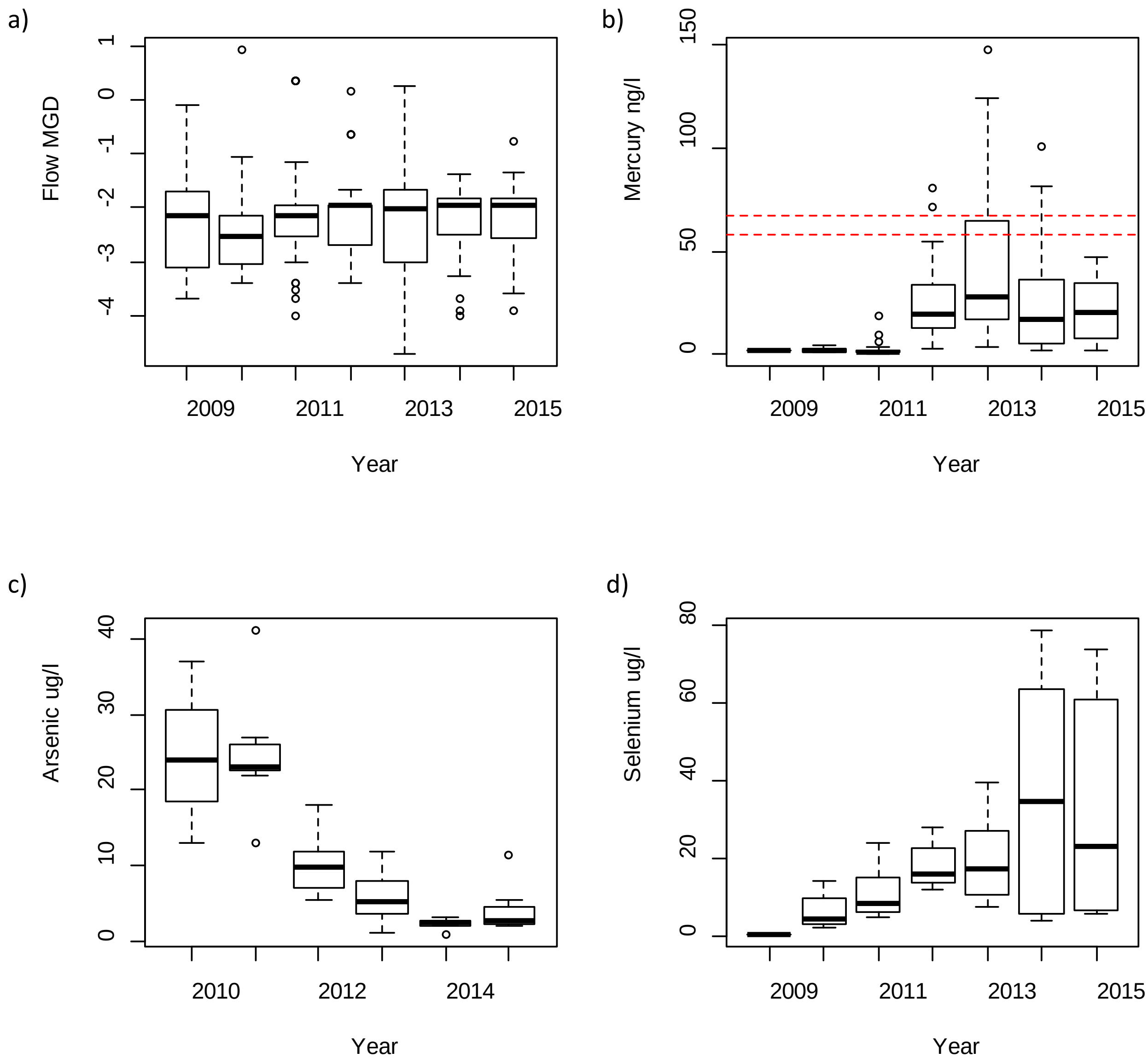

Figure 10 — Distributions of parameters reported under the permit for the Ohio Valley Electric Kyger Creek station, outfalls 026, 028, 030 and 031. Note that the data were pooled for all for outfalls and the flows are shown on a log10 scale. a) Flows, b) mercury, c) arsenic and d) selenium. The dashed red lines in the mercury plot shows the monthly concentration limits for 028 (67 ng/L) and 031 (58 ng/L).

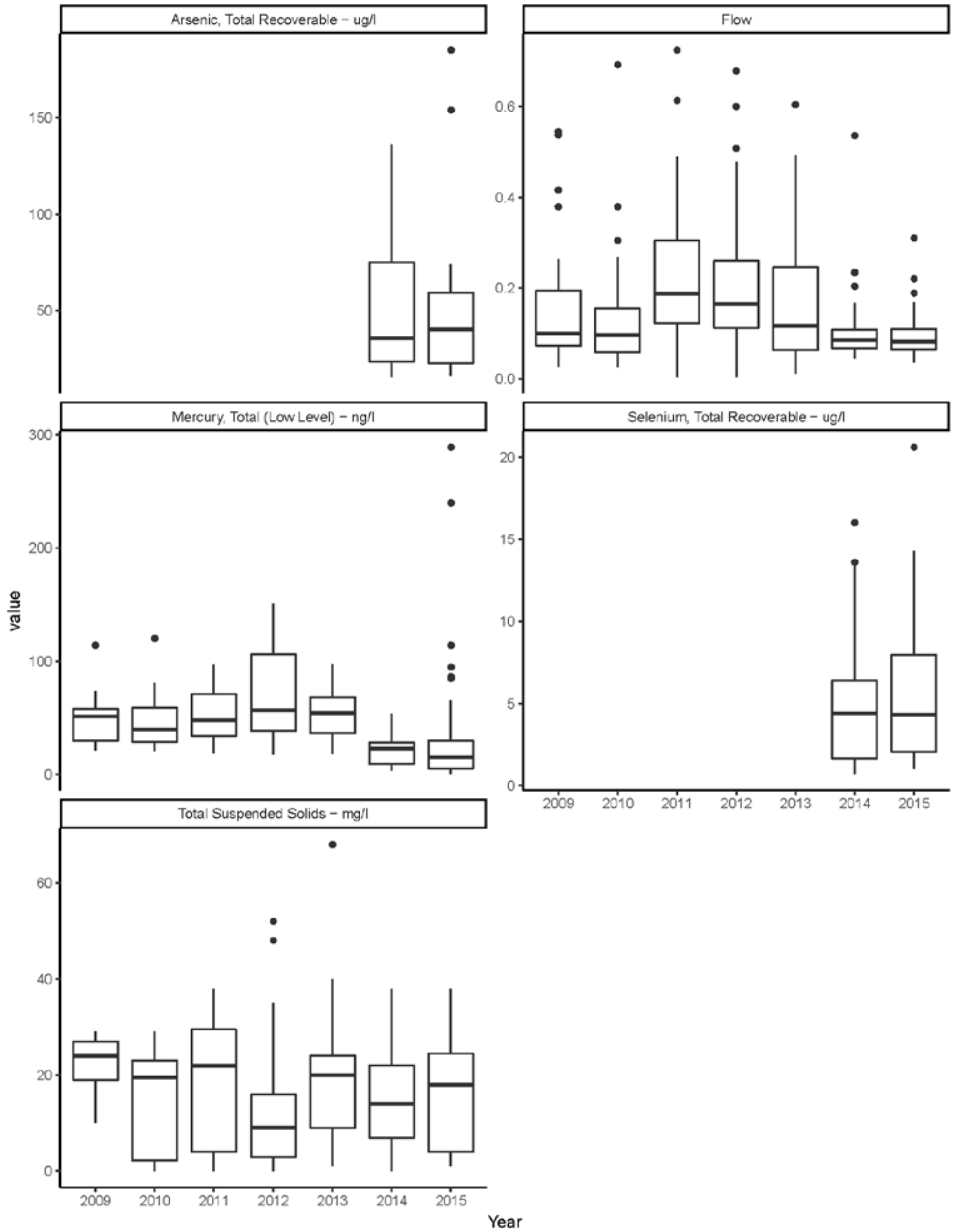

Figure 11 — Distributions of parameters reported under the permit for the Gavin Plant, outfalls 007, 008 and 009. Note that the data were pooled for the three outfalls.

0IN00121 Gallia County Landfill

Stormwater and leachate from the Gallia County Landfill discharges to White Oak Creek via an unnamed tributary with a confluence near RM 3.6. Being driven by rainfall, flows are highly variable (Figure 12a), as are concentrations of suspended sediment (Figure 12b). No impacts to aquatic life were apparent.

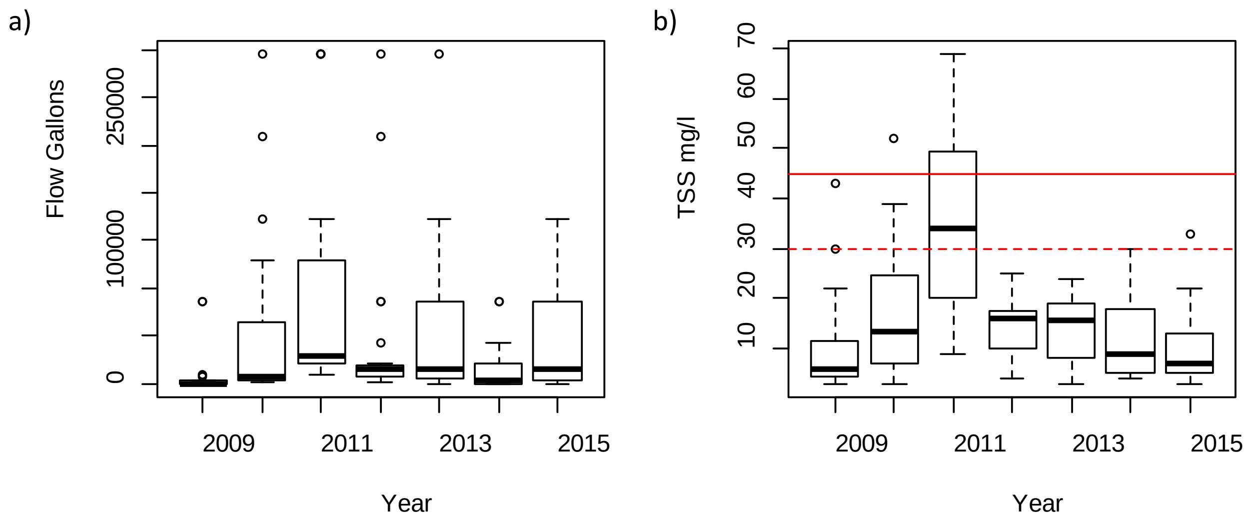

Figure 12 — a) Flows and b) suspended sediment concentrations from the Gallia County Landfill outfall 001.

0IQ00023 Little Hocking Service Center dba Estep Recovery

The Little Hocking Service Center, an automotive repair center, discharges to the Little Hocking River via an unnamed tributary with a confluence point at approximately RM 4.3, which is downstream from any point on the river included in the present survey. Flows from the facility in 2009 and 2010 frequently exceeded average design capacity (Figure 13a) but were generally less than the design capacity after 2011. Effluent concentrations of TSS were more variable in 2014 and 2015, and BOD5 edged higher in 2015 relative to previous years (Figure 13 b and c). Whether this represents an emerging trend or an operational problem is unknown but bears watching.

0PR00097 Par Mar Store No. 14

The Par Mar Store, a gas station, discharges treated sanitary effluent to the Little Hocking River via an unnamed tributary with a confluence at approximately RM 4.3. Flows reported by the plant are all estimated values and reported almost exclusively as 240 gallons per day. Monitoring is, however, required for several typical parameters including TSS, cBOD5, ammonia and residual chlorine. For those parameters, concentrations of TSS and cBOD5 varied considerably from year to year, and often exceeded respective effluent limits (Figure 14 a and b). Residual chlorine levels reported in 2011 routinely exceeded permit limits, but not subsequently (Figure 14c). No permit limits were set for ammonia, but reported concentrations are highly variable and typically at levels toxic to aquatic life (Figure 14d).

0PT00046 Eastern Local School District

The Eastern Local School District WWTP discharges to the East Branch Shade River at RM 4.1. Daily plant flows are required to be reported as actual measured values and were reported as 0.001 MGD for approximately 99 percent of the days between 2009 and 2015. Effluent concentrations of TSS, cBOD5, residual chlorine and ammonia (Figure 15) were fairly uniform and remained below permit limits except for several ammonia values reported in 2009.

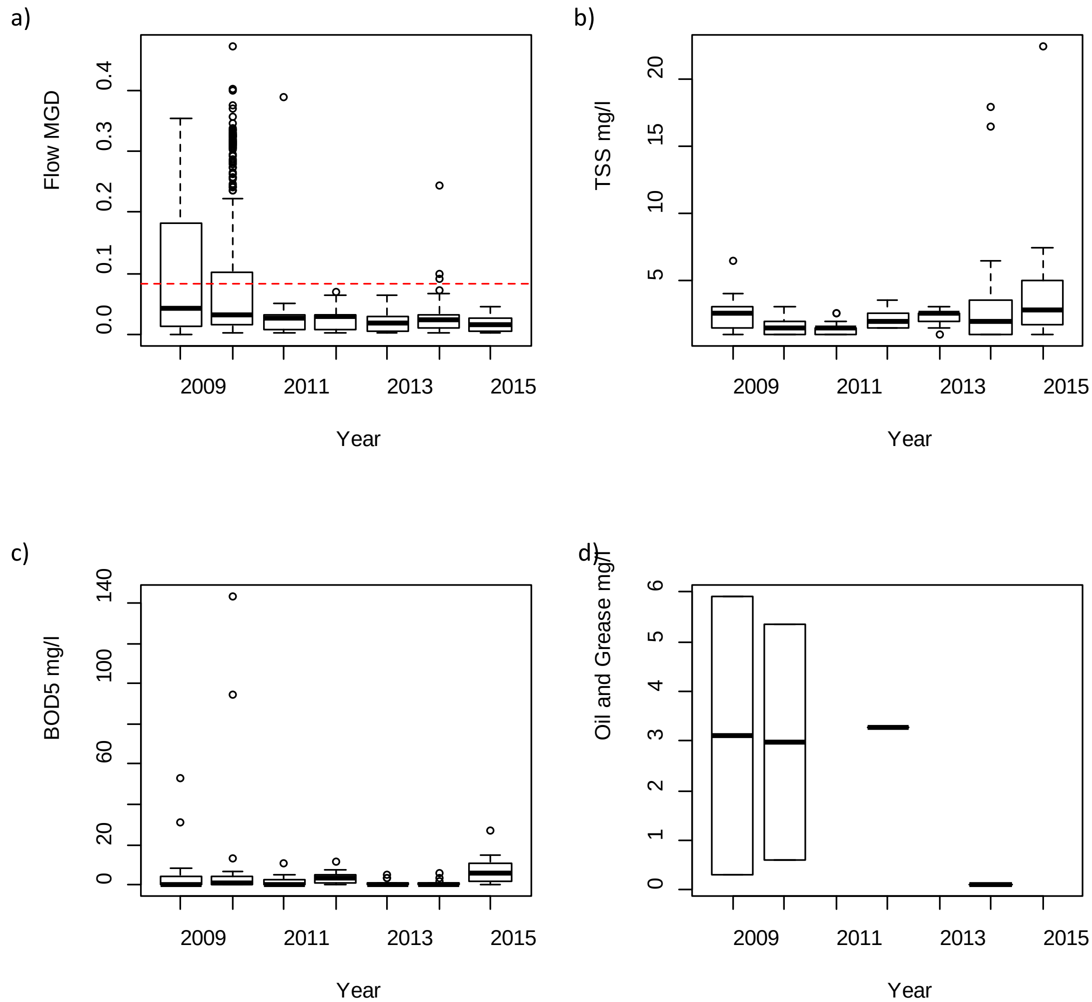

Figure 13 — Distributions of a) Flow in millions of gallons per day (MGD), b) total suspended solids, c) 5-day biochemical oxygen demand, and d) oil and grease reported by the Little Hocking Service Center.

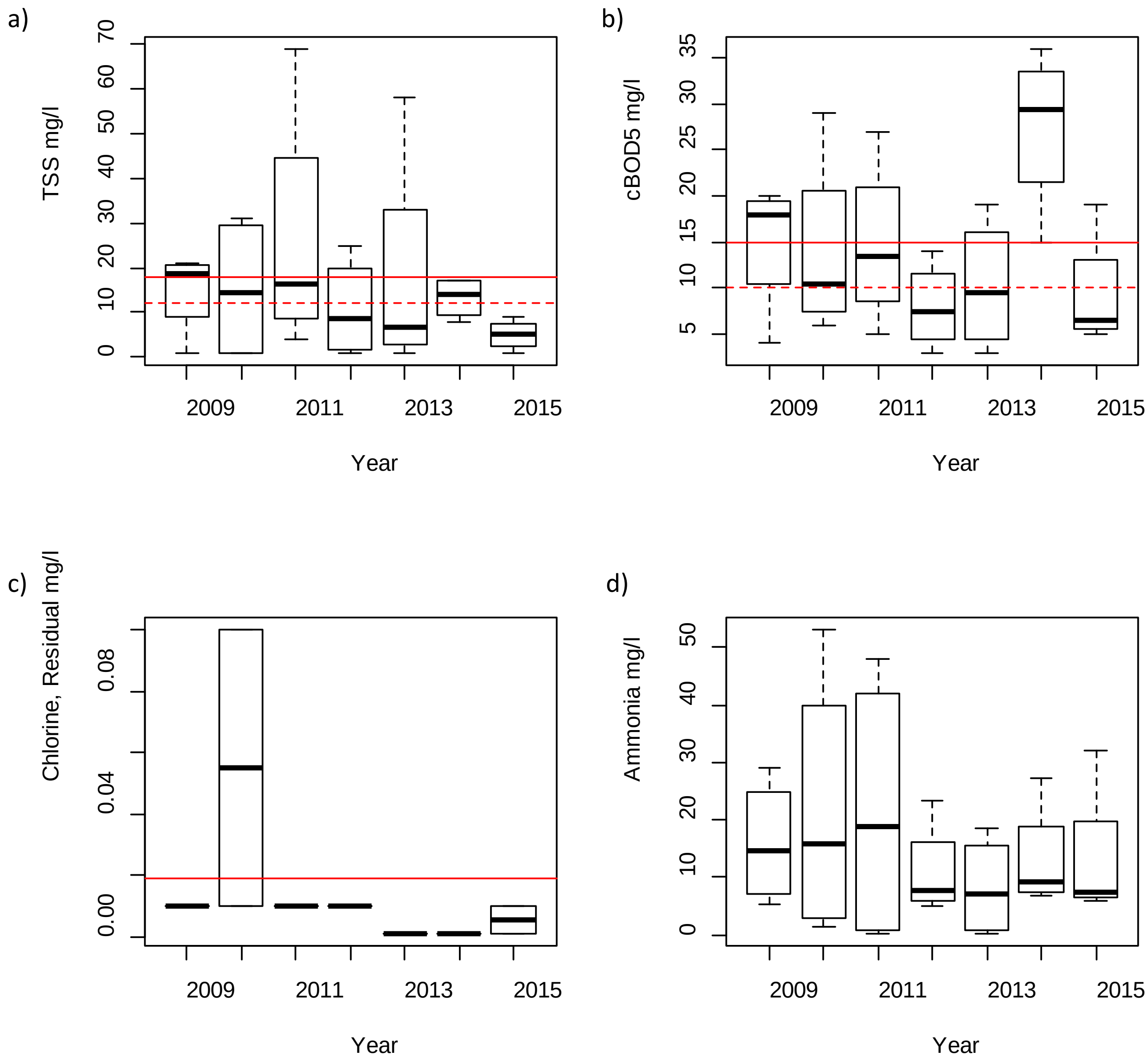

Figure 14 — Effluent concentrations reported by the Par Mar Store Number 14 for a) suspended solids, b) 5-day carbonaceous biochemical oxygen demand, c) residual chlorine and d) ammonia. Solid red lines indicate daily maximum concentration limits, and dashed red lines represent monthly average limits.

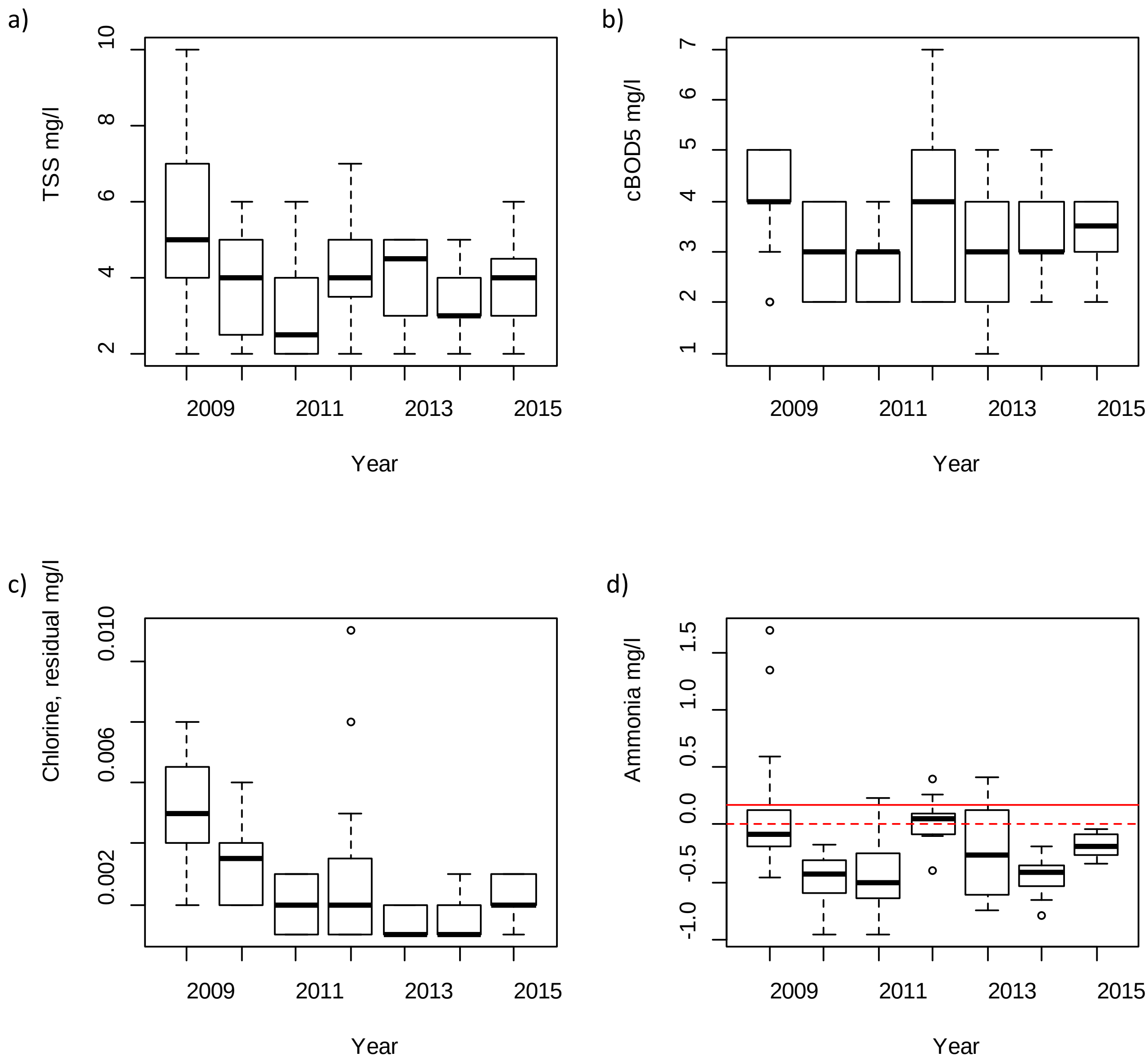

Figure 15 — Effluent concentrations reported by the Eastern Local School District for a) suspended solids, b) 5-day carbonaceous biological oxygen demand, c) residual chlorine and d) ammonia. The solid and dashed red lines in the ammonia plot respectively show weekly and monthly limits for the summer months. Note that the y-axis for the ammonia plot is a log10 scale.

Surface Water Quality

Overview

Water quality samples were collected from 55 locations in the SEORT survey area during the summer index period (June 15 – October 15). Sampling frequency varied by sampling location, but the minimum sampling frequency was four samples collected during the summer index period (June 15 – October 15), yielding 252 sampling events. The range of hydrologic conditions captured at each station were similar (Figure 16).

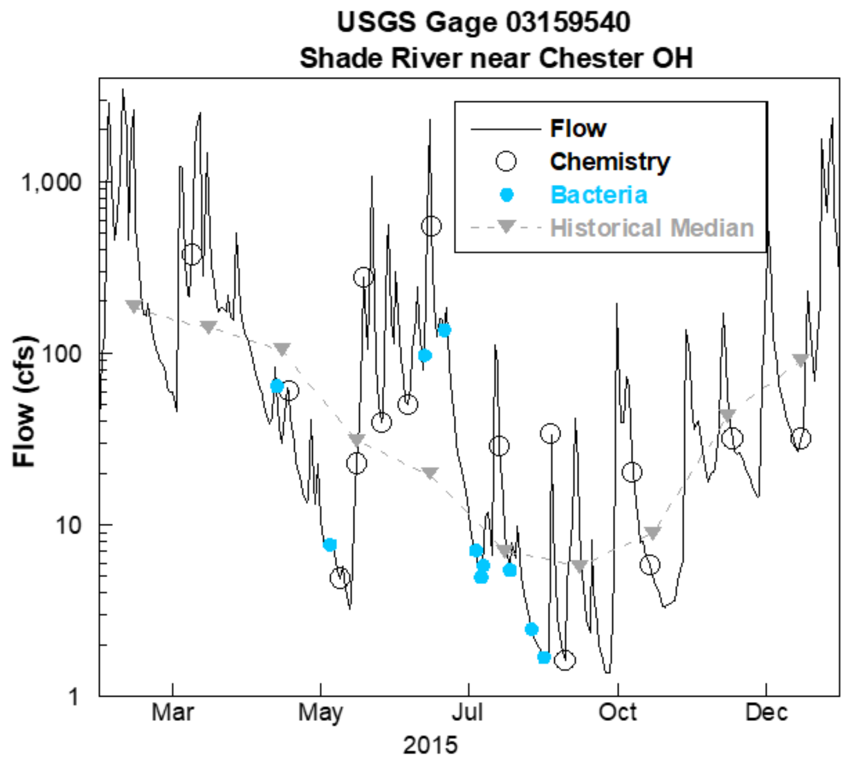

Figure 16 —Flow hydrograph for the Shade River near Chester, OH (USGS Gage #03159540) from March through December 2015. Dates of surface water chemical and bacteria sampling are shown.

Sampling results indicate that water quality in the Shade River survey area is influenced broadly by mining and locally by industrial discharges within and adjacent to the Kyger Creek basin. Additionally, two sites — Forest Run (301805) and the East Branch Little Hocking River (R19P03) — had elevated levels of ammonia and phosphorus, though no source was readily apparent. Lastly, one site on Oldtown Creek (W04W12) was apparently contaminated by trash dumped adjacent to Sharron Hollow Rd. under the U.S. 33 overpass, where lead values exceeded the aquatic life Outside Mixing Zone Average water quality criterion. The relative magnitude of how dissimilar the water quality is at these sites compared to the other survey sites is illustrated in Figure 17.

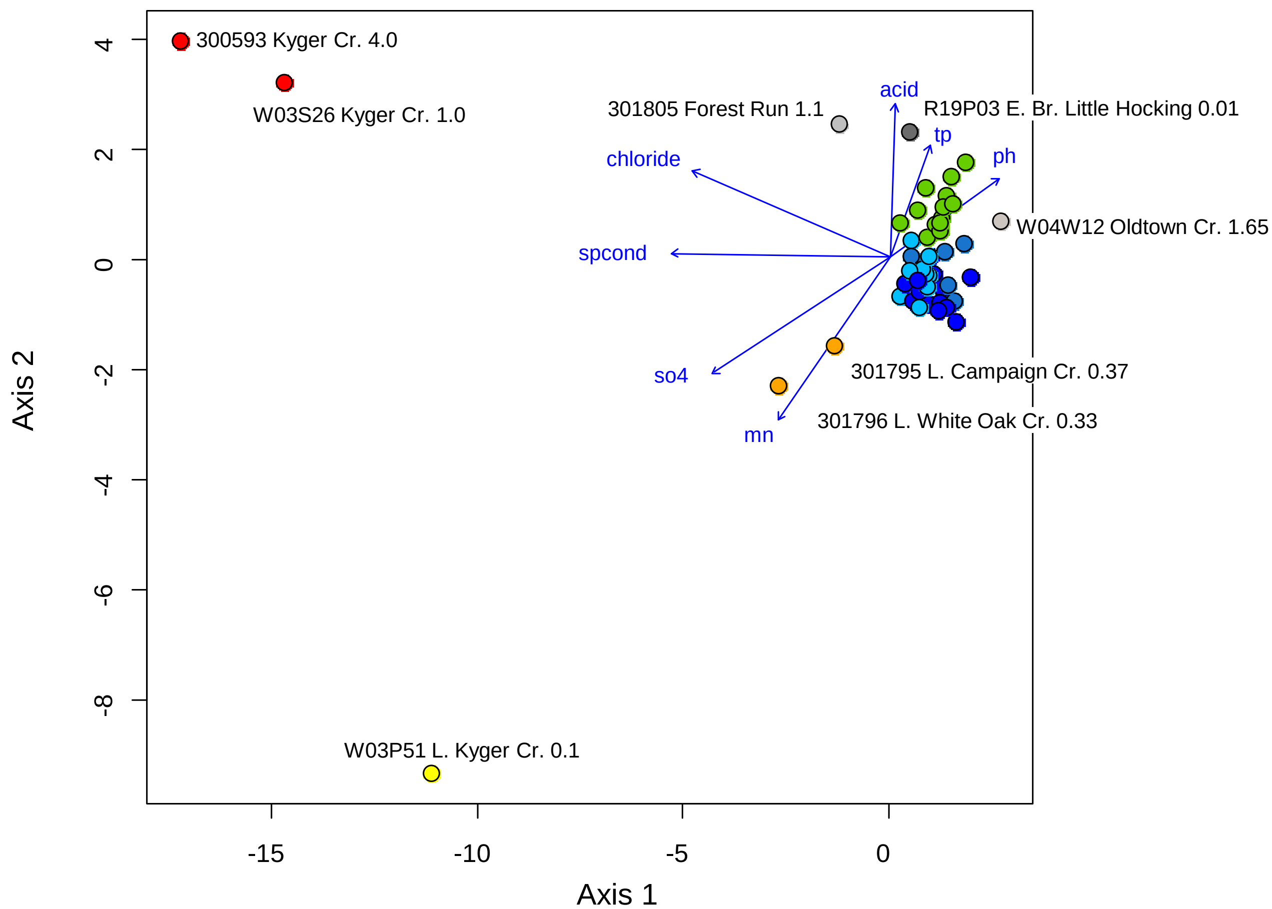

Figure 17 — An ordination plot of inorganic parameters from sites sampled from the SEORT survey area during 2015. Points lying away from the central cluster are labeled. Colors represent groups of sites suggested by hierarchical clustering. The red-yellow sites are all located in the Kyger Creek and Campaign Creek watersheds. Blue-shaded sites are headwaters and smaller wadeable streams. Green-shaded sites are larger wadeable streams.

In Figure 17, it is visually apparent is that a handful of sites are strongly separate along a gradient that broadly represents total dissolved solids, and this is captured in a directional sense almost perfectly by specific conductance. However, within that gradient, sites track individual ions. For example, the two sites on Kyger Creek located downstream from the FGD leachate outfall (the Gavin Plant 008, 009 outfalls; OVEC 005 outfall) are aligned with chloride, and this is in keeping with high chloride concentrations typical of FGD purge streams. Little Kyger Creek, Little Campaign Creek and Little White Oak Creek are aligned with sulfate and manganese, reflecting the fact that these creeks receive mine drainage. Although mining appears to affect these sites in particular, a more general east-west pattern is evident in relation to the bedrock underlying the study area. The eastern side of the area is underlain by the Dunkard Group and the western side is underlain by the coal-bearing Conemaugh and Monongahela groups (Figure 18).

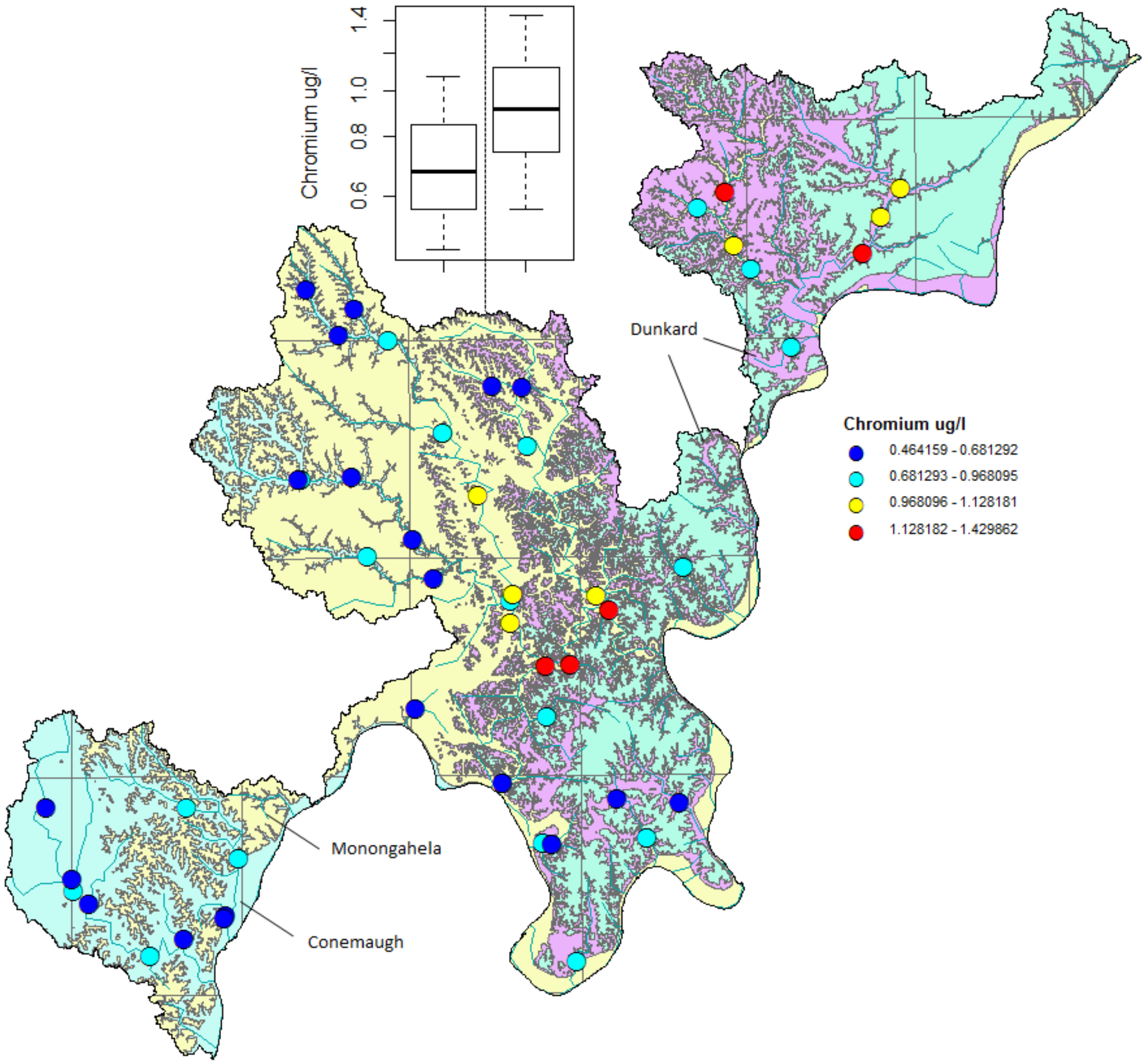

Figure 18 — Bedrock units and chromium concentrations in the SEORT study area. The box plot shows the distribution of concentrations when stratified by a longitude that roughly (by eye) corresponds to the divide between the Monongahela Group and the Dunkard Group. The units are log10(concentration in ug/l x 1000).

Manganese concentrations tend to run higher on the western side (Figure 19), whereas chromium concentrations tend to be higher on the eastern side. This is not to say that chromium concentrations are problematic — none of the concentrations were particularly elevated — simply that a pattern was evident that coincided with the parent geology. Manganese concentrations, on the other hand, do appear to be problematic, as will be detailed in the sections on aquatic life.

Forest Run and the East Branch Little Hocking River had elevated levels of ammonia and total phosphorus relative to other sites in the survey area (Figure 20). Typically, this combination signals organic enrichment. In the case of the East Branch Little Hocking River, D.O. concentrations were chronically low based on measurements recorded by automated data loggers, and *Escherichia coli* counts were elevated, suggesting a possible source. Local land use in the immediate catchment for either of these sites was no more adverse than other sites in the survey area; however, portions of Forest Run were historically mined, and mean concentrations of water quality parameters associated with mining (for example, manganese, nickel, sulfate, etc.) ran in the upper quintile for this site. This is not to say that phosphorus and ammonia in Forest Run were related to mining, simply to acknowledge that mining parameters were also elevated. Ammonia and manganese concentrations are highly correlated in the data set for the survey as a whole, but Forest Run and the East Branch Little Hocking appear as outliers (Figure 21). In either case, the magnitude of enrichment was modest at best. The lead water quality parameter caused Oldtown Creek (W04W12) to appear dissimilar to all other sites. The mean lead concentration at this site was 3.1 µg/L. All other sites had mean concentrations less than the method detection limit of 2.0 µg/L. One possible source for the lead may be a trash dump located adjacent to Sharron Hollow Rd. Otherwise, survey sites are relatively similar with respect to water quality apart from a minor gradient represented by total phosphorus and pH that is positively correlated with drainage area. Note that total phosphorus concentrations were not elevated at any site, and concentrations for all other parameters were typical for the ecoregion (Figure 20).

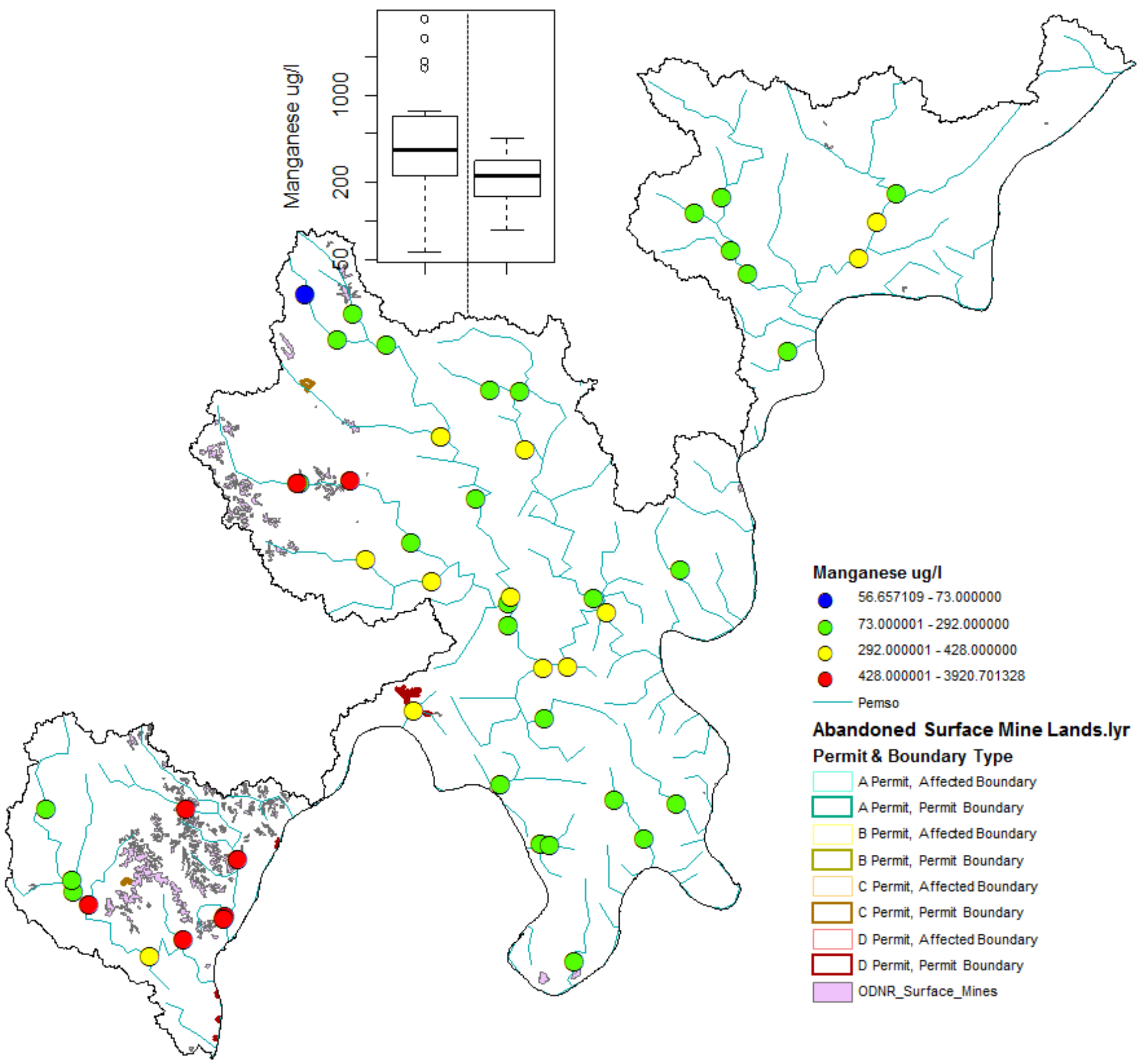

Figure 19 — Manganese concentrations in the SEORT study area in relation to surface mines. The box plot shows the distribution of concentrations when stratified by a longitude that roughly corresponds to the divide between the Monongahela Group and the Dunkard Groups (Figure 18).

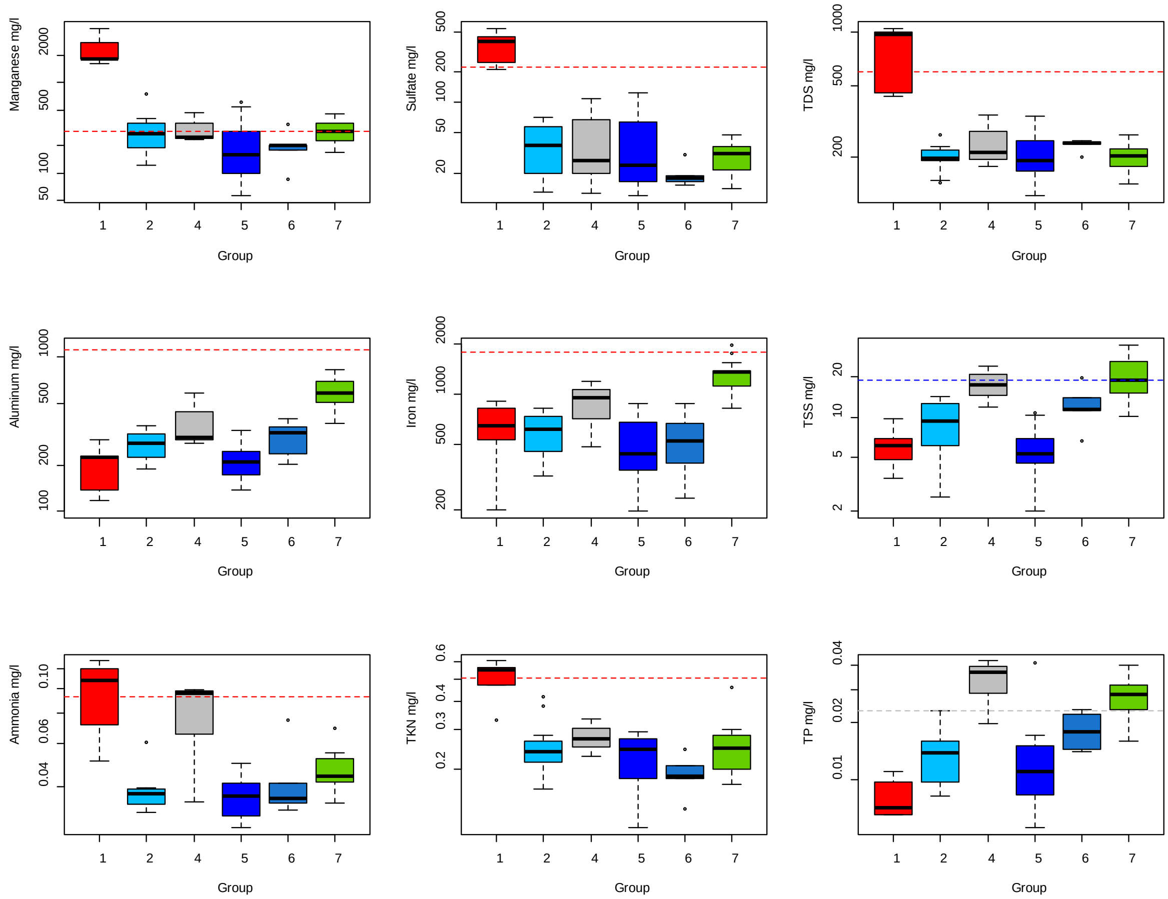

Figure 20 — Distributions of concentrations for various representative parameters measured in water quality samples collected during the SEORT survey, 2015. Colors represent the groupings shown in Figure 17, but note that Little Kyger, Little Campaign and Little White Oak are included in Group 1 (red) on this plot. The red stippled line shows the 90th percentile concentration for wadeable reference sites in the WAP ecoregion. The blue stippled line represents the 75th percentile (in the TSS plot) and the gray stippled line (in the TP plot) shows the median for wadeable WAP reference sites.

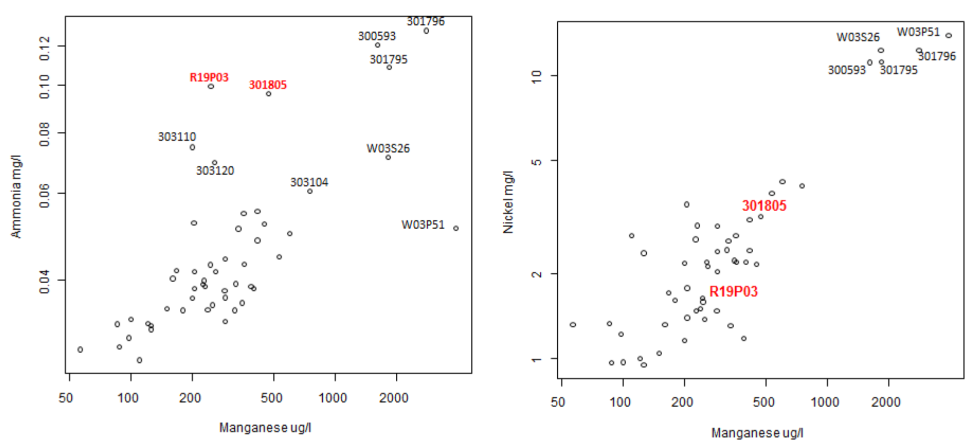

Figure 21 — Mean concentrations of ammonia and nickel plotted against mean concentrations of manganese for sites sampled in the SEORT survey area, 2015. Forest Run (301805) and the East Branch Little Hocking River (R19P03) sites are highlighted. Water quality in Forest Run is likely influenced by mine drainage as indicated by its position in the nickel-manganese plot.

Table 4 — Exceedances of Ohio WQS criteria (OAC 3745-1) for chemical/physical water parameters measured in grab samples taken from the SEORT study area, April 2015 — February 2016. Bacteria exceedances are presented in the Recreation Use Section.

RM	Sampling Location	Parameter (value - mg/L unless noted)
Campaign Creek		**(WWH, PCR, AWS, IWS)**
16.6	At Morgan Center Rd. (Co. Rd. 111)	None
11.5	Dst. White Oak Creek, adj. Campaign Rd.	None
6.25	At Bulaville Pike (Co. Rd. 3), W of Addison	Dissolved oxygen: (3.36; 3.39)[A]
Little Campaign Creek		**(WWH, PCR, AWS, IWS)**
0.37	NE of Bulaville at Brick School Rd.	Dissolved oxygen: 3.96[A]
Little White Oak Creek		**(WWH, PCR, AWS, IWS)**
0.33	E of Porter at Campaign Rd.	Ammonia: 2.63 µg/L[B]; Dissolved oxygen: 1.38[A]
Whiteoak Creek		**(WWH, PCR, AWS, IWS)**
0.38	Whiteoak Rd. NE of Porter	None
Kyger Creek		**(WWH, PCR, AWS, IWS)**
8.42	Upst. Kyger at St. Rte. 554, across from Van Zant	None
Kyger Creek		**(MWH, PCR, AWS, IWS)**
4.00	Adj. St. Rte. 554, upst. Rousch Cemetery, dst. AEP 008	Selenium: (75.5 µg/L; 62.5 µg/L)[CB]; (47 µg/L; 37.7 µg/L; 10.6 µg/L; 10.5 µg/L; 10.4 µg/L; 8.4 µg/L; 7.2 µg/L; 6.9 µg/L; 6.7 µg/L; 6.6 µg/L)[B]; Total dissolved solids: (3,180; 3,030; 2,610; 2,600)[B]
1.00	Near Addison, upst. Power Plant, dst. L. Kyger Creek	Selenium: (34 µg/L; 24.2 µg/L; 8.5 µg/L; 6.1 µg/L) [B]; Total Dissolved Solids: (1,870; 1,700)[B]
Little Kyger Creek		**(MWH, PCR, AWS, IWS)**
0.01	Two mi. N of Addison at mouth	Temperature (26.36)[D]
1.1	N of Welshtown, just upst. Kerr Run	None
Bowman Run		**(WWH, PCR, AWS, IWS)**
0.42	near Pine Grove Rd. N of Racine	None
Yellowbush Creek		**(WWH, PCR, AWS, IWS)**
1.48	E of Racine at Yellowbush Rd.	None
0.85	Dst. mine at powerlines, S of Racine	Dissolved oxygen: 3.95[A]
Johns Run		**(WWH, PCR, AWS, IWS)**
1.4	At Rowe Rd. at Apple Grove	Dissolved oxygen: 3.45[A], Iron: 5,160 µg/L[C]
Oldtown Creek		**(WWH, PCR, AWS, IWS)**
4	At Co. Rd. 35 Portland Rd., near Spiller	None
1.65	near Rolandus, adj. Co. Rd. 124	Lead: 64.6 µg/L[B]
Groundhog Creek		**(WWH, PCR, AWS, IWS)**
2.3	At Sellers Ridge Rd.	None
Forked Run		**(WWH, PCR, AWS, IWS)**
4.72	Adj. Number 9 Rd. (Rd. 265), dst. Tributary	None
Georges Creek		**(WWH, PCR, AWS, IWS)**
1.2	Lane off St. Rte. 7, near Addison	None
Shade River		**(WWH, PCR, AWS, IWS)**
17.13	At Chester at St. Rte. 248	Iron: 5,020 µg/L[C]
11.64	Dst. Chester at gage, at Twp. Rd. 112	Lead: (11.6 µg/L; 7.8 µg/L)[B] Iron: (13,200 µg/L; 7,290 µg/L; 5,860 µg/L; 5,790 µg/L)[C]
5.84	Near Keno, adj. Twp. Rd. 114	Iron: 6,390 µg/L[C]
Horse Cave Creek		**(WWH, PCR, AWS, IWS)**
4.88	At Vanmeter Hill Rd., near Morningstar	
0.35	SE of Chester at Garen Rd.	None, Lead: 7.8 µg/L[B]; Iron: 11,100 µg/L[C]
E. Branch Shade River		**(WWH-R, PCR, AWS, IWS)**
15	W of Lottridge, at Co. Rd. 57	None

RM	Sampling Location	Parameter (value - mg/L unless noted)
11.84	NE of Alfred, near Orange Cemetery, at Co. Rd. 53	None
0.87	At St. Rte. 248, E of Chester	Iron: (5,610 µg/L; 5,520µg/L)[C]
Dog Hollow Run		**(WWH, PCR, AWS, IWS)**
2.5	At Warner Rd.	None
M. Branch Shade River		**(WWH-R, PCR, AWS, IWS)**
28.2	At Old St. Rte. 33, S of Athens	None
25.8	At Old St. Rte. 33, near Angel Ridge Rd., S of Athens	Dissolved oxygen: 3.46[A]
22.5	At Fossil Rock Rd. (Co. Rd. 42), S of Athens	None
14.8	Dst. Pratts Fork at Twp. Rd. 227 Covered Bridge	Iron: 5,140 µg/L[C]
8.1	SW of Alfred at road off Co. Rd. 44	None
0.42	N of Chester at St. Rte. 7	Iron: 5,260 µg/L[C]
Pratts Fork		**(WWH, PCR, AWS, IWS)**
0.02	S of Garden, at mouth, at Blackwood Covered Bridge	Iron: 10,400 µg/L[C]
Long Run		**(WWH, PCR, AWS, IWS)**
1.4	Long Run Rd., SE of Athens	None
W. Branch Shade River		**(WWH, PCR, AWS, IWS)**
16.5	At St. Rte. 681, W of Burlingham	None
13.8	Adj. Burlingham Rd., at St. Rte. 33, W of Burlingham	None
7.8	At Clark-Midkiff Rd.	Temperature (28.7)[D]
0.16	N of Chester at St. Rte. 7	None
Trib to W. Branch Shade River (RM 16.35)		**(WWH-R, PCR, AWS, IWS)**
0.1	At St. Rte. 681	None
Kingsbury Creek		**(WWH, PCR, AWS, IWS)**
6.75	NW of Kingsbury at Kingsbury Rd.	None
2.08	S of Hemlock Grove at Twp. Rd. 82	Dissolved oxygen: (3.89; 3.6)[A]
Dunfee Run		**(WWH, PCR, AWS, IWS)**
1.4	At Twp. Rd. 297 (Collins Rd.)	None
Little Hocking River		**(WWH, PCR, AWS, IWS)**
15.2	Upst. Veto Lake at Bracken Ridge Rd., N of Veto	Temperature (24.8)[D]
9.89	At Co. Rd. 85, NW of Belpre	Dissolved oxygen: 3.21[A]
7.55	N of Porterfield at St. Rte. 339	None
Mile Run		**(WWH, PCR, AWS, IWS)**
1.1	St. Rte. 550, near Cole Coffman Rd. (T13), W of Marietta	None
W. Branch Little Hocking		**(WWH, PCR, AWS, IWS)**
8.7	At Twp. Rd. 256, upst. Gilbert Rd., W of Filmore	None
4.8	At Co. Rd. 111 (Welch Rd.), S of Decaturville	None
2.87	At Co. Rd. 248 (Ross Rd.)	Lead: 9.4 µg/L[B]; Iron: 10,100 µg/L[C]
Gilbert Run		**(WWH, PCR, AWS, IWS)**
1.3	At Turkey Hollow Rd., S of Cutler	None
E. Branch L. Hocking River		**(WWH, PCR, AWS, IWS)**
0.01	SE of Veto Lake at mouth	None

A Exceedance of the applicable minimum D.O. criteria – WWH: 4.0 mg/L, LRW: 2.0 mg/L.
B Exceedance of the aquatic life Outside Mixing Zone Average water quality criterion.
C Exceedance of the statewide water quality criteria for the protection of agricultural uses.
D Exceedance of the maximum temperature criteria (ORC 3745-1-07 Table 7-14).

Summary of Results from Automated Data Loggers

Multi-parameter water quality sondes were deployed to monitor temperature, D.O., pH and specific conductance (conductivity). Temperature, D.O. and pH are influenced by diel patterns that reflect air temperature, solar radiation, base flow (ground water), discharge and shading. In general, daily fluctuations in temperature increase as base flow, discharge and shading decrease. These diel patterns have the greatest impact on streams during a critical condition that includes stable, low streamflow. Specific conductance is not influenced by the same diel triggers but is monitored because it is a good indicator of changes in streamflow. The automated sondes collect readings hourly to monitor these parameters throughout a daily cycle.

Dissolved oxygen responds in a similar diel pattern to temperature, as it is affected by similar factors. 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, D.O. produced by photosynthesis is often sufficient to overwhelm the inverse relationship, causing the trends to follow similar trajectories. Daily fluctuations in D.O. are driven by primary production (photosynthesis) and respiration (consumption of oxygen by the microbial community). In highly enriched systems, D.O. concentrations may become super-saturated during the day and depleted by respiration at night. The result is a diel trend that typically reaches a maximum in the early afternoon and a minimum just after daybreak. In some cases, D.O. does not exhibit strong diel trends. Either primary productivity is limited or decomposition of organic matter in the stream depletes available D.O. Diel monitoring helps to identify whether water quality disturbances are related to 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, 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 D.O.

Sixteen sites were sampled with water quality sondes in the study area. Sonde sites were chosen primarily to describe and assess water quality conditions in the watershed, as there are few point sources or historic issues outside of the Kyger Creek watershed.

Sondes were deployed at all sites in this study area from Sept. 1-3, 2015. As shown in Figure 22, this period captured the best combination of low flows and warm air temperatures for the season. Air temperatures were well above normal, making the deployment an excellent snapshot of the critical condition. Summary plots of all data collected are included in Appendix E of this document. The plots are of hourly readings taken for temperature, D.O., pH and specific conductance.

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 the following: maximum daily temperature; minimum D.O.; 24-hour average D.O.; 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 D.O. 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 (critical condition). A summary of the exceedances is presented in Table 5. The table includes comments about exceedances that are made based on Ohio EPA staff's best professional judgment.

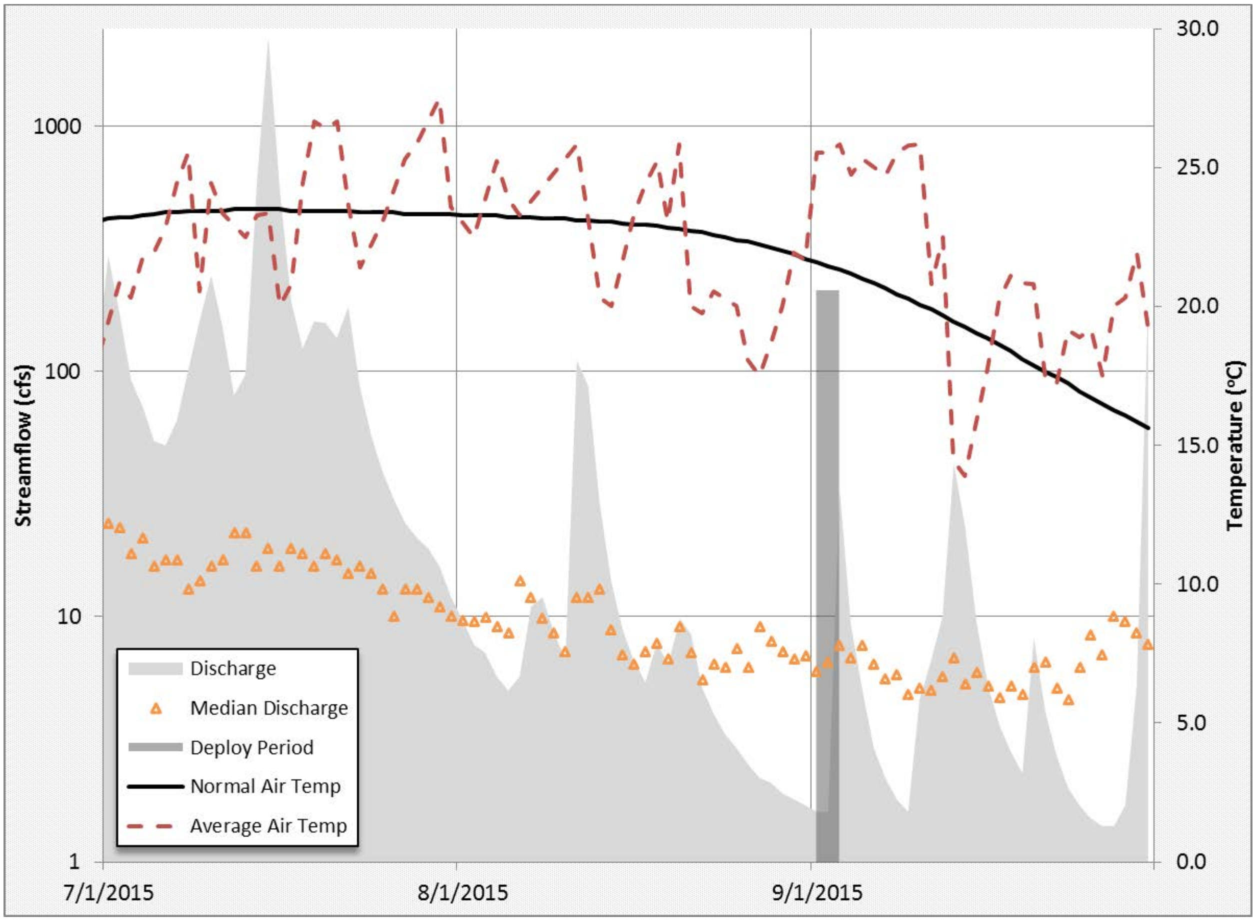

Figure 22 — Graph of average daily streamflow (USGS 03159540 – Shade River near Chester, OH) relative to the median streamflow, including the average and normal daily air temperature (NOAA - GHCND:USC00334927) for the sampling season.

Table 5 — Exceedances of Ohio Water Quality Standards criteria (OAC 3745-1) for chemical and physical parameters derived from diel monitoring.

Sonde water quality monitors recorded hourly readings throughout the deployment (9/1/15 — 9/3/15). Consequently, exceedances can be presented as both a measure of magnitude and duration. 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 parentheses after the duration. Rolling 24-hour averages were calculated using the hourly readings for comparison against the average D.O. criteria. Applicable water quality criteria include: minimum D.O.[a]; average D.O.[b]; maximum temperature[c]; pH[d]; and specific conductance[e].

RM	Location	Parameter (D.O. in mg/L and Sp. Cond. in uS/cm)	Comments
Campaign Creek		**Warmwater Habitat (Existing)**	
6.25	At Bulaville Pike Co. Rd. 3 W of Addison	D.O. min.: 2 (3.8); 1 (3.9) D.O. avg.: 8 (4.8)	Negligible departure
Kyger Creek		**Modified Warmwater Habitat – Mine Affected Recommended**	
4.0	Adj St. Rte. 554 upst. Rousch Cem., dst. AEP 008	Sp. Cond.: 47 (6,552)	
Little Kyger Creek		**Modified Warmwater Habitat – Mine Affected Recommended**	
0.01	Two miles N of Addison at mouth	None	
Shade River		**Warmwater Habitat (Existing)**	
11.64	Dst. Chester at gage at Twp. Rd. 112	None	
Horse Cave Creek		**Warmwater Habitat (Existing)**	
0.35	SE of Chester at Garen Rd.	D.O. min.: 2 (3.6); 1 (3.6); 3 (3.3) D.O. avg.: 27 (4.2)	Negligible departure
East Branch Shade River		**Warmwater Habitat (Recommended)**	
11.84	NE of Alfred, near Orange Cem. at Co. Rd. 53	D.O. min.: 4 (3.6); 3 (3.1); 7 (3.1) D.O. avg.: 11 (4.7)	Negligible departure
0.87	at St. Rte. 248 E of Chester	None	
Middle Branch Shade River		**Warmwater Habitat (Recommended)**	
22.5	At Fossil Rock Rd. (Co. Rd. 42) S. of Athens	None	Sonde only collected 10 hours of usable data, so no 24-hr averages calculated.
0.42	N. of Chester at St. Rte. 7	None	
Pratts Fork		**Warmwater Habitat (Existing)**	
0.02	S of Garden, at mouth, at Blackwood Covered Bridge	None	
West Branch Shade River		**Warmwater Habitat (Existing)**	
16.5	At St. Rte. 681 W of Burlingham	D.O. avg.: 2 (4.9)	Negligible departure
0.16	N of Chester at St. Rte. 7 or Texas Rd.	None	
Kingsbury Creek		**Warmwater Habitat (Existing)**	
2.08	S of Hemlock Grove at Twp. Rd. 82	D.O. min.: 18 (3.0); 15 (2.7) D.O. avg.: 27 (3.5)	Potentially stressful
W Branch Little Hocking River		**Warmwater Habitat (Existing)**	
2.87	At Co. Rd. 248 Ross Rd.	D.O. min.: 1 (3.8) D.O. avg.: 23 (4.6)	Negligible departure
E Branch Little Hocking River		**Warmwater Habitat (Existing)**	
0.01	SE of Veto Lake at mouth	D.O. min.: 7 (2.3); 4 (3.6); 16 (1.9); 2 (3.0) D.O. avg.: 24 (3.3)	Chronic condition

a The General Ohio River basin daily maximum temperature criteria apply; See OAC 3745-1-07, Table 7-14(G).
b Applicable minimum 24-hour average D.O. criteria – LRW: 3.0 mg/L; WWH: 5.0 mg/L.
c Applicable minimum D.O. criteria – LRW: 2.0 mg/L; WWH: 4.0 mg/L.
d The criteria for pH is 6.5-9.0 S.U.
e The criteria for specific conductivity is 2,400 µS/cm.

Sites on these tributaries to the Ohio River are generally turbid, deep and shaded, with widespread incision throughout the watershed. These conditions, along with potential ground water influence, contribute to the low water temperatures measured during the critical condition. Even though flow was well below normal and air temperature well above, no stream temperature exceedances were recorded during sonde deployment.

Depressed D.O. was pervasive in the study area and minimum and average D.O. criteria exceedances were common. Campaign Creek, Horse Cave Creek, East Branch Shade River, West Branch Shade River, Kingsbury Creek, West Branch Little Hocking River and East Branch Little Hocking River all had similar D.O. exceedances. The mainstem of Little Hocking River also displayed low D.O. with point readings, but technical issues with the sonde deployment prevented the continuous data from being used.

While the available data does not demonstrate a clear, singular cause for this widespread D.O. depression, lack of primary production, limited reaeration and potential ground water contributions could all be stressors. Signatures are similar to those seen with organic enrichment, although sandy substrates did not appear to be laden with organic material. Flows were very low during the study period —20^{th} percentile for measurements taken September 1-2 over the last 50 years—further exacerbating issues with reaeration and groundwater.

No exceedances were observed for pH.

The monitoring location on Kyger Creek (RM 4.0) was the only site in the study area with elevated specific conductance. With a maximum measurement of 6,552 µS/cm, this stream exceeded the water quality criterion for 47 consecutive hours. Industrial activities supporting the Gavin Power Kyger Creek Station are present upstream and the likely contributor of this conductance.

Physical Habitat Quality for Aquatic Life - Western Tributaries

Overview

Habitat quality in the Shade River system and adjacent direct tributaries to the Ohio River, including Kyger Creek, Campaign Creek and the Little Hocking River, is strongly influenced by a disequilibrium between the processes of erosion and sediment transport. Specifically, the rate and volume of sand delivered to the stream channel by erosion and bank wasting overwhelms the hydraulic process by which sediments are either transported by, or purged from, the stream channel. This imbalance is most directly the result of channel incision brought on by historic deforestation (Fitzpatrick & Know, 2000). Channel incision disrupts sediment transport by preventing high flows from accessing the historic (formerly active) floodplain, and by inhibiting sediments from being sorted into defined channel features such as pools, riffles and point bars.

The net effect of this disequilibrium on physical habitat quality is most evident in the frequency with which modified attributes are noted on the QHEI sheet, especially embeddedness and low channel development (Table 6). When compared to regional reference sites, the ratio of modified attributes to warmwater attributes is higher in the Shade River survey area, and QHEI scores average lower[1] (Figure 23). The median ratio of modified attributes to warmwater attributes for sites in the Shade system is 0.85, as opposed to 0.36 for reference sites. The mean QHEI score for Shade sites is 67.0. This suggests that despite the pervasive effect of channel incision, streams in the system generally possess the physical habitat capable of supporting fish assemblages typical of the ecoregion. However, because the effect of incision is pervasive, the biological expectation (in terms of the IBI) for a given level of habitat quality would be uniformly lower in the Shade system relative to regional reference expectations.

[1] Adjusting for differences in drainage area, ANCOVA, $p<0.01$

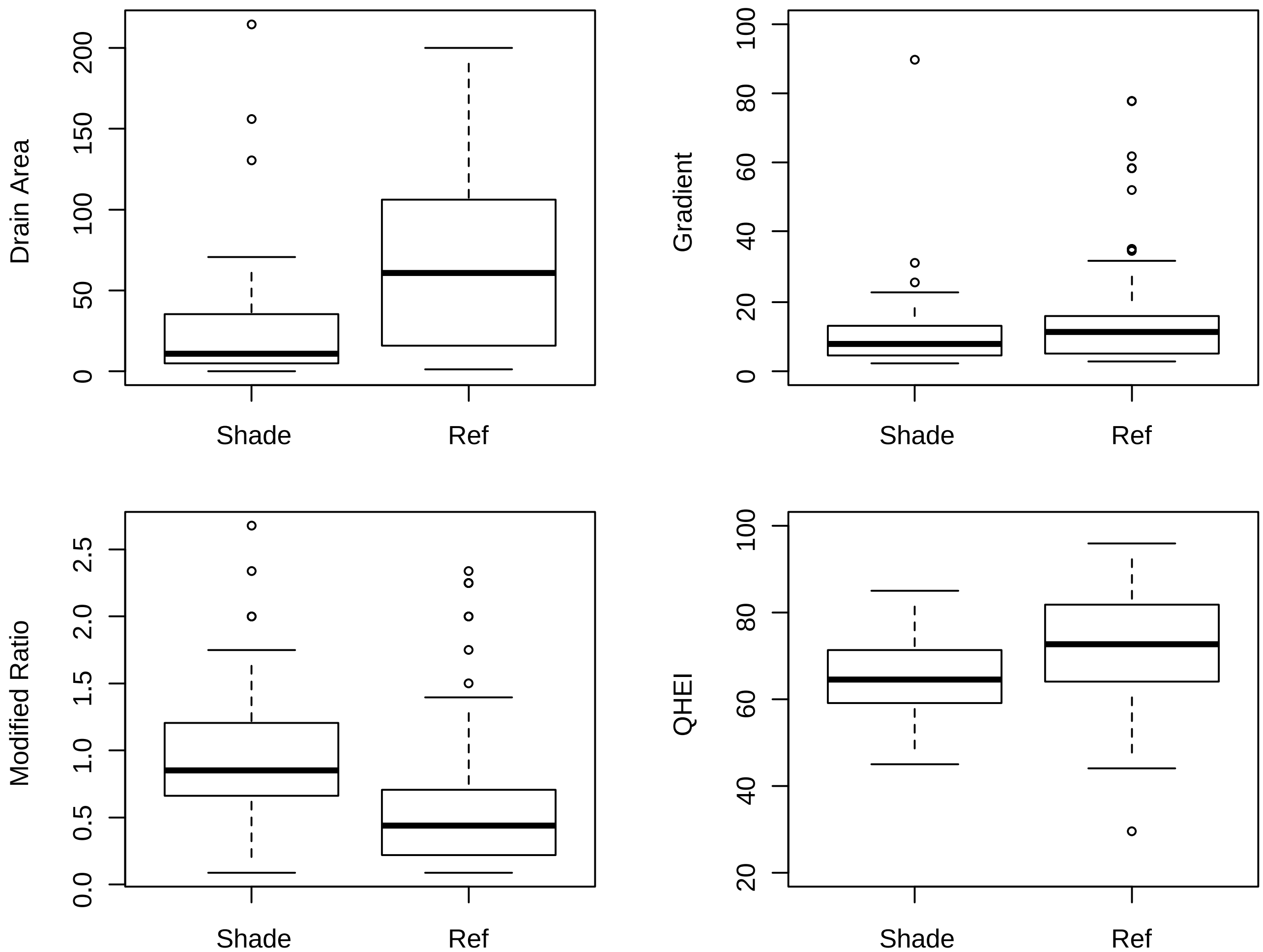

Figure 23 — Box and whisker plots showing distributions of drainage area (mi²), gradient (ft•mi⁻¹), the ratio of modified to warmwater habitat attributes, and QHEI scores from WAP reference sites and the Shade River study area.

Ironically, it is through the process of bank erosion that channel widening occurs, allowing for the formation of an active floodplain, defined channel features and eventual aggradation. The irony lies in the fact that this natural response invites efforts to combat erosion with rip-rapping and channelization, and other expensive measures that are counter-productive to restoring a stable geometry. Fortunately, few stream segments are channelized in the Shade system, and for those that are, all are noted as recovering. This includes segments that are obviously maintained as ditches such as Campaign Creek along Bulaville Pike (Figure 24). Note in Figure 24 that relatively complex channel features were recovered where a bend in the stream jump-started erosion. This example is fairly emblematic of what was observed at 15 other locations where recent or historic channelization was noted. These locations exhibit the near absence of modified attributes considered highly impacted (Table 6). Given enough time, and in the absence of either changes to the hydrology or significant habitat modifications, the system will move toward a better equilibrium between erosion and deposition, and that will result in generally improved biological conditions.

This describes the system as a whole, but variation within the system exists, with some streams and segments appearing more disturbed than others. The streams with the most sand entrained in their channels were Little Kyger Creek, Kyger Creek, Kingsbury Creek, Pratts Fork and Johns Run. The West Branch Shade River and an unnamed tributary to the West Branch (RM 16.35) also had notable amounts of entrained sand but had eroded and widened enough that the sand was not uniformly embedding the channel. On the other end of the spectrum, the streams least impacted by incision and sedimentation were Oldtown Creek, Forked Run, Dog Hollow Run and the East Branch Shade River.

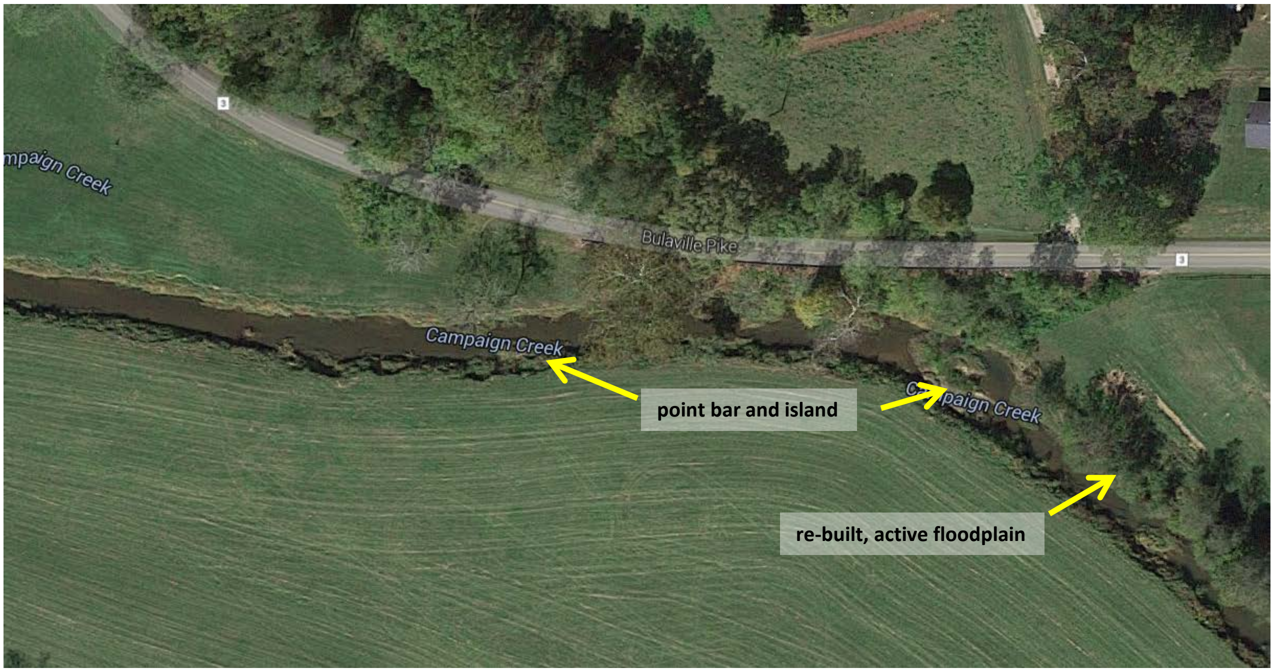

Figure 24 — An aerial photo of Campaign Creek adjacent to Bulaville Pike showing reformed channel features in a ditched segment.

Table 6 - QHEI attribute table for the SEORT study area, 2015.

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
Campaign Creek (09-051-000)																																			
W03K05	16.6	**59.8**	10.71	X	X				X		X	X		5						0	X				X	X			X			X	5	0.33	1.17
301794	11.5	**66.0**	6.67		X			X	X		X	X		5						0	X			X	X	X			X	X	X		7	0.33	1.50
301794	11.5	**72.8**	6.67	X	X		X	X	X			X		6						0		X							X	X	X		4	0.14	0.86
303029	6.3	**57.0**	2.90	X		X			X			X		4						0					X	X			X	X	X		5	0.20	1.40
W03S28	5.6	**58.5**	5.09	X				X	X			X		4						0		X			X				X	X	X		5	0.20	1.40
Little Campaign Creek (09-052-000)																																			
301795	0.4	**60.0**	15.69	X				X	X			X		4				X		1	X				X				X	X	X	X	6	0.60	1.60
303097	1.4	**63.5**	2.13	X	X		X	X	X			X		6				X		1		X			X				X	X	X	X	6	0.29	1.14
Little Whiteoak Creek (09-054-000)																																			
301796	0.2	**58.0**	13.16	X	X			X	X			X		5						0	X	X		X	X	X			X	X	X	X	9	0.33	1.83
Whiteoak Creek (09-055-000)																																			
303121	0.4	**72.0**	10.34	X	X		X	X	X		X	X		7						0				X					X	X	X	X	5	0.13	0.75
Kyger Creek (09-057-000)																																			
W03S13	8.4	**67.3**	9.22	X	X		X	X	X			X		6						0									X	X	X		3	0.14	0.71
300593	4.0	**71.3**	9.52	X			X	X	X			X		5						0									X	X	X		3	0.17	0.83
W03S26	1.0	**61.3**	1.50	X					X		X	X		4						0		X		X	X	X			X	X	X		7	0.20	1.80
Little Kyger Creek (09-058-000)																																			
W03P51	0.1	**69.8**	16.81	X			X	X	X			X		5						0									X	X	X		3	0.17	0.83
Forest Run (09-065-000)																																			
301805	1.1	**58.5**	21.30	X	X				X	X	X	X	X	7						0	X	X			X	X		X		X	X	X	8	0.25	1.13
Bowman Run (09-068-000)																																			
303117	0.4	**65.5**	6.00	X	X		X	X	X			X		6						0					X			X	X	X	X		5	0.14	1.00
Yellowbush Creek (09-071-000)																																			
W04W11	1.5	**60.8**	14.81	X	X				X		X	X	X	6						0					X	X		X	X			X	5	0.14	1.00
303120	0.9	**63.0**	1.67	X	X			X	X			X		5						0		X			X				X	X	X	X	6	0.17	1.17
Johns Run (09-075-000)																																			
303119	1.4	**45.3**	6.49	X								X		2				X		1		X			X	X		X	X	X		X	7	0.67	3.00
Oldtown Creek (09-079-000)																																			
303116	4.0	**77.8**	30.00	X	X		X	X	X	X	X	X	X	9						0											X		1	0.10	0.20
W04W12	1.7	**74.0**	10.70	X	X		X	X	X	X	X	X	X	9						0								X			X		2	0.10	0.40
Groundhog Creek (09-083-000)																																			
303115	2.3	**73.3**	11.67	X	X		X	X	X		X	X	X	8						0	X				X	X			X			X	5	0.22	0.67
Forked Run (09-091-000)																																			
303114	5.1	**79.3**	9.09	X	X	X	X	X	X		X	X	X	9						0									X				1	0.10	0.20
Shade River (09-600-000)																																			
W04S01	17.1	**74.3**	2.36	X	X		X	X	X			X	X	7						0									X	X			2	0.13	0.38

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
W04S02	11.6	85.0	6.17	X	X		X	X	X	X	X	X	X	9						0													0	0.10	0.10
609170	5.8	68.5	3.33	X					X			X		3						0		X	X		X	X			X	X	X		7	0.25	2.00
Horse Cave Creek (09-604-000)																																			
303112	4.9	78.0	11.11	X	X		X	X	X			X		6						0									X	X	X		3	0.14	0.57
W04S04	0.4	58.0	1.87	X					X		X	X		4						0	X				X	X			X	X	X		6	0.40	1.60
East Branch Shade River (09-610-000)																																			
W04K07	15.0	71.0	6.25	X	X			X	X			X	X	6						0					X				X	X	X		4	0.14	0.86
W04S08	11.8	66.0	1.34	X	X		X	X	X		X	X	X	8						0				X					X				2	0.11	0.44
303028	0.9	63.5	2.56	X	X			X	X			X		5						0					X				X	X	X		4	0.17	1.00
Dog Hollow (09-620-000)																																			
303113	2.5	64.0	30.00	X	X			X	X		X	X	X	7						0	X				X			X	X	X			5	0.25	0.88
Middle Branch Shade River (09-630-000)																																			
303105	28.2	66.3	24.30	X	X		X		X		X	X	X	7						0	X				X	X		X	X			X	6	0.25	0.88
303110	25.8	71.3	15.90	X	X		X	X	X		X	X	X	8						0					X				X			X	3	0.11	0.44
303106	22.5	62.0	2.70	X			X		X		X	X	X	6						0					X	X			X	X	X		5	0.14	1.00
W04K10	14.8	63.8	3.28	X			X	X	X			X		5						0		X			X	X			X	X	X		6	0.17	1.33
W04K09	8.1	69.3	3.45	X	X			X	X		X	X	X	7						0					X				X				2	0.13	0.38
W04S06	0.4	67.3	6.45	X	X		X	X	X			X	X	7						0	X				X	X			X	X	X		6	0.25	1.00
Pratts Fork (09-633-000)																																			
W04S09	0.0	48.0	14.00	X								X		2				X		1		X			X	X		X	X	X	X	X	8	0.67	3.33
Long Run (09-634-000)																																			
303109	1.4	71.3	16.67	X	X		X	X	X			X	X	7						0					X				X	X			3	0.13	0.63
Spring Branch (09-635-000)																																			
303345	0.6	54.5	88.80	X				X			X		X	4				X	X	2					X				X			X	3	0.60	1.00
West Branch Shade River (09-640-000)																																			
303104	16.5	59.3	9.50	X					X		X	X		4						0	X				X	X			X	X	X		6	0.40	1.60
303111	13.8	61.8	3.32	X			X	X	X			X		5						0					X				X	X	X		4	0.17	1.00
W04K11	7.8	51.8	4.62			X			X			X		3						0	X				X	X			X	X	X		6	0.50	2.00
W04S05	0.2	55.0	1.27	X					X			X		3						0					X	X			X	X	X		5	0.25	1.75
Trib. To West Branch Shade River (16.35) (09-640-001)																																			
303103	0.1	59.3	6.06	X		X		X	X			X		5						0	X				X				X	X	X		5	0.33	1.17
Kingsbury Creek (09-643-000)																																			
301809	6.8	46.5	4.54					X				X		2				X		1	X				X			X	X	X	X		6	1.00	2.67
W04S10	2.1	64.0	3.85	X					X			X	X	4						0	X	X			X	X			X	X			6	0.40	1.60
Dunfee Run (17-025-000)																																			
303102	1.4	64.0	7.14	X			X	X	X			X		5				X		1					X				X	X	X		4	0.33	1.00
Little Hocking River (17-900-000)																																			
303026	9.9	58.8	1.12	X				X	X			X		4				X		1		X			X				X	X	X		5	0.40	1.40
W04S15	5.6	69.5	6.00	X					X			X	X	4				X		1		X			X	X			X	X	X		6	0.40	1.60

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
Mile Run (Or Trib @ Rm 808.45) (17-900-001)																																			
303096	1.1	**70.8**	20.00	X	X			X	X			X		5				X		1		X			X				X	X	X		5	0.33	1.17
West Branch Little Hocking River (17-901-000)																																			
303100	8.7	**76.5**	9.53	X	X		X	X	X			X		6						0					X				X	X	X		4	0.14	0.86
303099	4.8	**70.8**	9.80	X	X			X	X			X		5						0					X				X	X	X		4	0.17	1.00
303027	2.9	**73.0**	1.28	X			X	X	X			X		5						0		X			X				X	X	X		5	0.17	1.17
Gilbert Run (17-903-000)																																			
303101	1.3	**76.8**	20.00	X	X			X	X		X	X	X	7						0					X				X	X	X	X	5	0.13	0.75
East Branch Little Hocking River (17-908-000)																																			
R19P03	0.0	**59.5**	11.76	X	X			X	X			X		5				X		1		X			X			X	X	X	X		6	0.33	1.33
Tupper Creek (17-910-000)																																			
303097	1.4	**63.5**	2.13	X	X		X	X	X			X		6				X		1		X			X				X	X	X	X	6	0.29	1.14

Biological Quality – Fish Assemblages

Overview

As noted in the previous section, the pervasive effects of channel incision on habitat should adversely affect biological assemblages in the Shade system relative to expectations drawn from the reference population. Indeed, when IBI scores from WAP reference sites are compared to IBI scores from the Shade system, the mean IBI (45.68 ± 0.91 SE) scores from the Shade River watershed average about 1.85 points lower than the reference population after adjusting for differences in drainage area and QHEI scores (Figure 25). Shade River sites that lay close to the lower 10th percentile of WAP reference condition (Figure 25) can be considered to deviate strongly from expectation based on existing habitat. These are the sites that are either influenced most strongly by incision or are affected by other stressors.

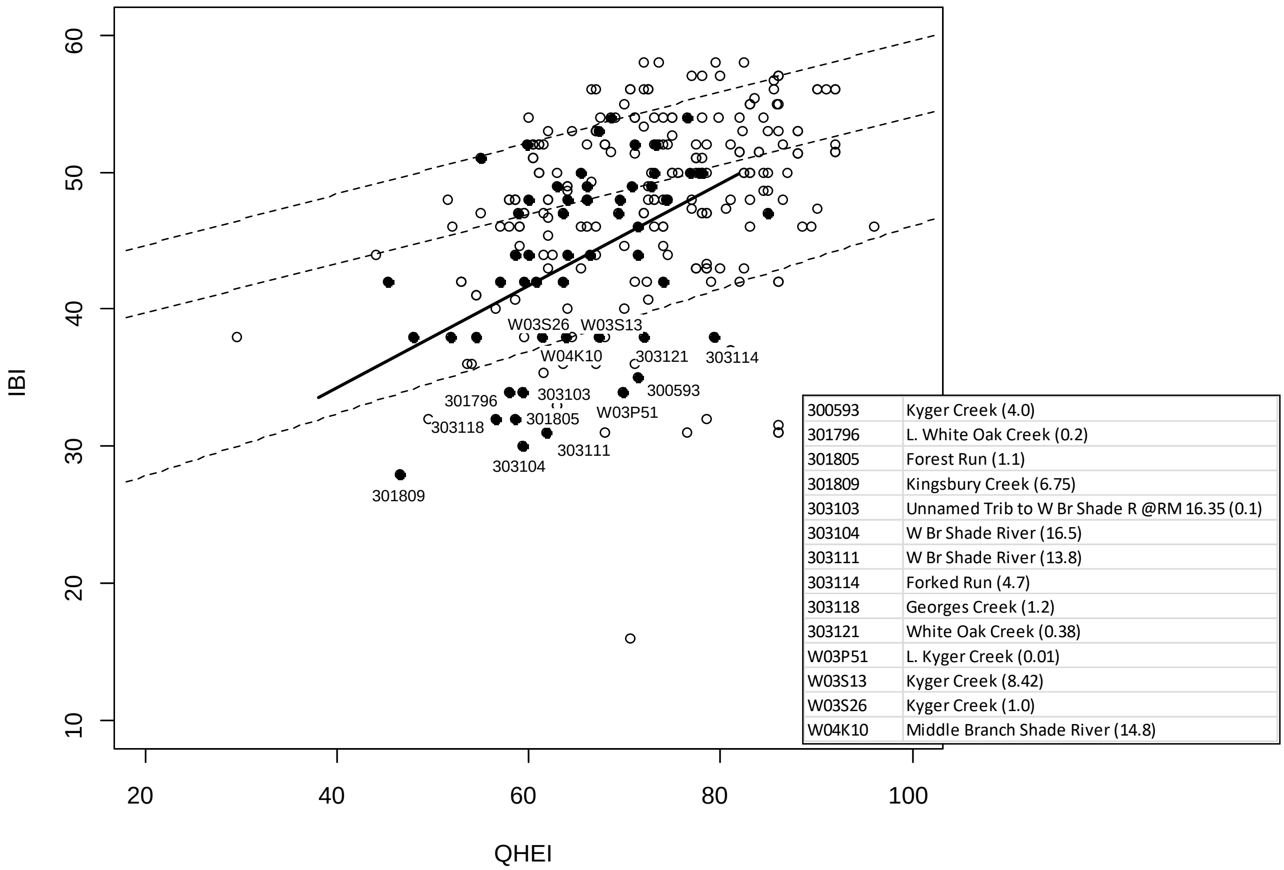

Figure 25 — Scatter plot showing the relationship between the QHEI and the IBI for WAP reference sites (hollow points) and SEORT survey sites (filled points). The solid black line is the fitted regression line for the Shade sites, the stippled lines are drawn from quantile regression at the 90th, 50th and 10th quantiles from reference sites.

Table 7 — Results from a regression of IBI scores on water quality variables. The model shown was chosen by all subset's regression based on the lowest Bayesian Information Criterion value for competing models.

	Estimate	SE	t	p	partial r
(Intercept)	65.177	11.411	5.712	<0.00001	
SO_4	-8.196	1.871	-4.380	0.00006	0.281
QHEI	0.252	0.092	2.742	0.00850	0.133

When other stressors are considered, as given by measured water quality parameters, habitat quality contributes less information relative to sulfate concentrations in predicting IBI scores from the Shade River. A linear combination of sulfate concentrations and QHEI scores explain about 38 percent of the variation in IBI scores, with the QHEI accounting for about 13 percent of the explained variance (Table 6).

Simple linear models derived from environmental data sets often provide an incomplete picture or can be misleading, given the high degree of collinearity typical of such sets. A more robust approach to examining environmental data sets is to simultaneously examine how an ordination of the biological assemblages relates to a matrix of environmental variables. For example, the plot in Figure 26 shows how sites relate to each other in ordination space based on compositional similarity, and how measured environmental variables correlate to the ordination axes. The ordination shown in Figure 26 is from non-metric multidimensional scaling (NMDS)[2] of a distance matrix of assemblage data formed from Bray-Curtis distances. Plot symbols were color-coded based on groups suggested by hierarchical cluster analysis[3] of the distance matrix. At first glance, the groups suggested by hierarchal clustering are generally positioned together in ordination space, indicating that results from the two methods are in agreement. Next, it is noticeable that several water quality parameters (total Kjeldahl nitrogen, manganese, sulfate, pH and alkalinity) define a dominant environmental gradient, both separating the groups and correlating them with IBI scores. Chloride forms a minor gradient. Lastly, the combination of drainage area and stream slope form an intuitively obvious gradient (large wadeable streams have different assemblages than small headwaters).

Given the results from all subsets regression analysis discussed previously, sulfate is less prominent in the ordination plot compared to TKN or manganese. However, sulfate does correlate well with both TKN and manganese, as indicated by the similar direction of the arrows. Table 7 shows the fit between various environmental parameters and the NMDS ordination. In Table 7, environmental parameters with similar vectors (the similar values listed under NMDS1 and NMDS2) would be strongly correlated with each other (for example, see Cu and Fe, the raw correlation between the two is 0.71).

Now that the dominant environmental gradients have been identified, it is also instructive to look at the distributions of the individual parameters comprised by those gradients within the groups suggested by cluster analysis (Figure 27). Groups 1 and 4 tend to contain sites with the lowest IBI scores, otherwise, IBI scores are fairly similar between groups. Group 1 tends to have high concentrations of manganese, TKN and sulfate (and COD, not shown, see Table 8), and low alkalinity and pH. Group 4 also tends toward higher concentrations of manganese and sulfate, and lower alkalinity and pH, but not to the degree of group 1. Group 4 sites were observed to be particularly incised and sandy.

[2] R development core team, vegan package 2.3-1 [(Oksanen, et al., 2017)]
[3] hclust function in the R base package {stats}; linkage method = ward.D2

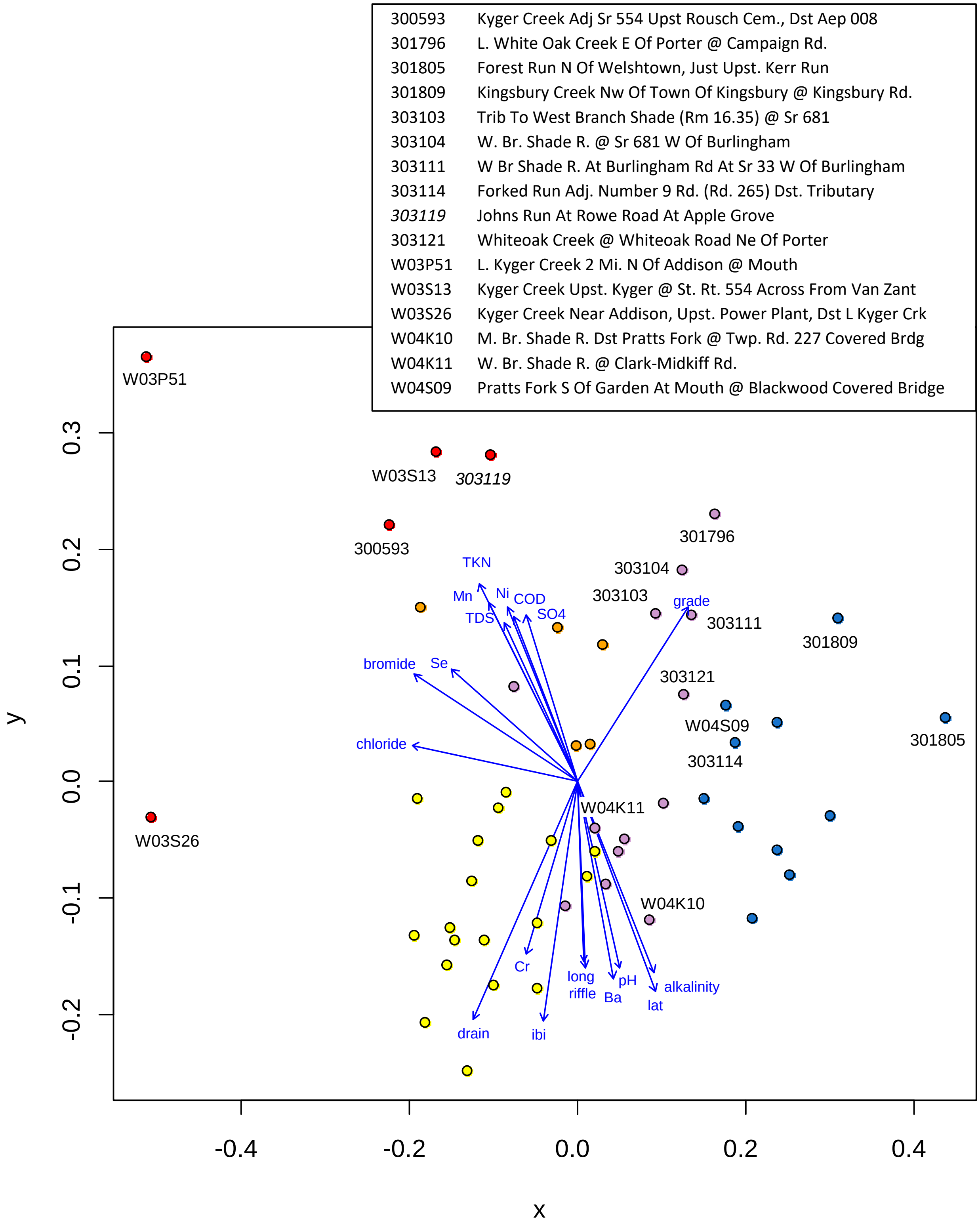

Figure 26 — A plot of SEORT area survey sites in ordination space as given by Nonmetric Multidimensional Scaling (NMDS). Plotted points are color-coded based on group membership suggested by hierarchical cluster analysis. Sites labeled with STORET station codes have IBI < 40 (Johns Run, 303119, has an IBI of 42). The blue arrows and associated environmental parameters show the correlation of the given parameter to the axes (chloride is correlated to the x-axis, IBI is correlated to the y-axis). The relative strength of the overall correlation is given by the length of the arrow.

Table 8 — Environmental parameters and their relationship with the ordination of fish assemblages from the SEORT survey. NMDS1 and NMDS2 correspond to the x and y axes in Figure 27, and the numbers (vectors) appearing under each show how a given environmental variable is aligned with each axis (the numbers are actually cosines); an absolute value close to 1 indicates that the parameter is highly aligned with the axis (the cosine of 0 and 180 is 1 and -1). Correlation coefficients (r2) show the total correlation between a given environmental variable and both axes (for example, for aluminum, correlation with NMDS1 is 0.024 and NMDS2 is 0.194). P-values have their usual interpretation.

	NMDS1	NMDS2	r2	Pr(>r)
Drain	-0.52038	-0.85393	0.5712	0.0010
Bromide	-0.90296	0.42972	0.4662	0.0010
IBI	-0.19957	-0.97988	0.4392	0.0010
TKN	-0.56696	0.82374	0.4310	0.0010
Lat	0.45805	-0.88893	0.4100	0.0010
Gradient	0.65713	0.75378	0.4018	0.0010
Chloride	-0.98723	0.15931	0.4016	0.0010
Alkalinity	0.48791	-0.87289	0.3537	0.0010
Mn	-0.56334	0.82623	0.3490	0.0010
TP	0.16869	-0.98567	0.3229	0.0010
Ba	0.24636	-0.96918	0.3062	0.0010
Ni	-0.48409	0.87502	0.2953	0.0010
pH	0.29573	-0.95527	0.2837	0.0010
Cr	-0.38085	-0.92464	0.2592	0.0010
Pool	-0.61833	-0.78592	0.2581	0.0010
Long	0.04978	-0.99876	0.2416	0.0010
Se	-0.84039	0.54199	0.3215	0.0020
TDS	-0.53727	0.84341	0.2644	0.0020
COD	-0.46651	0.88451	0.2614	0.0020
Riffle	0.05754	-0.99834	0.2566	0.0020
TSS	-0.24677	-0.96907	0.2302	0.0020
TempC	-0.91497	-0.40353	0.2283	0.0020
Cu	-0.78794	-0.61575	0.2204	0.0020
Sulfate	-0.39805	0.91737	0.2449	0.0030
Pb	-0.70837	-0.70584	0.2390	0.0030
Na	-0.80227	0.59696	0.2343	0.0030
Zn	-0.90187	-0.43201	0.2277	0.0030
DO	0.36688	0.93027	0.1804	0.0040
Al	-0.27965	-0.96010	0.2161	0.0050
Sp. Cond	-0.63583	0.77183	0.2031	0.0050
Mg	-0.53854	0.84260	0.1871	0.0100
K	-0.93553	0.35326	0.1930	0.0140
DOsat	0.23097	0.97296	0.1450	0.0210
As	-0.80978	-0.58674	0.1435	0.0260
Fe	-0.84403	-0.53629	0.1383	0.0260
Hardness	-0.54537	0.83819	0.1485	0.0280
Cover	-0.57339	-0.81928	0.1312	0.0320
Sr	-0.73659	0.67634	0.1210	0.0480
Ca	-0.55413	0.83243	0.1203	0.0549
NH3	-0.25581	0.96673	0.1044	0.0769
Acidity	0.44773	-0.89417	0.0753	0.1299
QHEI	-0.19145	-0.98150	0.0709	0.1578
Cd	-0.99911	-0.04220	0.0675	0.1838
Channel	-0.71848	-0.69554	0.0453	0.3347
Substrate	0.9010	-0.43382	0.0440	0.3516
NOx	-0.58878	-0.80829	0.0392	0.3696
NO2	0.65723	0.75369	0.0154	0.6983
Riparian	-0.03285	-0.99946	0.0031	0.9251

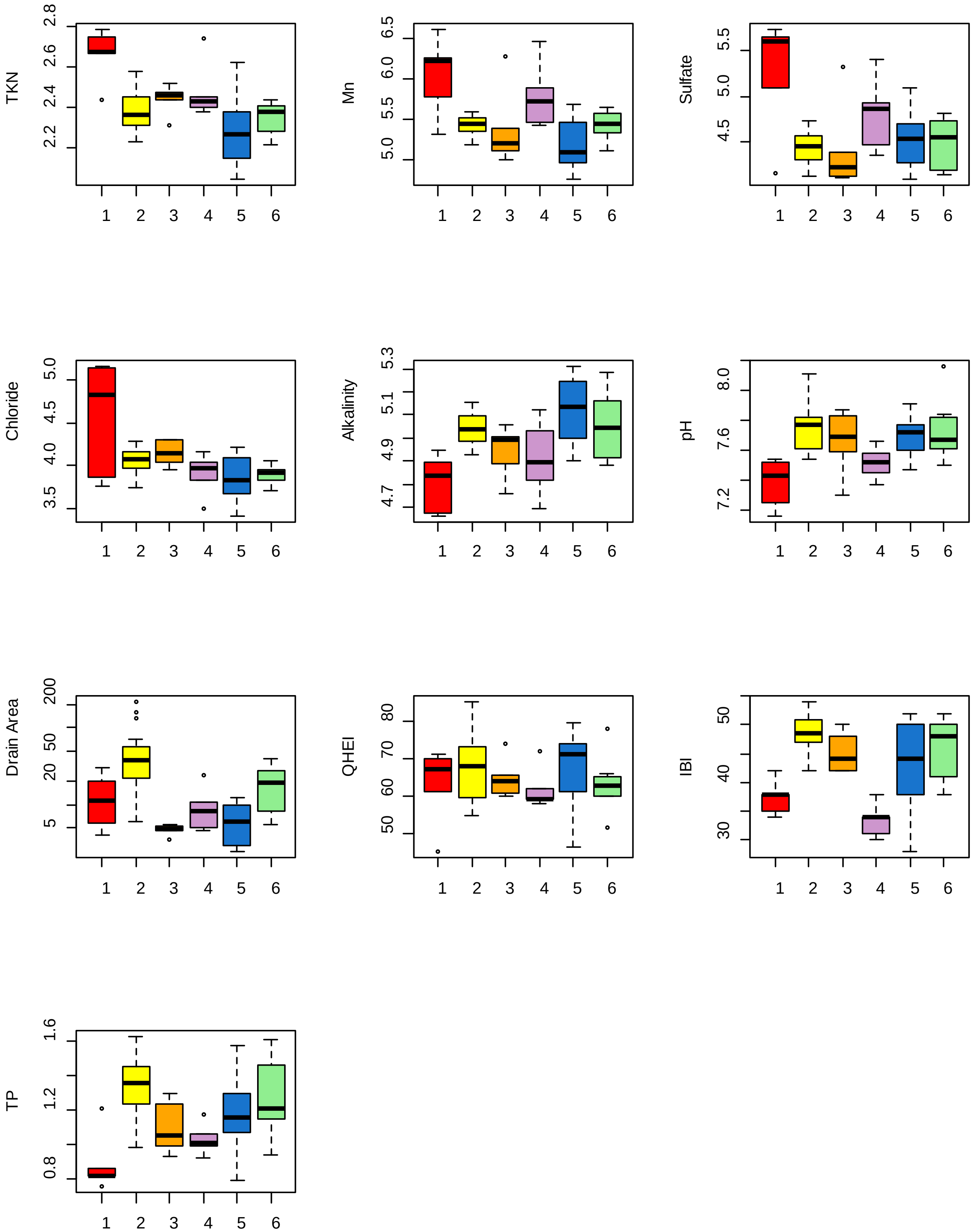

Figure 27 — Distributions of selected environmental variables within groups suggested by hierarchical cluster analysis. With the exception of the QHEI and IBI, Y-axis scales are log units.

Table 9 — Sites sampled from the SEORT survey area arranged by groups identified through ordination. Cells containing IBI scores failing the biocriterion of 44 are shaded yellow, and those within the four-point range of non-significant departure are shaded gray.

River	STATION	IBI	QHEI	Mn (µg/L)	SO_4 (mg/L)	Alkalinity (mg/L)	Comment, Cause or Stressor
Group One							
Johns Run	303119	42	45.3	206	14	78	
Kyger Creek	W03S13	38	67.3	603	122	89	Incision; non-acidic mine drainage
Kyger Creek	300593	35	71.3	1,682	468	45	Non-acidic mine drainage
Kyger Creek	W03S26	38	61.3	1,813	400	46	Non-acidic mine drainage
Little Kyger Creek	W03P51	34	69.8	3,921	535	68	Non-acidic mine drainage
Group Two							
Campaign Creek	W03K05	52	59.8	251	27	126	
Campaign Creek	301794	50	66.0	228	20	125	
Campaign Creek	303029	42	57.0	336	54	110	
East Branch Shade River	W04S08	48	66.0	350	16	192	
Horse Cave Creek	303112	50	78.0	200	14	77	
Horse Cave Creek	W04S04	48	60.0	448	15	80	
Kingsbury Creek	W04S10	44	64.0	399	46	97	
Middle Branch Shade River	303106	50	62.0	126	65	146	
Middle Branch Shade River	W04K10	38	63.8	230	48	144	Incision
West Branch Shade River	W04K11	38	51.8	291	61	86	Incision
Group Three							
Bowman Run	303117	50	65.5	100	16	101	
Dunfee Run	303102	48	64.0	126	13	78	
Groundhog Creek	303115	52	73.3	150	13	94	
Little Campaign Creek	301795	44	60.0	1,835	213	57	Non-acidic mine drainage; IBI inflated by transients
Oldtown Creek	W04W12	42	74.0	238	13	114	
Yellowbush Creek	W04W11	42	60.8	161	24	98	
Yellowbush Creek	303120	49	62.5	258	36	108	
Group Four							
Forked Run	303114	42	79.3	88	12	80	
Little Whiteoak Creek	301796	34	58.0	2,795	250	49	Livestock (organic enrichment); Incision; non-acidic mine drainage
Pratts Fork	W04S09	38	48.0	415	37	142	Incision
Trib. to W. Br. Shade (16.35)	303103	34	59.3	260	22	108	Incision
West Branch Shade River	303104	30	59.3	754	71	66	Incision; non-acidic mine drainage
West Branch Shade River	303111	31	61.8	531	84	79	Incision
Whiteoak Creek	303121	38	72.0	290	30	132	Livestock (organic enrichment)
Group Five							
Dog Hollow	303113	50	64.0	86	18	205	
East Branch Shade River	W04K07	52	71.0	179	19	186	
Forest Run	301805	38	58.5	471	110	137	Very small drainage area
Gilbert Run	303101	50	76.8	98	34	108	
Kingsbury Creek	301809	28	46.5	417	65	92	Incision
Long Run	303109	46	71.3	110	124	133	
Middle Branch Shade River	303105	44	66.3	57	34	173	
Middle Branch Shade River	303110	44	71.3	201	30	177	

River	STATION	IBI	QHEI	Mn (µg/L)	SO_4 (mg/L)	Alkalinity (mg/L)	Comment, Cause or Stressor
Oldtown Creek	303116	50	77.8	121	15	87	
Group Six							
East Branch Little Hocking	R19P03	42	59.5	247	27	135	
East Branch Shade River	303028	47	63.5	210	17	142	
Little Hocking River	303026	47	58.8	394	20	119	
Little Hocking River	W04S15	48	69.5	334	19	109	
Middle Branch Shade River	W04K09	43	69.3	204	36	143	
Middle Branch Shade River	W04S06	53	67.3	357	32	139	
Shade River	W04S01	46	74.3	289	40	108	
Shade River	W04S02	43	85.0	353	36	102	
Shade River	609170	54	68.5	320	29	97	
West Branch Little Hocking	303100	54	76.5	243	23	98	
West Branch Little Hocking	303099	49	70.8	198	22	94	
West Branch Little Hocking	303027	50	73.0	270	22	97	
West Branch Shade River	W04S05	51	55.0	227	47	85	

High manganese and sulfate concentrations and low pH are characteristic of mine drainage (Johnson, 2003). Also, of note is the relationship between TKN and TP, which is the inverse of what is typically observed; TKN and TP are usually tightly and positively correlated. Note that the absolute concentrations of TP are quite low across all the groups (the max value on the y-axis is 0.039 mg/L). What is telling about this is that the high TKN (and COD) concentrations may be a product of the organic substrates used in non-acidic mine drainage treatment, and the vanishingly small concentrations of TP in group 1 may reflect phosphorus limitation within the organic substrates or chemical precipitation (Kalin, Fyson, & Wheeler, 2006).

The other dominant gradient is drainage area, which helps explain the formation of groups 2, 5 and 6. Group 2 is made up of larger drainage area sites from the lower Shade River and the Little Hocking (Figure 28), group 6 consists of larger, more alkaline headwaters, and group 5 is smaller with more alkaline headwaters (< ~10 mi^2). Group 3 can be described as headwaters with assemblages influenced by the Ohio River. This is especially true given the presence of emerald shiners. When comparing the distribution of environmental parameters within group 3, one site had elevated manganese and sulfate concentrations, along with low pH and alkalinity (Figure 27). That site (Little Campaign Creek [301795]), is likely influenced by mine drainage. If the obvious Ohio River transient species are excluded, the IBI score from the site would drop 12 points, and the assemblage would more closely resemble those from group 4. Eliminating the obvious transients from the other four sites in group 3 has a smaller effect on IBI scores, decreasing the IBI scores by a range of two to six points. These findings do not suggest that these transient species should be excluded from calculations, rather they demonstrate that the IBI scores as reported are not simply taken at face value; they are interpreted considering available information.

In summary, mine drainage appears to be an immediate limiting stressor for several streams in the survey area, especially those draining northeastern Gallia County and western Meigs County where the underlying bedrock originates from the coal-bearing Conemaugh Group. Beyond being detrimental to the system, channel incision and sediment entrainment appeared to be the most proximate stressors affecting several streams, notably Kingsbury Creek and the West Branch Shade River. Clearly, at sites where mine drainage appeared to be the most proximate stressor, incision and sedimentation was a co-stressor. Similarly, mine drainage appeared to be a co-stressor at three of the sites where incision seemed to be the most proximate stress. Table 8 lists all the sites from the Shade River area survey arranged by cluster group, along with a brief narrative description of stressors impacting sites failing to meet IBI biocriterion for the WAP ecoregion.

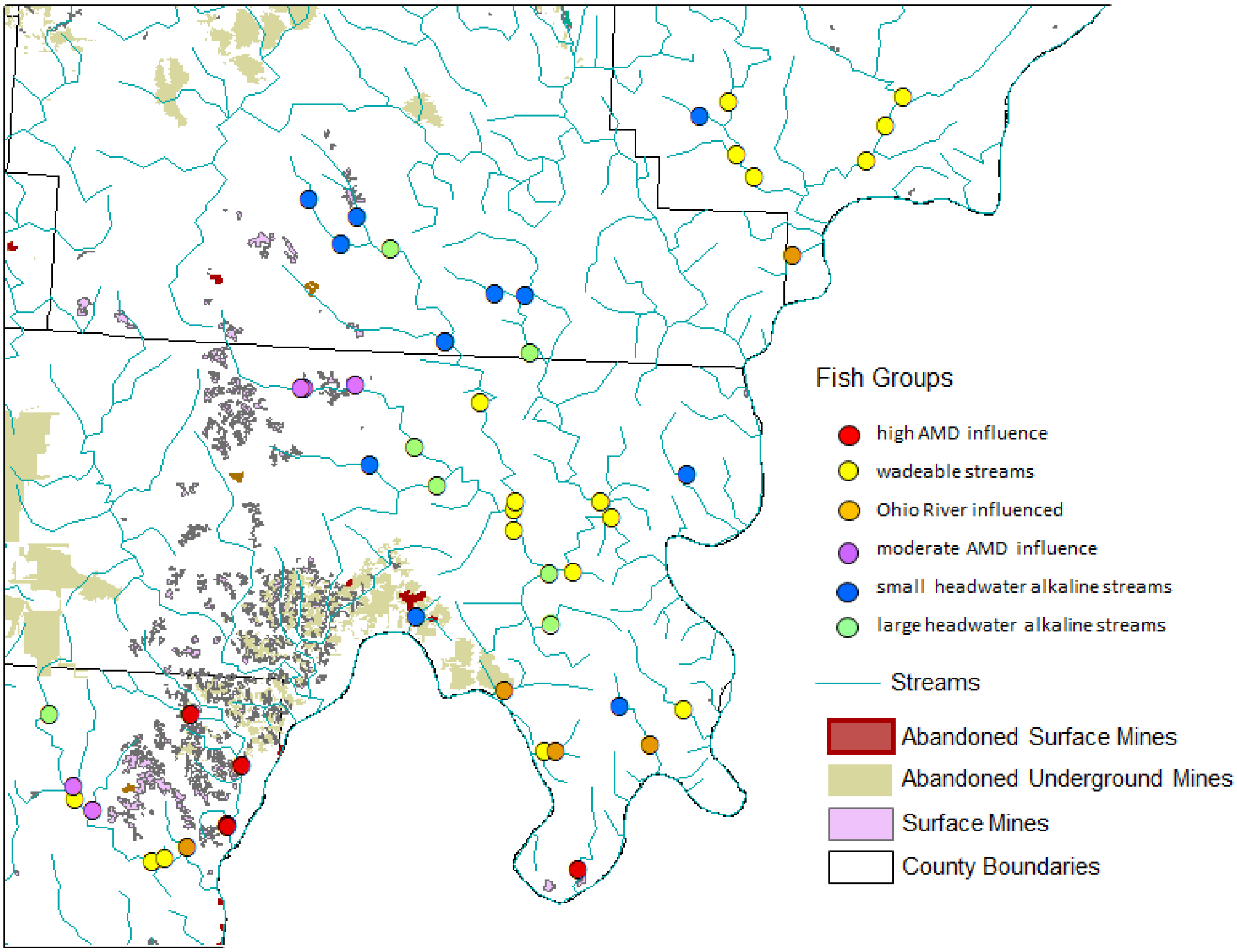

Figure 28 — Sites sampled from the SEORT survey area color-coded by groups identified via ordination. A narrative descriptor for each group is shown in the accompanying legend.

Biological Quality – Macroinvertebrate Assemblages

Overview

Macroinvertebrate assemblages were sampled from 55 locations in the Shade River survey area, and most of the samples were rated as meeting applicable or recommended standards for aquatic life use. For the seven sites that fell short, mine drainage was the primary cause of impairment at four sites and a contributing cause at one site (W04S09 Pratts Fork). For this latter site, the primary cause was most likely sedimentation. Otherwise, one site was limited by sediment deposition and another by organic enrichment from livestock; both with no other apparent stressors.

When binned by groups identified through hierarchical clustering of the macroinvertebrate assemblages (Figure 29), concentrations of water quality indicators showed clear patterns largely analogous to those identified by the fish assemblages. Group 1 represents medium-sized headwaters and small wadeable streams influenced strongly by mine drainage and containing compromised macroinvertebrate assemblages. Group 2 represents medium-sized headwaters and small wadeable streams with generally unperturbed water quality and good biology. The third group represents less alkaline headwaters with elevated levels of mine drainage indicators, and generally marginal or worse biology. The fourth group is formed by larger streams with generally intact biology and unperturbed water quality. And the fifth group represents small, alkaline headwaters with coarser substrates and macroinvertebrate assemblages rated as good to excellent. Table 9 lists all the macroinvertebrate sites arranged by groups identified via hierarchical clustering. Table 10 lists sites arranged by stream name and provides summary information about the macroinvertebrate assemblage found at each site. Figure 30 reveals how the sites are arranged geographically in relation to active or historically mined areas.

Although sites within groups identified by hierarchical clustering were generally positioned together in ordination space (from nonmetric multidimensional scaling) as shown in Figure 31, one site sampled from Pratts Fork (W04S09) appears as an anomaly. This site is positioned away from the yellow and green groups, but along a third axis not shown. No water quality indicator is associated with that third axis. Based solely on water quality, Pratts Fork had elevated levels of mine drainage indicators, and was clearly impacted by excessive sedimentation.

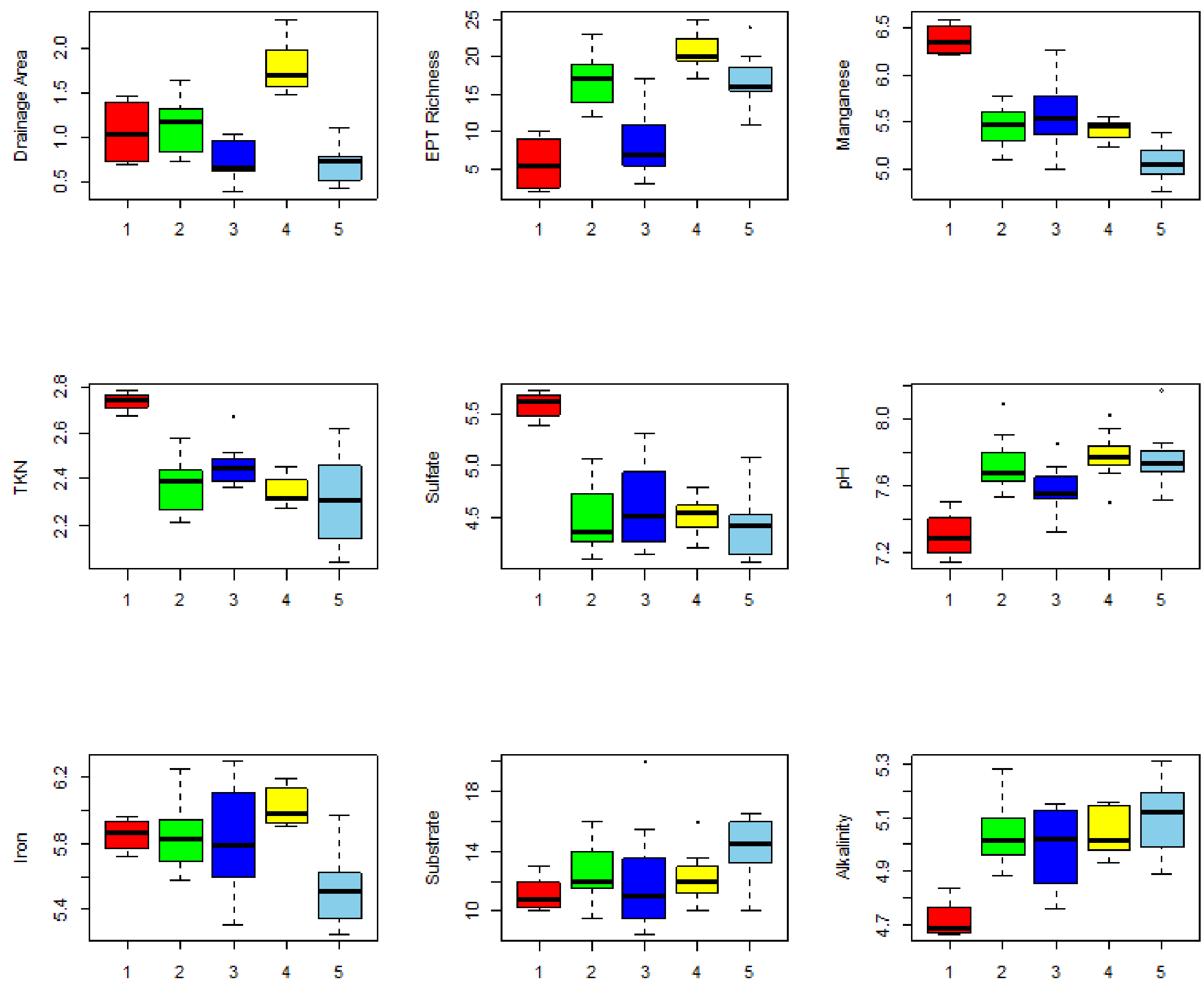

Figure 29 — Distributions of water quality indicators stratified by groups identified via hierarchical clustering. All y-axes are log10 µg/L except for drainage area, EPT richness and pH.

Table 10 — Macroinvertebrate sampling sites arranged by groups identified via hierarchical clustering.

Station Number	River code	RM	River	EPT	pICI	Quality Rating	Comments
Mine drainage							
301796	09-054-000	0.33	Little Whiteoak Creek	3	23.80	P	High levels of manganese, sulfate and TKN
300593	09-057-000	4.00	Kyger Creek	8	33.87	E	
W03S26	09-057-000	1.00	Kyger Creek	10	37.00	MG	
W03P51	09-058-000	0.01	Little Kyger Creek	2	17.83	P	
Alkaline headwaters and smaller wadeable streams							
W03K05	09-051-000	16.60	Campaign Creek	18	44.63	VG	
301794	09-051-000	11.50	Campaign Creek	16	44.84	VG	
303029	09-051-000	6.25	Campaign Creek	13	43.07	G	
W03S13	09-057-000	8.42	Kyger Creek	14	43.28	G	
W04W11	09-071-000	1.48	Yellowbush Creek	12	40.80	MG	
303120	09-071-000	0.85	Yellowbush Creek	13	43.18	G	
303115	09-083-000	2.30	Groundhog Creek	17	45.38	VG	
303112	09-604-000	4.88	Horse Cave Creek	17	45.37	VG	
W04S04	09-604-000	0.35	Horse Cave Creek	15	44.36	G	
W04K07	09-610-000	15.00	East Branch Shade River	17	44.84	VG	
W04S08	09-610-000	11.84	East Branch Shade River	23	47.42	E	
303106	09-630-000	22.50	Middle Branch Shade River	14	43.42	G	
303111	09-640-000	13.80	West Branch Shade River	17	45.45	G	
301809	09-643-000	6.75	Kingsbury Creek	19	46.10	E	
W04S10	09-643-000	2.08	Kingsbury Creek	18	46.36	VG	
303026	17-900-000	9.89	Little Hocking River	20	47.05	E	
W04S15	17-900-000	7.55	Little Hocking River	22	47.54	E	
303100	17-901-000	8.70	West Branch Little Hocking River	23	47.24	E	
Small headwaters, mixed stress							
301795	09-052-000	0.37	Little Campaign Creek	5	26.70	LF	Mine drainage
303121	09-055-000	0.38	Whiteoak Creek	3	19.32	P	Organic enrichment
301805	09-065-000	1.10	Forest Run	6	31.76	F	Mine drainage
303117	09-068-000	0.42	Bowman Run	7	34.09	MG	
303119	09-075-000	1.40	Johns Run	7	33.17	F	Sediment
W04S09	09-633-000	0.02	Pratts Fork	8	32.44	F	Sediment, mine drainage
303104	09-640-000	16.50	West Branch Shade River	17	45.66	VG	
303103	09-640-001	0.10	Trib. to West Branch Shade River (16.35)	14	43.72	G	
Larger streams, intact water quality							
W04S01	09-600-000	17.13	Shade River	22	48.81	E	
W04S02	09-600-000	11.64	Shade River	19	48.25	E	
609170	09-600-000	5.84	Shade River	20	48.00	E	
303028	09-610-000	0.87	East Branch Shade River	21	47.09	E	
W04K10	09-630-000	14.80	Middle Branch Shade River	25	47.68	E	
W04K09	09-630-000	8.10	Middle Branch Shade River	20	47.19	E	
W04S06	09-630-000	0.42	Middle Branch Shade River	23	48.41	E	
W04K11	09-640-000	7.80	West Branch Shade River	19	46.42	VG	
W04S05	09-640-000	0.16	West Branch Shade River	23	48.09	E	
303099	17-901-000	4.80	West Branch Little Hocking River	17	46.12	VG	
303027	17-901-000	2.87	West Branch Little Hocking River	20	46.80	VG	

Station Number	River code	RM	River	EPT	pICI	Quality Rating	Comments
Small, alkaline headwaters							
303116	09-079-000	4.00	Oldtown Creek	18	46.02	VG	
W04W12	09-079-000	1.65	Oldtown Creek	16	43.93	VG	
303114	09-091-000	4.72	Forked Run	24	46.81	E	
303113	09-620-000	2.50	Dog Hollow	16	43.87	VG	
303105	09-630-000	28.20	Middle Branch Shade River	11	37.84	MG	
303110	09-630-000	25.80	Middle Branch Shade River	19	45.26	E	
303109	09-634-000	1.40	Long Run	16	44.58	VG	
303102	17-025-000	1.40	Dunfee Run	20	47.08	E	
303096	17-900-001	1.10	Mile Run (OR trib at RM 808.45)	15	44.26	VG	
303101	17-903-000	1.30	Gilbert Run	15	44.70	VG	
R19P03	17-908-000	0.01	East Branch Little Hocking River	16	45.99	VG	

Table 11 — Summary of macroinvertebrate data collected from artificial substrates (quantitative sampling) and natural substrates (qualitative sampling) in the SEORT study area, June to October 2015.

Stream RM	Drainage Area (mi^2)	Qual. Taxa	EPT Ql/ Total	Sensitive Taxa Ql/ Total	Density Ql/Qt	Cold-water Taxa	Predominant Organisms on the Natural Substrates	ICI	Narrative Evaluation
Campaign Creek (09-051-000)									
16.60	6.8	43	18	16	M-L	2	Chimarra caddisflies; hydropsychid caddisflies; stoneflies	-	Very Good
11.50	21.7	57	16/21	13/18	M-L	2	*Isonychia* mayflies; hydropsychid caddisflies	48	
6.25	35.4	49	13	11	M-L	0	*Isonychia* mayflies; hydropsychid caddisflies; blackflies	-	Good
5.56	37.0	43	11/15	9/13	M-L	1	Hydropsychid caddisflies; midges; *Isonychia* mayflies	50	
Little Campaign Creek (09-052-000)									
0.37	4.7	20	5	2	L	1	*Hexatoma* craneflies	-	Low Fair
Little White Oak Creek (09-054-000)									
0.33	5.1	15	3	0	M-L	0	Hydropsychid caddisflies	-	Poor
White Oak Creek (09-055-000)									
0.38	4.7	26	3	0	L	0	Stenelmis beetles	-	Poor
Kyger Creek (09-057-000)									
8.42	11.5	38	14	11	L	0	Hydropsychid caddisflies; blackflies	-	Good
4.00	20.3	31	8/12	5/9	L	0	Hydropsychid caddisflies	46	
1.00	30.1	43	10	8	M-L	0	Hydropsychid caddisflies; *Neuroclipsis* caddisflies	-	Marginally Good
Little Kyger Creek (09-058-000)									
0.01	5.8	20	2	1	L	0	Hydropsychid caddisflies	-	Poor
Forest Run (09-065-000)									
1.10	2.5	34	6	2	L	3	Baetid mayflies; hydropsychid caddisflies	-	Fair
Bowman Run (09-068-000)									
0.42	4.9	25	7	6	L	0	Midges	-	Marginal
Yellowbush Creek (09-071-000)									
1.50	5.5	49	12	8	M	0	Hydropsychid caddisflies	-	Marginally Good
0.85	7.0	46	13	9	M	0	Hydropsychid caddisflies; baetid mayflies	-	Good
Johns Run (09-075-000)									
1.40	4.1	33	7	6	L	0	Midges	-	Fair
Oldtown Creek (09-079-000)									
4.00	2.7	60	18	18	M	4	Hydropsychid caddisflies; baetid mayflies; midges	-	Very Good
1.65	5.4	47	16	10	M-L	3	Hydropsychid caddisflies; heptageniid mayflies	-	Very Good
Groundhog Creek (09-083-000)									
2.30	6.2	53	17	12	M	0	Hydropsychid caddisflies; heptageniid mayflies	-	Very Good
Forked Run (09-091-000)									
4.70	6.1	51	24	17	M	1	Stoneflies; riffle beetles	-	Exceptional
Shade River (09-600-000)									

Stream RM	Drainage Area (mi^2)	Qual. Taxa	EPT Ql/ Total	Sensitive Taxa Ql/ Total	Density Ql/Qt	Cold-water Taxa	Predominant Organisms on the Natural Substrates	ICI	Narrative Evaluation
17.13	131.0	61	22 /25	20/21	H	0	Hydropsychid caddisflies; *Chimarra* caddisflies; *Isonychia* mayflies	44	
11.64	156.0	59	19/23	20/24	H	0	Hydropsychid caddisflies; heptageniid mayflies; *Isonychia* mayflies	42	
5.84	215.0	54	20/24	16/20	H	0	Heptageniid mayflies; hydropsychid caddisflies	52	
Horse Cave Creek (09-604-000)									
4.88	5.5	50	17	15	M	3	Hydropsychid caddisflies; heptageniid mayflies	-	Very Good
0.35	9.8	50	15	13	M	2	Hydropsychid caddisflies	-	Good
East Branch Shade River (09-610-000)									
15.00	10.4	51	17	11	H-M	1	Baetid mayflies; heptageniid mayflies	-	Very Good
11.84	18.6	54	23	17	H	1	Baetid mayflies; heptageniid mayflies	-	Exceptional
0.87	45.0	53	21/24	18/21	M	0	Hydropsychid caddisflies; Heptageniid mayflies	50	
Dog Hollow (09-620-000)									
2.50	3.1	41	16	11	M	2	Stoneflies; heptageniid mayflies	-	Very Good
Middle Branch Shade River (09-630-000)									
28.20	2.8	23	11	5	M-L	1	Beetles; stoneflies; hydropsychid caddisflies	-	Marginally Good
25.80	9.1	44	19	13	L	1	Baetid mayflies; heptageniid mayflies	-	Exceptional
22.50	20.3	52	14/15	12/12	L	1	Midges	42	
14.80	40.1	63	25	24	M	1	Midges; Isonychia mayflies; hydropsychid caddisflies	-	Exceptional
8.10	49.7	50	20	14	H	1	Hydropsychid caddisflies	-	Exceptional
0.42	57.5	70	23/26	16/19	H-M	1	Midges; *Isonychia* mayflies; heptageniid mayflies	46	
Pratts Fork (09-633-000)									
0.02	10.8	25	8	4	L	0	Heptageniid mayflies; hydropsychid caddisflies	-	Fair
Long Run (09-634-000)									
1.40	4.5	39	16	11	L	1	Hydropsychid caddisflies; riffle beetles	-	Very Good
West Branch Shade River (09-640-000)									
16.50	10.9	46	17	16	M	1	Baetid mayflies; black flies	-	Very Good
13.80	24.0	47	17/19	12/16	M	1	Hydropsychid caddisflies; *Isonychia* mayflies	38	
7.80	36.0	49	19/21		M	0	Hydropsychid caddisflies	40	
0.16	71.0	64	23/24	21/22	M-L	0	Midges; heptageniid mayflies	54	
Unnamed Trib to West Branch Shade River (09-640-001)									
0.10	8.3	45	14	10	H-M	0	Baetid mayflies	-	Good
Kingsbury Creek (09-643-000)									
6.75	12.2	43	19	16	H-M	1	Heptageniid mayflies; *Chimarra* caddisflies; *Isonychia* mayflies	-	Exceptional
2.08	19.7	40	18	14	M	1	Heptageniid mayflies; hydropsychid caddisflies	-	Very Good

Stream RM	Drainage Area (mi^2)	Qual. Taxa	EPT Ql/ Total	Sensitive Taxa Ql/ Total	Density Ql/Qt	Cold-water Taxa	Predominant Organisms on the Natural Substrates	ICI	Narrative Evaluation
Dunfee Run (Whites Run) (17-025-000)									
1.40	3.5	55	20	19	L	4	Hydropsychid caddisflies; heptageniid mayflies; baetid mayflies		Exceptional
Little Hocking River (17-900-000)									
15.20	7.7	52	23	13	M	2	Hydropsychid caddisflies; baetid mayflies	-	Exceptional
9.89	37.5	61	20	12	M	0	Hydropsychid caddisflies; baetid mayflies; midges	-	Exceptional
7.55	45.0	62	22	22	H	1	Hydropsychid caddisflies; baetid mayflies; heptageniid mayflies	-	Exceptional
Mile Run (17-900-001)									
1.10	5.5	48	15	19	H-M	1	Hydropsychid caddisflies; baetid mayflies	-	Good
West Branch Little Hocking River (17-901-000)									
8.70	19.9	54	23	18	H-M	1	Hydropsychid caddisflies; heptageniid mayflies; baetid mayflies	-	Exceptional
4.80	30.3	45	17/17	15/15	H	0	Hydropsychid caddisflies; *Chimarra* caddisflies	42	
2.87	37.5	53	20/21	14/16	H	0	Hydropsychid caddisflies; *Baetisca* mayflies	48	
Gilbert Run (17-903-000)									
1.30	6.2	43	15	17	L	1	*Leuctra* stoneflies; heptageniid and baetid mayflies; hydropsychid and *Chimarra* caddisflies		Good
East Branch Little Hocking River (17-908-000)									
0.01	13.0	44	16	13	L	0	Midges; baetid mayflies; heptageniid mayflies	-	Very Good
Tupper Creek (17-910-000)									
1.42	8.3	51	18	11	M-L	0	Hydropsychid caddisflies; midges; baetid and heptageniid mayflies	-	Very Good

RM: River mile.
Ql: Qualitative sample collected from the natural substrates.
Sensitive Taxa: Taxa listed on Ohio EPA's Macroinvertebrate Taxa List as MI (moderately intolerant) or I (intolerant).
Qt: Quantitative sample collected on Hester-Dendy artificial substrates, density is expressed in organisms per square foot.
Qualitative sample relative density: L=low; M=moderate; H=high.

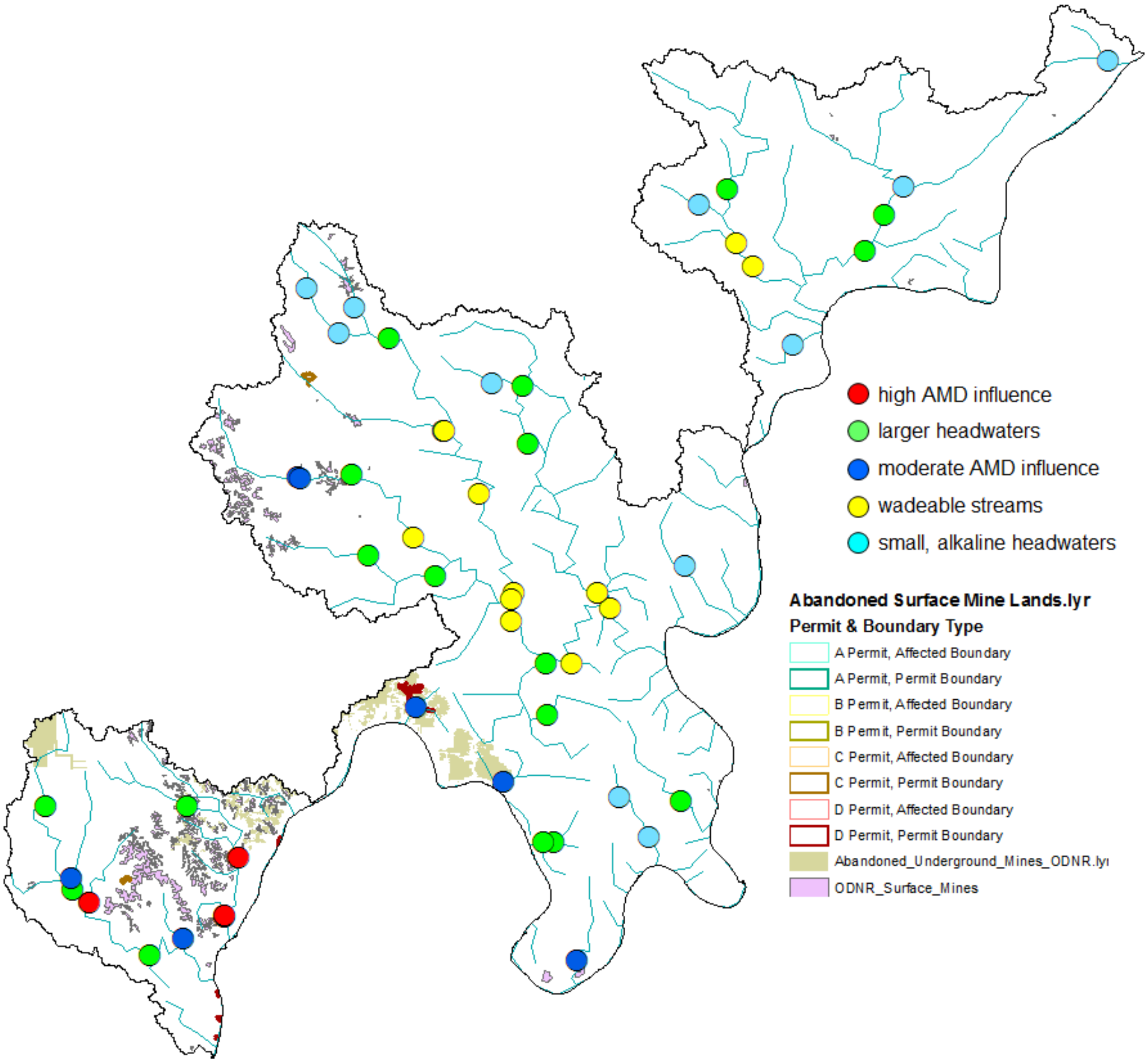

Figure 30 — Macroinvertebrate sites sampled in the SEORT survey area, 2015. Sites are color-coded based on groups identified via hierarchical clustering.

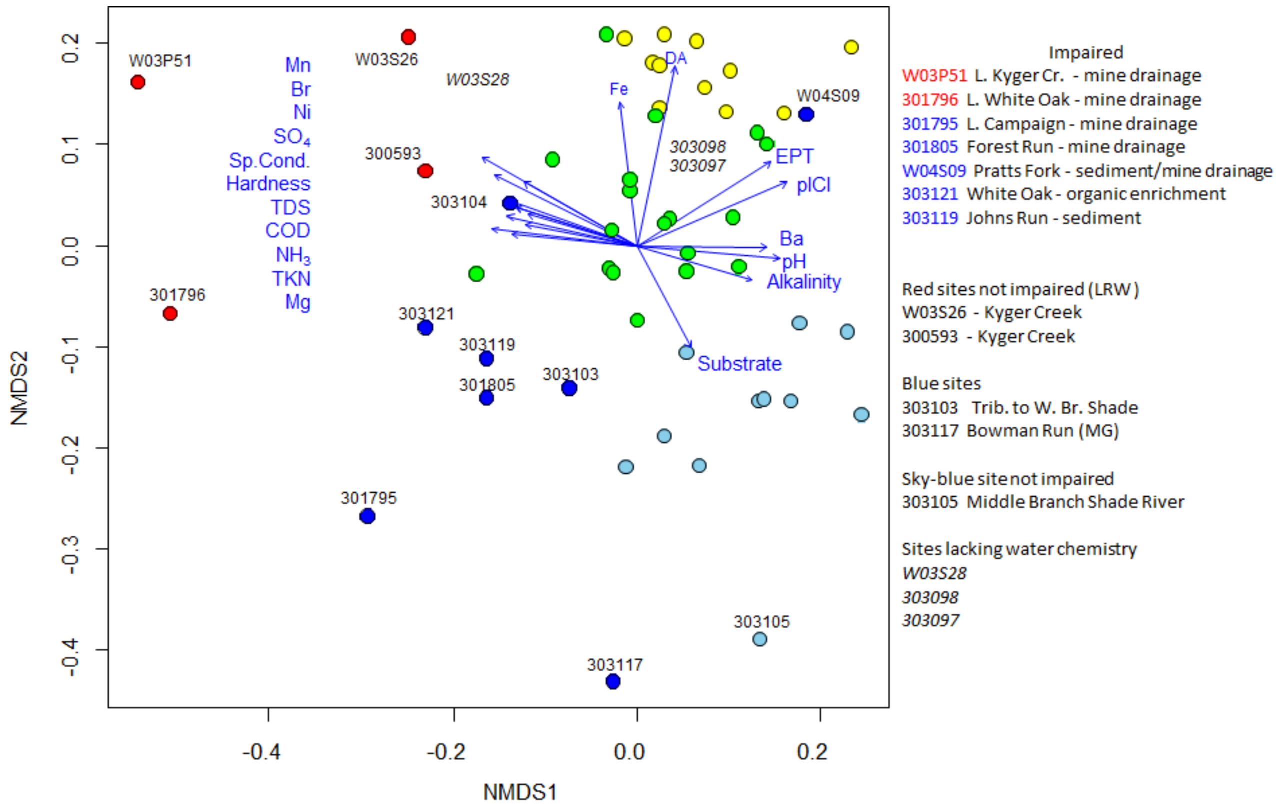

Figure 31 — A plot of macroinvertebrate sites based on an ordination of assemblages from nonmetric multidimensional scaling. Sites are color-coded based on groups identified through hierarchical clustering. Water quality parameters correlating significantly with one or both of the axes are shown on the plot. Arrow lengths and directions show the relative strength of correlation along the corresponding axis (ions correlate with the x-axis; drainage area with the y-axis, EPT richness with both axes). Only parameters with relatively strong correlations (as judged by a p-value of < 0.002) are shown. Points labeled in the plot are arrayed along the right margin. Note that the labels in italics are from sites lacking water chemistry - the position of those labels on the plots shows the approximate location where those sites would lay if included in the plot (note that none of those was impaired). The position of the Pratts Fork site (W04S09) on the plot is correct. A third dimension to the NMDS moves that site cleanly away from the yellow and green groups, but no water quality indicator is correlated with that axis.

Trends in Biological Community Indices

Within the Kyger Creek and Campaign Creek catchments, several common sites have been sampled between years, and the distributions of both IBI scores and continuously scaled qualitative macroinvertebrate scores (the pICI) suggest a trajectory of considerable improvement. Given that 2015 was the first major survey of the Shade River system, few individual sites have been sampled in multiple years, so little in the way of trends can be inferred. The few commonly sampled sites, however, suggest conditions have remained stable (at least in the lower reaches of the Middle Branch, West Branch and Shade mainstem where all the scores were recorded).

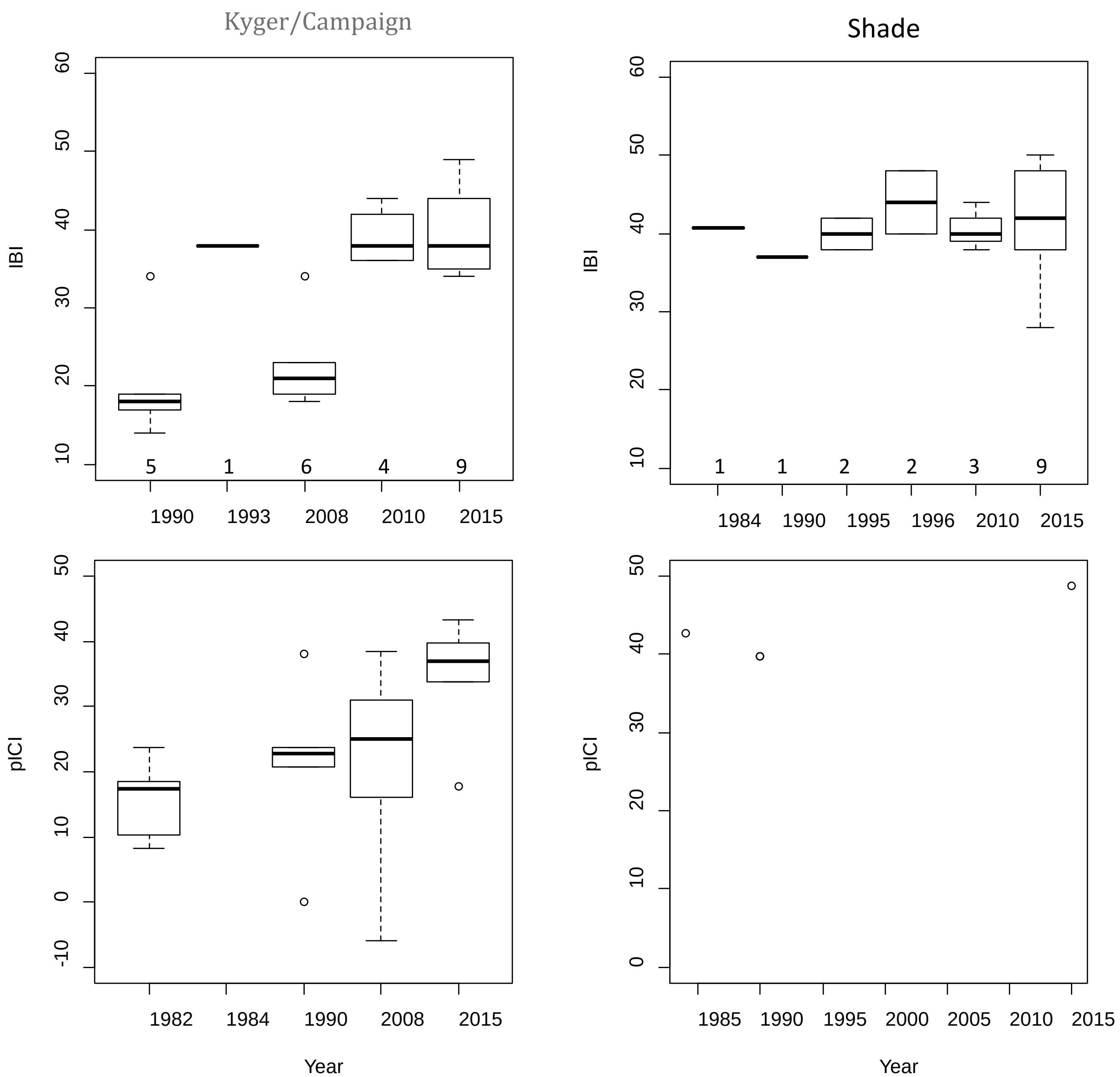

Figure 32 — Distributions of fish IBI and macroinvertebrate indicator (pICI) scores by year for sites sampled in Kyger and Campaign catchments (left column) and the Shade River. Note that only one site was sampled for macroinvertebrates in the Shade River.

Kyger Creek and Little Kyger Creek

Instream habitat quality for fish in Kyger Creek has been consistent with WWH expectations since the 1990s. In the absence of other stressors, it could be reasonably assumed that WWH fish and macroinvertebrate communities would be present in Kyger Creek. Influences from upstream sources, including historic upstream surface mining, and two coal-fired power plants are currently prohibiting WWH attainment of Kyger Creek.

Limited Resource Water in Ohio (ORC 3745-1-07 (g)) is defined as "waters that have been the subject of a use attainability analysis and have been found to lack the potential for any resemblance of any other aquatic life habitat as determined by the biological criteria…". In addition, "use attainability analysis must demonstrate that the extant fauna is substantially degraded and that the potential for recovery of the fauna to the level characteristic of any other aquatic life habitat is realistically precluded due to natural background conditions or irretrievable human induced conditions…".

Kyger Creek

Steady improvements in fish and macroinvertebrate performance through time indicates ongoing recovery of water quality, making the LRW designation inappropriate (Figure 33). Acid mine drainage does not appear to be an underlying source of impairment as pH was normal (mean = 7.4 in 2015). This is in contrast to 2008 when the pH at river mile 1.0 in Kyger Creek averaged 6.28. Similarly, pH in Little Kyger Creek in 2008 averaged 5.4, whereas in 2015, pH averaged 7.2.

Non-acid mine drainage does appear to be influencing aquatic life in the form of excess sediment and elevated mining-related chemistry parameters. The indicators are manganese, sulfate, nickel and total dissolved solids. These parameters are near WAP reference site expectations in the WWH portion of Kyger Creek and rise to near the 90th percentile of reference condition in the portion designated MWH-MA (Figure 34).

While the QHEI scores from the lower two sites sampled on Kyger Creek and Little Kyger Creek are similar to unmodified streams, examination of the submetrics indicate the potential for fish community limitations due to excessive sedimentation. This is indicated by low substrate submetric scores with more typical scores for other submetrics (Ohio Environmental Protection Agency, 1989) (Table 11). QHEI metric endpoints to restore or protect WWH in streams are greater than or equal to 13 for the substrate metric, greater than or equal to 3 for substrate embeddedness, and greater than or equal to 14 for the channel metric score (Ohio Environmental Protection Agency, 1999). These low substrate and riffle embeddedness scores indicate that sedimentation is precluding a WWH designation at this time.

Table 12. QHEI submetric scores from sites in the MWH section of Kyger Creek and Little Kyger Creek.

Station ID	Stream	RM	QHEI	Substrate		Riffle Embeddedness	Channel
300593	Kyger Creek	4.0	71.25	13.0		1.5	15.5
W03S26	Kyger Creek	1.0	61.25	10.5		2.0	13.0
W03P51	Little Kyger Creek	0.1	69.75	10.0		1.0	16.0

The excessive sediment, as well as stressors from upstream sources, continue to limit WWH biological potential in Kyger Creek and Little Kyger Creek, and evidence suggests that the LRW due to acid mine drainage is no longer appropriate, leaving the MWH-MA as the appropriate ALU at this time.

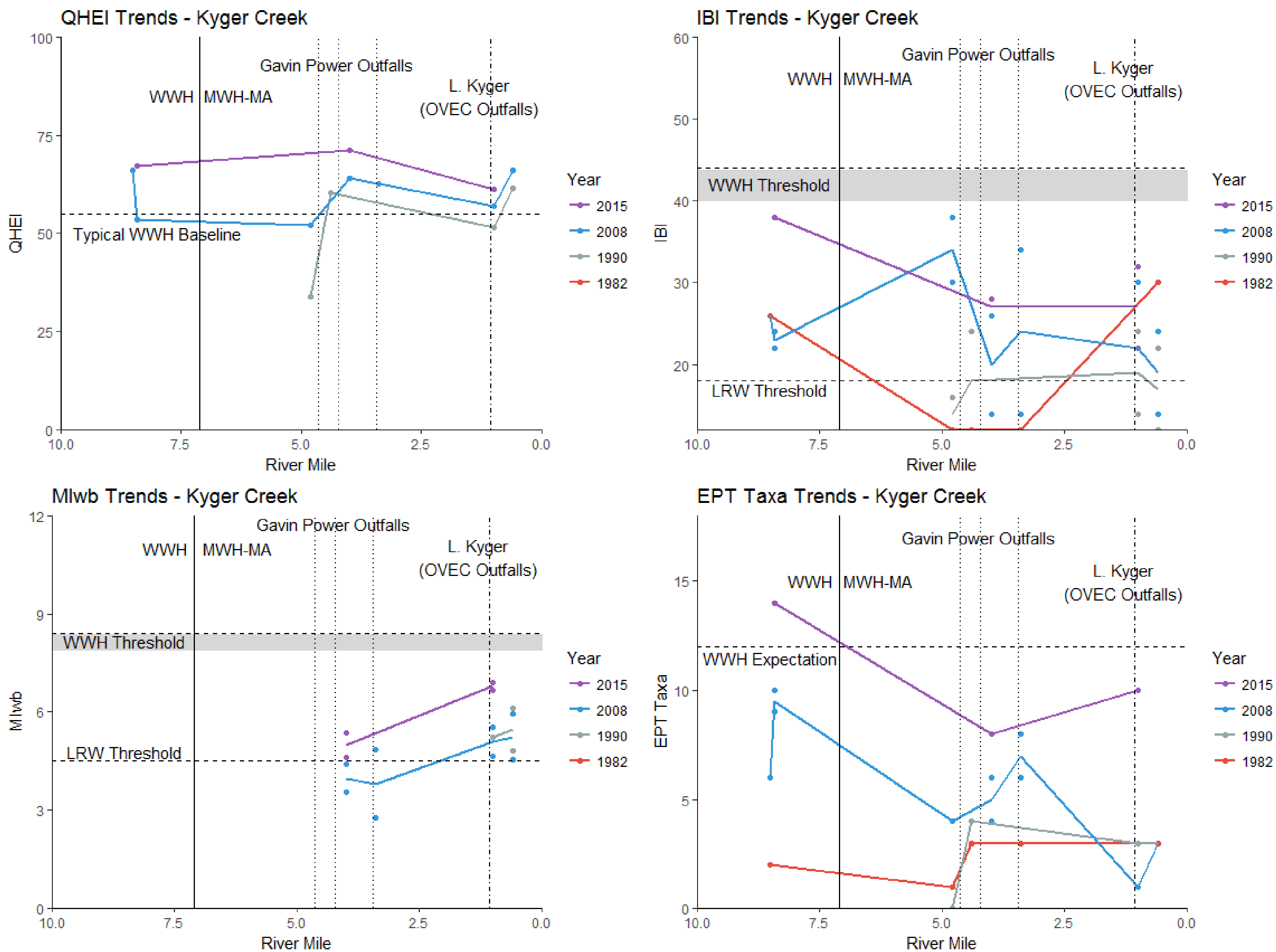

Figure 33 — Steady improvement in biological performance has been observed in Kyger Creek.

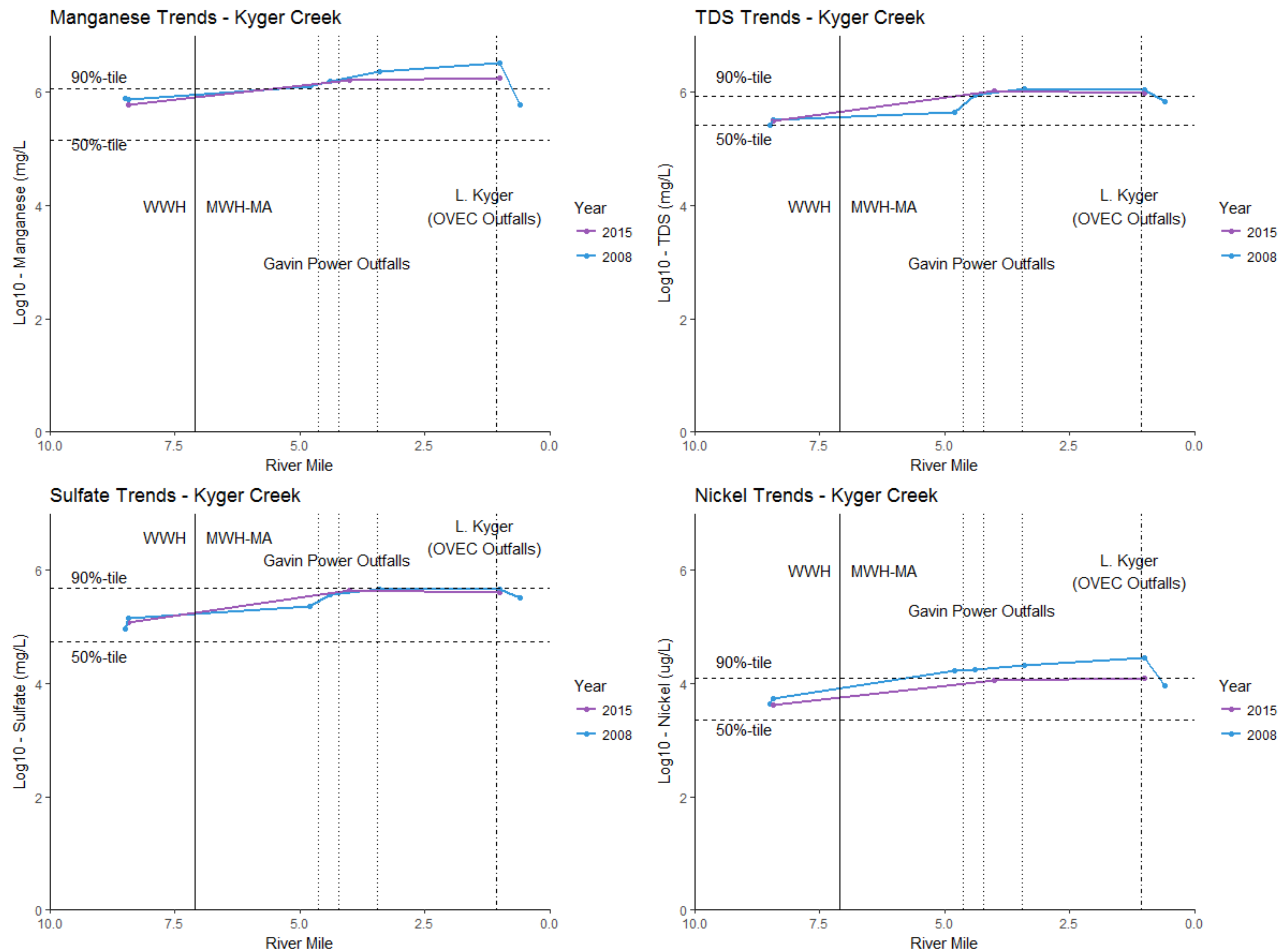

Figure 34 — Chemical signatures of mine-related impacts were elevated in the MWH-MA section of Kyger Creek. Mean values were log transformed: $log_{10}(1000 * \bar{X}_{parameter})$.

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 on the presence or absence of bacteria indicators (*Escherichia coli*) in the water column. Revisions to the recreation use rules in Ohio became effective on Jan. 4, 2016. However, since sampling protocols for this survey were designed and carried out when the previous rules were in effect, the assessment of data and determination of recreation use attainment status provided in this section were based on the prior rules.

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* comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufor, 1977). Current technology does not provide a 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 containing such wastes. *E. coli* bacteria can also become entrained within stream sediments and may remain viable for some time. Therefore, sediment re-suspension during storm events can also result in elevated numbers of *E. coli* bacteria in the water column.

Pathogenic 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 illness including: ear, nose and throat infections; stomach upsets; skin rashes; and diarrhea. Young children, the elderly and those with depressed immune systems are most susceptible to infection.

All streams in the Shade River and Little Hocking River study areas evaluated during this survey are designated PCR use in OAC Rules 3745-1-16 or 3745-1-24. 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)]. During the survey period, there were three classes of PCR use to reflect differences in the potential frequency and intensity of use. Streams designated PCR Class A typically have identified public access points and support, or potentially support, primary contact recreation. Streams designated PCR Class B support, or potentially support, occasional primary contact recreation activities. Streams designated PCR Class C support, or potentially support, infrequent primary contact recreation activities such as, but not limited to, wading. All streams assessed for recreation use during this survey are designated Class B PCR waters.

Water bodies with a designated recreational use of Secondary Contact Recreation (SCR) "...are 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" [OAC 3745-1-07 (B)(3)(c)]. The *E. coli* criteria that apply to PCR Class A, B, or C streams include a geometric mean criterion of 126, 161, or 206 colony forming units (cfu)/100 ml, respectively, to be met during the recreation season. The *E. coli* criterion that applies to SCR streams includes a geometric mean of 1,030 cfu/100 ml to be met during the recreation season. The geometric mean is based on two or more samples and is used as the basis for determining attainment status when more than one sample is collected.

Summarized bacteria results are listed in Table 11, and the complete dataset is reported in Appendix Table D. Ohio EPA sampled 24 locations in the Shade River and Little Hocking River study areas for *E. coli* four to 12 times, from May 12 – Sept. 15, 2015. Evaluation of *E. coli* results revealed that none of the locations sampled attained the applicable geometric mean criterion, and none were in attainment of the PCR use either.

Most sampling locations in the Shade River and Little Hocking River watersheds are in areas without centralized sewage treatment. Non-attainment is likely due to unsanitary conditions from failing HSTS. Another likely source of non-attainment is pasture and cropland runoff, agricultural activities such as land application of manure and biosolids, and livestock production. Grazing and row crops are evident in the floodplains of the larger drainages in the Shade River and Little Hocking River watershed. Runoff from livestock manure application and livestock grazing areas could be improved by the installation of buffers between the livestock activity and the stream. Attainment of the recreation use standards for areas impacted by failing HSTS could be achieved through individual HSTS improvements to reduce the discharge of bacteria.

Two sampling locations had extremely elevated maximum values on July 21, 2015. West Branch Shade River at State Route 681 west of Burlingham (RM 16.5) and Bowman Run near Pine Grove Rd., north of Racine (RM 0.42) had maximum *E. coli* values of 48,000 cfu and 26,000 cfu, respectively. However, both elevated samples were collected when stream flows were elevated above the median flow due to rain. Localized rain events can stir up bacteria that has settled in the sediment which gets suspended in the water column, significantly increasing bacteria counts in water samples.

Table 13 — A summary of *E. coli* data for the 24 locations in the SEORT study area sampled May through August 2015. Recreation Use Attainment is based on comparing the recreation season geometric means to applicable PCR Class B geometric mean criterion (161 cfu).

Location	RM	Recreation Use	# of Samples	Geomean	Maximum Value	Attainment Status	Potential Source(s) of Bacteria[1]
Mile Run-Ohio River (05030202 01 02)							
Mile Run	1.1	PCR Class B	10	373	2,000	NON	HSTS
Headwaters Little Hocking River (05030202 01 03)							
E. Branch Little Hocking	0.01	PCR Class B	5	362	430	NON	HSTS
West Branch Little Hocking River (05030202 01 04)							
W. Branch Little Hocking River	2.87	PCR Class B	10	321	1,700	NON	HSTS
West Branch Little Hocking River-Little Hocking River (05030202 01 05)							
Little Hocking River	9.89	PCR Class B	10	238	870	NON	AG; HSTS
Sandy Creek-Ohio River (05030202 01 06)							
Dunfee Run	1.4	PCR Class B	5	481	2,000	NON	AG; HSTS
Headwaters West Branch Shade River (05030202 02 01)							
West Branch Shade River	16.5	PCR Class B	5	1,497	9,900	NON	AG; HSTS
Kingsbury Creek (05030202 02 02)							
Kingsbury Creek	2.08	PCR Class B	5	245	1,100	NON	AG; HSTS
Headwaters Middle Branch Shade River (05030202 02 03)							
Middle Branch Shade River	22.5	PCR Class B	5	178	500	NON	AG; HSTS
Middle Branch Shade River	28.2	PCR Class B	4	222	450	NON	AG; HSTS
Pratts Fork	0.02	PCR Class B	5	321	430	NON	AG
Elk Run-Middle Branch Shade River (05030202 02 04)							
Middle Branch Shade River	0.42	PCR Class B	5	570	890	NON	AG; HSTS
Walker Run-West Branch Shade River (05030202 02 05)							
Bowman Run	0.42	PCR Class B	5	752	26,000	NON	AG; HSTS
West Branch Shade River	7.8	PCR Class B	4	305	4,000	NON	AG; HSTS
West Branch Shade River	0.16	PCR Class B	5	435	1,500	NON	AG; HSTS
Horse Cave Creek (05030202 03 01)							
Horse Cave Creek	0.35	PCR Class B	5	361	1,100	NON	HSTS
Headwaters East Branch Shade River (05030202 03 02)							
East Branch Shade River	11.84	PCR Class B	5	658	1,300	NON	AG; HSTS
Big Run-East Branch Shade River (05030202 03 03)							
East Branch Shade River	0.87	PCR Class B	10	263	1,400	NON	AG; HSTS
Spruce Creek-East Branch Shade River (05030202 03 04)							
Shade River	11.64	PCR Class B	9	205	430	NON	AG; HSTS
Forked Run-Ohio River (05030202 04 04)							
Forked Run	4.72	PCR Class B	7	354	1,100	NON	HSTS
Groundhog Creek-Ohio River (05030202 08 02)							
Groundhog Creek	2.3	PCR Class B	5	939	4,900	NON	AG; HSTS
Oldtown Creek-Ohio River (05030202 08 03)							
Oldtown Creek	1.65	PCR Class B	5	503	8,900	NON	HSTS
West Creek-Ohio River (05030202 08 04)							
Yellowbush Creek	1.5	PCR Class B	5	402	1,200	NON	AG
Kyger Creek (05030202 09 01)							
Kyger Creek	4	PCR Class B	10	321	4,800	NON	HSTS
Campaign Creek (05030202 09 02)							
Campaign Creek	6.25	PCR Class B	10	261	650	NON	AG; HSTS

1 Possible Sources: AG = agriculture; HSTS = home sewage treatment system.

Sediment

Sampling locations were selected to determine background sediment quality, assess the impact from point sources and nonpoint runoff and evaluate downstream transport and recovery. Samples were collected following the *Sediment Sampling Guide and Methodologies*, 3rd Edition (Ohio EPA, 2012). The goal was to collect a representative sample that is composed of > 30 percent silt and clay particles. These fine-grained particles are much more physically, chemically and biologically reactive than coarse material such as sand and gravel because they hold more interstitial water and have unbalanced electrical charges that can attract contaminants.

Sediment sample results were evaluated using Tier I procedures for aquatic life described in the *Guidance on Evaluating Sediment Contaminant Results* (Ohio EPA, 2010). 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, 2008) and toxicity values in the *Development and Evaluation of Consensus-based Sediment Quality Guidelines for Freshwater Ecosystems* (MacDonald, Ingersoll, & Berger, 2000). When contaminants are at concentrations above the SQGs either appropriate treatment options should be explored to remediate the problem or consideration should be given to determine if bioavailability affects toxicity, which would likely require further investigation.

Ohio EPA collected sediment samples at six locations in the SEORT on Aug. 10 and Sept. 18, 2015. Sampling locations were co-located with biological sampling sites. Samples were analyzed for metals, nutrients and semivolatile organic compounds. Specific chemical parameter results are listed in Appendix Table C. All sediment sampling occurred in areas along the stream bank, where sparse deposits of fine-grained material accumulated. These near bank areas comprised only a small fraction of the bottom substrates of the streams surveyed. Bottom substrates at sediment sites were dominated by sand and gravel material. The sparse deposits of fine-grained material that were target for analysis revealed low exposure levels of potential sediment contaminants to biological communities.

Metals and nutrient levels are presented in Table 12. Organic chemical parameters were tested at all six sampling locations and laboratory analysis determined levels below detection. Arsenic concentrations were above the TEC in Kyger Creek, but below the PEC and are unlikely to cause any harmful effects. All other sediment metals sampled were below Ohio Sediment Reference Values, TEC values and PEC values.

Table 14 — Chemical parameters measured above screening levels in samples collected by Ohio EPA from surficial sediments in the SEORT, August and September 2015. Contamination levels were determined for parameters using Ohio Sediment Reference Values (SRVs), consensus-based sediment quality guidelines (MacDonald, et.al 2000) and ecological screening levels (US EPA 2003). Shaded numbers indicate values above the following: SRVs (blue); Threshold Effect Concentration – TEC (yellow); Probable Effect Concentration – PEC (red).

Parameter (mg/kg)	Shade River USGS GAGE @ TR 112 RM 11.64	E BR Shade River @ SR 248 E OF CHESTER RM0.87	Little Hocking River @ CR 85 RM 9.89	W. Br. L. Hocking River @ CR 248 ROSS RD. RM 2.87	Campaign Creek @ Bulaville Pike CR 3 RM 6.25	Kyger Creek ADJ SR 554 UST Rousch Cem. DST AEP 008 RM 4.0	Sediment Reference Value (SRV)	Threshold Effect Conc. (TEC)	Probable Effect Conc. (PEC)
Aluminum	6800	6680	9190	9120	6140	19300	53000		
Ammonia	NA	NA	NA	NA	NA	37			
Arsenic	4.32	4.68	7.07	6.91	4.91	13.8	19	9.79	33
Barium	120	137	123	153	83.6	133	360		
Cadmium	0.288	0.257	0.337	0.303	0.229	0.533	0.8	0.99	4.98
Calcium	2030	2170	6020	1950	2490	2610	27000		
Carbon, Total Organic (TOC)	1.4	1.3	1	0.9	1.1	1.3			
Chromium	9.79	9.89	14.7	13.2	10.1	21.5	53	43.4	111
Copper	10.6	10.2	13.3	12.3	10.6	22.4	33	31.6	149
Iron	16900	16800	24100	22300	17700	33200	51000		
Lead	12.1	11.3	15.8	14.6	12.2	21.7	47	35.8	128
Magnesium	1670	1840	2860	2480	1540	2380	9900		
Manganese	911	886	883	892	847	421	3000		
Mercury	<0.016	<0.0195	<0.018	<0.0215	<0.013	0.041	0.12	0.18	1.06
Nickel	12.6	12.2	16.3	15.1	12.7	19.5	61	22.7	48.6
Phosphorus	485	409	535	551	382	619			
Potassium	<675	<645	<625	<710	<580	2000	14000		
Selenium	<0.675	<0.625	<0.58	<0.735	<0.71	<0.645	2.3		
Silver	<0.06	<0.0585	<0.0675	<0.074	<0.0555	NA	0.43		
Sodium	<1685	<1615	<1570	<1780	<1445	<1835			
Strontium	23	20	37	22	18	48	250		
Zinc	43.7	40.3	52.9	52.4	46.7	79.4	170	121	459

Point Source and Nonpoint Source Impacts

There are fourteen individual National Pollutant Discharge Elimination System (NPDES)-permitted facilities located in the SEORT study area, including: Campaign Creek; Shade River; Little Hocking River; Kyger Creek; and select direct tributaries to the Ohio River. The types of discharge include municipal wastewater from schools, housing developments and business along with industrial wastewater from electric power generating plants, a landfill, coal mines and industrial mineral extraction. These watersheds also have 23 general NPDES permits. A general NPDES permit is a statewide permit that covers numerous facilities with similar operations and types of discharges. There are 14 construction storm water permits and nine small (25,000 gallons per day or less) sanitary discharger permits.

Coal mining in the study area may have started as early as 1806 (Crowell, 1995). In 1877, underground coal mining was taking place within the village boundary of Pomeroy. The Pomeroy Coal Company operated a drift mine, mining the Pomeroy No. 8A coal in the Pennsylvania Era Monongahela Group. Drift mines start where the coal seam is exposed at the land surface, a convenient location for a mine entry. Drift mines are susceptible to water seepage through the upper layers, resulting in mine drainage into streams and rivers. A new underground mine was started in the Yellowbush Creek area in the mid-2000s. The Gatling Ohio LLC - Yellowbush Mine is a room and pillar mine. Room and pillar mining is an underground mining technique that extracts coal from the room leaving behind the pillar which supports the overburden. Most older underground coal mines used this technique. Another underground mining practice is longwall mining. Southern Ohio Coal Company's Meigs Mine No. 31, in the upper Campaign Creek watershed, used this method. A shaft is excavated down to the coal seam and a longwall miner cuts long sections off the coal face, which falls into a conveyor. As the longwall miner advances forward, the roof is allowed to fall behind the machine. Longwall mining allows for more coal to be extracted but can cause serious subsidence on the surface resulting in losing streams with water infiltrating into the subsidence. Both the Yellowbush mine and the Meigs Mine No. 31 and have ceased operations.

Underground coal mining was prevalent in the early 1900s, but slowly gave way to surface coal mining as machinery became big enough to remove large amounts of earth to get down to the coal. Surface mining was heaviest in lower Kyger Creek, Little Campaign Creek, Story Creek, West Branch of Shade River, Pratts Fork and Kingsbury Creek. Much of the surface mining within these watersheds was pre-law mining performed prior to the Surface Mining Control and Reclamation Act of 1977. Pre-law mining did not have to return the ground to its original grade, but instead left large piles of coal waste (gob), highwalls and mine pits. The mined areas not reclaimed can be a major source of mine drainage negatively impacting streams and rivers.

Southeast Ohio is the second oldest oil producing region in the United States (Miller, 1943). To date, there have been more than 5,000 wells permitted, drilled, producing or capped in the 561 mi^2 watershed (ODNR, 2014). Additionally, there are 14 Class II UIC wells for brine disposal in the Shade River watershed.

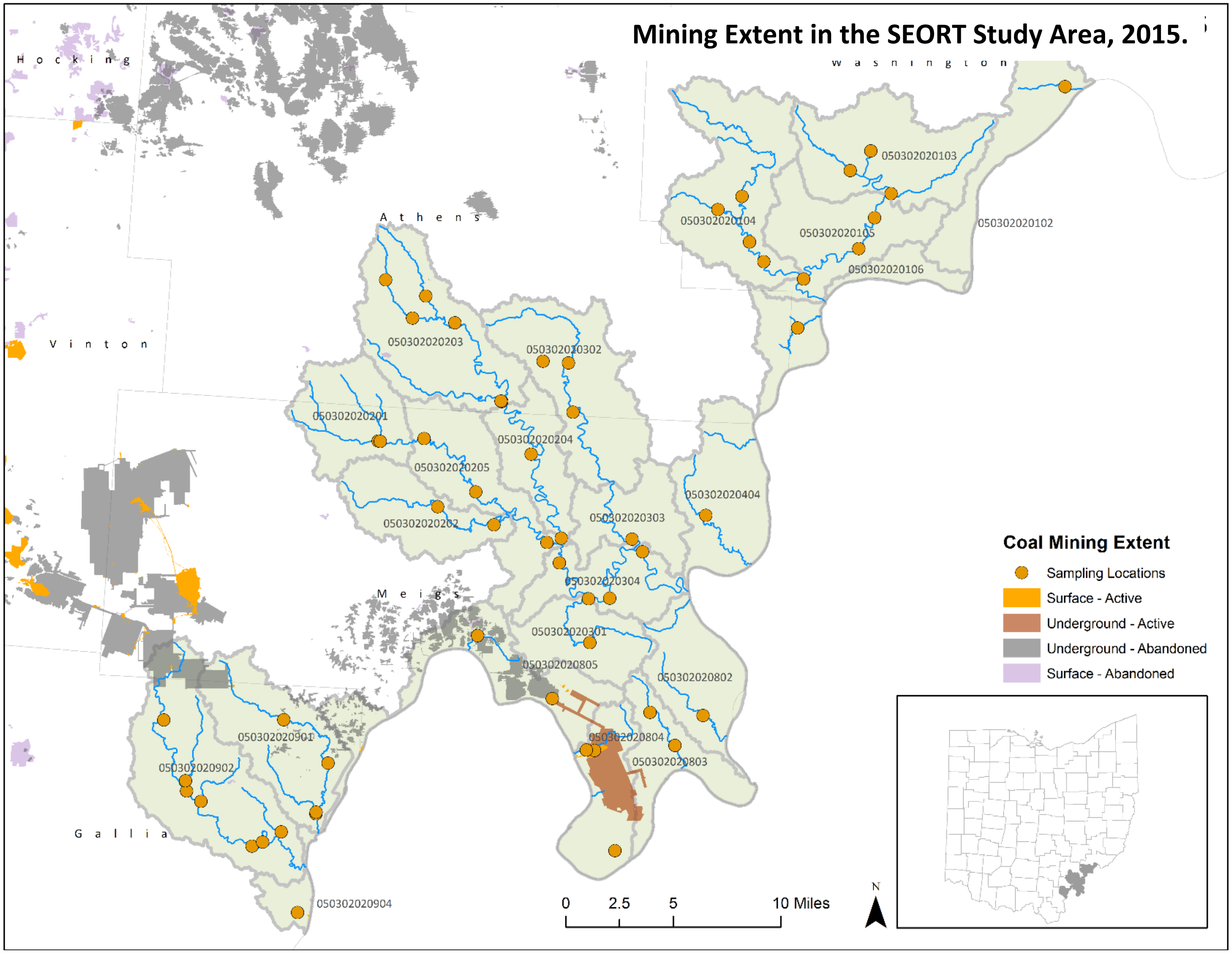

Figure 35 – Mine locations in the SEORT study area, 2015.

Spills

Ohio EPA's Office of Environmental Response received numerous spill reports from 2004 - 2017 within the three watersheds and Ohio River tributaries. Only 20 had the potential to reach Ohio's waterways. Of those, eight were reported along St. Rte. 7. These spills were the result of semi-truck accidents where the fuel tanks (saddle tanks) were ruptured, spilling diesel fuel. In January 2009, an accident along St. Rte. 7 from a tanker truck resulted in a 7,000-gallon spill of diesel fuel, some of which entered an unnamed tributary to the Shade River. Most fuel spills reported in the watershed were contained at the accident site. Incidents investigated by emergency responders included: spills of home heating oil; crude oil; oil and gas holding tanks containing water and oil; orphan drums; a broken mercury thermometer; diesel fuel; and a fish kill of unknown origin.

NPDES Facilities in the Little Hocking River watershed

There are six NPDES facilities with industrial or municipal permits that discharge treated wastewater to streams located in the Little Hocking River watershed. The Little Hocking River and direct Ohio River tributaries are located in Washington County just west of Marietta. Please see Figure 35 and Figure 36 for the location of the watershed, the NDPES facilities, the surface and underground mines and the location of known spills.

E.I. DuPont deNemours and Company, Inc., Little Hocking Service Center dba Estep Recovery (Ohio EPA Permit # 0IQ00023; outfall 001, 002)

The Little Hocking Service Center WWTP is located at 251 Arrowhead Road, Little Hocking, Washington County. The Little Hocking Service Center is a manufacturer that reforms and reformulates finished plastics into pellets. The primary plastic resins are Teflon™, polyethylene, nylon, polyesters and various filler materials including: boron; nitride; calcium carbonate; and fiberglass. The manufacturing process includes dry blending of resins, extrusion, cutting, product cooling and cleaning. The final product is sold to manufacturers who convert the plastic pellets into commercial products. The WWTP's outfall 002 discharges finished water that has undergone extended aeration, chlorination disinfection and de-chlorination. Outfall 001 discharges process cooling water, backwash from a deionized water system and air compressor condensate. Additional treatment at the 001 discharge includes screening to catch trash and pellets. No NPDES permit exceedances were reported for the review period of January 2011 and December 2015.

Par Mar Oil Company/Par Mar Store #14 STP (Ohio EPA Permit # 0PR000097; outfall 001)

The Par Mar Store (convenience store) #14 sewage treatment plant (STP) is located at the junction of St. Rte. 50 and Belpre Township Rd. 295, Little Hocking, Washington County. The STP is an extended aeration plant with chlorination disinfection and de-chlorination. The plant is designed to treat 1,500 gallons per day of domestic wastewater for the employees and customers of the gasoline station and convenience store. The WWTP discharges to an unnamed tributary of the Little Hocking River at RM 4.38. Between January 2013 and December 2015, the WWTP had 12 permit exceedances for five-day carbonaceous biochemical oxygen demand (CBOD5), four TSS permit exceedances and four *E. coli* permit exceedances. Ohio EPA sent Par Mar letters regarding these exceedances in May 2013, October 2013, May 2014, August 2014, October 2014, July 2015 and September 2015. Par Mar responded with the following actions to resolve the violations: adjusting the timers and operation of the blowers and cleaning of the sand filters. Additionally, Par Mar has requested and received assistance from Ohio EPA's Compliance Assistance Unit. The percent of exceedances has improved over time as a result of the continued attention and improvements to the system.

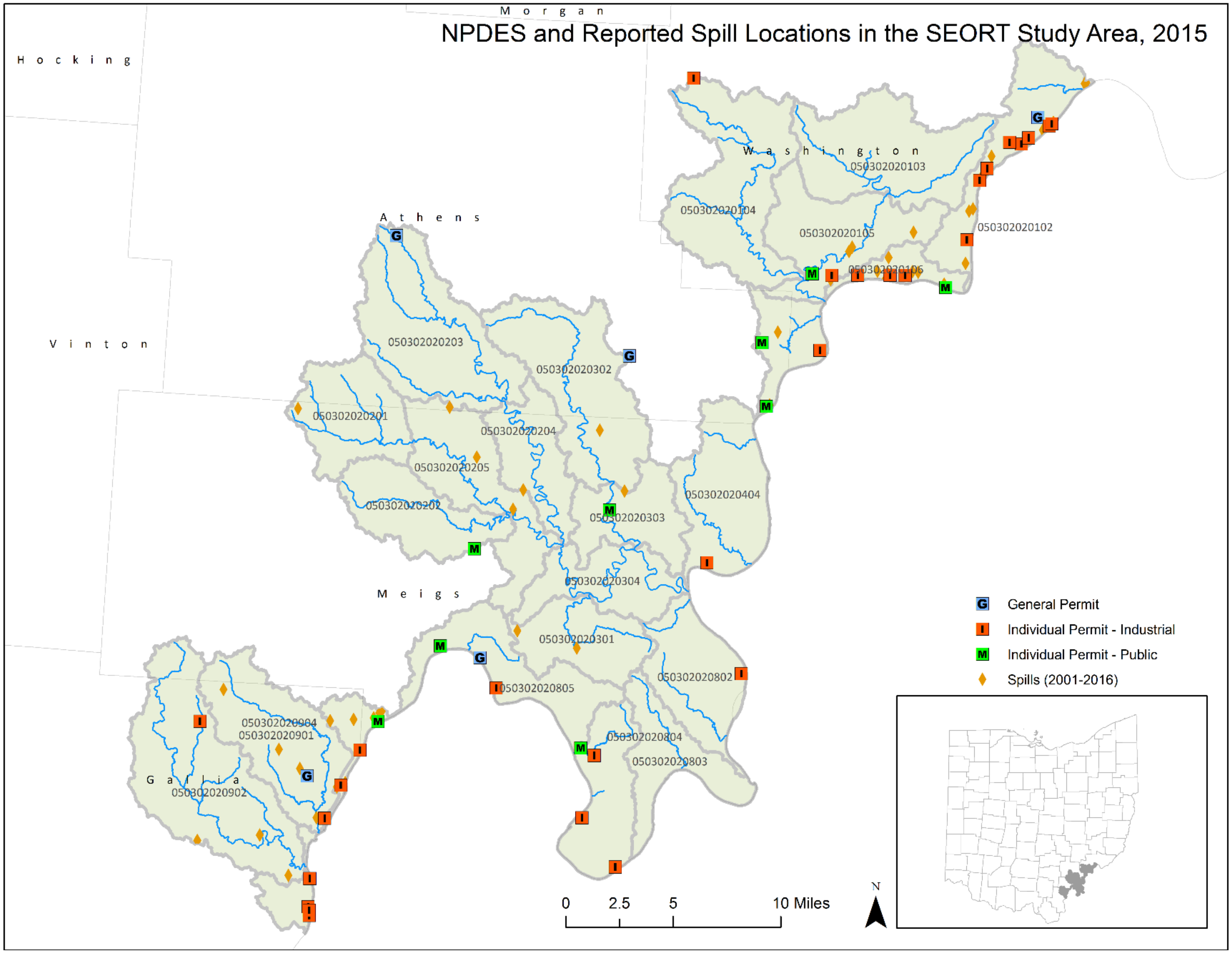

Figure 36 — NPDES facilities and reported spills in the Little Hocking SEORT study area, 2015.

Washington County Commissioners – Stacy Meadowcrest WWTP (Ohio EPA Permit # 0PG00057; outfall 001)
The Stacy Meadowcrest WWTP is located on Teri Lane, Belpre, Washington County. Stacy Meadowcrest has approximately 200 residents. The WWTP is an extended aeration plant with chlorination disinfection and de-chlorination. The plant, built in 1976, is designed to treat 33,000 gallons per day of domestic wastewater. After treatment the WWTP discharges to the Little Hocking River at RM 2.95. Between January 2011 and December 2015, the WWTP had two CBOD5, two fecal coliform, four D.O. and 10 ammonia permit exceedances. Ohio EPA sent the Washington County Commissioners two letters regarding these exceedances in October 2013 and April 2014. The facility has been able to routinely maintain compliance with the permit since the reported exceedances.

Torch Estates Homeowner's Association (Ohio EPA Permit # 0PW00026; outfall 001)
The Torch Estates WWTP is located at U.S. Rte. 50 and Co. Rd. 63, Coolville, Athens County. The Torch Estates WWTP is designed to serve 53 homes and consists of a septic tank, recirculation sand filter and a spray irrigation field or discharge after filtration. The WWTP is designed to treat 15,600 gallons per day of domestic wastewater. After treatment, the WWTP would discharge to an unnamed tributary of Whites Run at RM 2.88. As of the survey, the housing development had no homes built.

Roger Ketchum dba Hockingport Mobile Home Park (Ohio EPA Permit # 0PV00014; outfall 001)
The Hockingport MHP WWTP is located at the intersection of Twp. Rd. 160 and 161, Hockingport, Athens County. The Hockingport MHP WWTP serves 32 mobile homes and 11 homes. The WWTP is an extended aeration plant with chlorination disinfection and de-chlorination. The WWTP is designed to treat 15,600 gallons per day of domestic wastewater. After treatment the WWTP discharges to Swan Run at RM 0.15. No NPDES permit exceedances were reported for the review period between January 2013 and December 2015.

NPDES Facilities in the Shade River watershed

The Shade River watershed and several direct Ohio River tributaries are located mostly in Meigs County east of Pomeroy. There are four NPDES facilities with industrial or municipal permits to discharge treated wastewater to streams in this watershed. Please see Figure 35 and Figure 36 for the location of the watershed, the NDPES facilities, the surface and underground mines, the horizontal wells and the location of known spills.

Martin Marietta Aggregates - Apple Grove Plant (Ohio EPA Permit # 0IJ00015; outfall 001)
The Martin Marietta Aggregates Apple Grove Plant is located at 50427 St. Rte. 124, Racine, Meigs County. The Apple Grove Plant is an active sand and gravel dredging operation. Sand and gravel are both dry mined and open-water dredged, then the material is processed by sizing and segregating to produce construction material. Treatment for the outfall 001 discharge is sedimentation. Outfall 001 discharges to Johns Run at RM 0.25 (Ohio River backwaters). Outfall 002 discharges to the Ohio River. No NPDES permit exceedances were reported for the review period of January 2013 and December 2015.

Gatling Ohio, LLC dba Yellowbush Mine (Ohio EPA Permit # 0IL00145; outfalls 002, 003, 004, 006, 007 and 012)
The Gatling Ohio Yellowbush Mine is located at 48241 Twp. Rd. 100, Racine, Meigs County. The Yellowbush Mine is an underground room and pillar coal mine with a slope mine entry. The permitted surface affected area is 115 acres and the underground area is 746 acres. The surface facilities supporting the underground coal mine include coal refuse disposal area, coal preparation plant, coal storage piles and bathhouse. Treatment consists of sedimentation and pH adjustments. Discharge locations are: outfall 002 to Yellowbush Creek at RM 0.6; outfall 006 to Yellowbush Creek at RM 1.0; outfall 005 to Yellowbush Creek at RM 1.1; outfall 012 to Yellowbush Creek at RM 1.24; outfall 004 to Yellowbush Creek at RM 1.33; outfall 003 to Yellowbush Creek at RM 1.42; and outfall 007 to Jennie Watts Run at RM 0.09. No coal has been

mined since 2011 and reclamation has begun. Two additional permitted sites in conjunction with the Yellowbush Mine have not been utilized by the company nor did they discharge wastewater at the time of the survey. These are the Yellowbush Mine – Bowman Portal (NPDES # 0IL00151) and the Yellowbush Mine – Wolf Run Portal (NDPES # 0IL00150).

Eastern Local School District (Ohio EPA Permit # 0PT00046; outfall 001)
The Eastern Local School District facility is located at 38900 St. Rte. 7, Reedsville, Meigs County. The school's WWTP serves approximately 1,000 students and staff. The WWTP is an extended aeration plant with chlorination disinfection and de-chlorination. The WWTP is designed to treat 15,000 gallons per day of domestic wastewater. After treatment the WWTP discharges to the East Branch Shade River at RM 4.1. Between January 2011 and December 2015, the WWTP had seven ammonia, two TSS and two CBOD5 exceedances along with one D.O. exceedance of their permitted limits. Ohio EPA sent the Eastern Local School District three letters regarding these exceedances in February 2013, August 2013 and December 2014. The school district responded with the following actions to resolve the violations: adding air to the clarifiers and adding lime to the system. An inspection conducted in 2017 resulted in a Notice of Violation (NOV) being issued on Jan. 10, 2017 for: a lack of signage at the outfall; records not being maintained; no designated operator of record; and chlorine analyzation wasn't occurring as specified in 40 CFR 136. The school district responded to the NOV, resolved all cited violations and received a Resolution of Violation (ROV) letter dated Feb. 28, 2017.

Extendicare, Inc. dba Rock Springs Rehabilitation Center (Ohio EPA Permit # 0PX00014; outfall 001)
The Rock Springs Rehabilitation Center is located at 36759 Rock Springs Rd., Pomeroy, Meigs County. The habitation center and skilled nursing care's WWTP serves 100 patients and staff. The plant was upgraded in the mid-2000s and is designed to treat 16,000 gallons per day of sanitary wastewater. The WWTP is an extended aeration plant with chlorination disinfection and de-chlorination. After treatment the WWTP discharges to an unnamed tributary of Peach Fork at RM 0.92. Between January 2013 and December 2015, the WWTP had six ammonia and two *E. coli* exceedances. Additionally, an inspection was conducted in early 2017 that resulted in another NOV issued on April 21, 2017 citing violations including incorrect pH analysis, signage at the outfall and no monitoring of flow rate. The facility submitted necessary documentation and an ROV was issued on May 22, 2017.

NPDES Facilities in the Campaign and Kyger Creek watershed

The Campaign Creek and Kyger Creek watersheds are located mostly in Gallia County north of Gallipolis. There are three industrial NPDES facilities with permits to discharge treated wastewater to streams in the Kyger Creek watershed. Please see Figure 35 and Figure 36 for the location of the watershed, the NDPES facilities, the surface and underground mines and the location of known spills.

Gavin Power, LLC (formerly Ohio Power Company) (Ohio EPA Permit # 0IB00006, outfalls 001, 007, 008, 009)
http://wwwapp.epa.ohio.gov/dsw/permits/doc/0IB00006.pdf

The General James M. Gavin Power Plant is located at 7397 North St. Rte. 7, Cheshire, Gallia County. The Gavin Plant is a pulverized coal-fired steam electric generating facility consisting of two units, each rated at 1,300 megawatts of generating capacity. The Gavin Plant uses a dry fly ash handling system. The dry fly ash is mixed with flue gas desulfurization (FGD) filter cake and transported to a coal combustion byproduct landfill located north of the plant. Outfall 001 (Stingy Run at RM 0.81) contains storm water that passes through an existing fly ash pond that impounds part of Stingy Run. The company has not sent fly ash wastewater to this pond since December 1994. Treatment of this water consists of sedimentation in the pond and neutralization. Sodium hydroxide is added to raise the pH of the water. Outfalls 007 (Turkey Run at RM 0.6), 008 (Kyger Creek at RM 4.22) and 009 (Stingy Run at RM 0.30) are existing landfill leachate and storm water discharges from the FGD/fly ash landfill area. Outfall 008 also includes storm water runoff from the stacker pad (a loading area for scrubber solids). Outfalls 007 and 009 are also treated by sedimentation and neutralization. Outfall 008 is treated by sedimentation, neutralization and flocculation. Kyger Creek (in the zone of the power plant discharges), Stingy Run and Turkey Run are designated as LRW due to AMD. All other plant outfalls discharge directly to the Ohio River. The facility was purchased by Lightstone Generation in early 2017.

Ohio EPA conducted compliance sampling at the facility on Nov. 26 and 27, 2012. Two grab samples and a composite sample were collected. The bioassay test results for outfall 008 showed acute toxicity which was most likely due to the high concentration of TDS. Effluent toxicity data for Outfall 008 has exceeded the acute toxicity waste load allocation in approximately 42 percent of bioassay tests. Outfall 008 has the reasonable potential to contribute to exceedances of toxicity so acute toxicity limits are now in the NPDES permit. Because Outfalls 007 and 009 have dissolved solids concentrations equal to or greater than those in Outfall 008, the NPDES permit effective June 1, 2014 included acute toxicity limits as well. This permit contains a compliance schedule to allow time to meet the toxicity limits at all three of these outfalls. For additional details on Kyger Creek refer to Ohio EPA's technical report *Biological and Water Quality Study of Kyger Creek and Select Tributaries 2008* (Ohio EPA, 2011). In 2013 and 2014 the Gavin Plant had four mercury violations at outfall 008 and four copper and TSS exceedances at outfall 006. The facility personnel notified Ohio EPA about the nature of the violations and steps taken to resolve them so no further action was required.

Ohio Valley Electric Corporation (Ohio EPA # 0IB00005; outfall 005, 026, 027, 028, 030 and 031)
The Ohio Valley Electric Corporation (OVEC) Kyger Creek Station is a coal-fired power plant with a total generating capacity of 1,086 megawatts from five generating units. The facility is located at 5758 St. Rte. 7, near Cheshire, in Addison Township, Gallia County, Ohio. The facility underwent the installation of a FGD system which was complete and operating in 2012. A new wastewater stream or source referred to as the FGD chloride purge stream (CPS) was created as a result of this new FGD system. The chloride purge stream is a direct purge from the scrubber vessels.

This wastewater source is treated in a wastewater treatment plant prior to being discharged to the existing fly ash pond treatment system (existing NPDES outfall 0IB00005005). The wastewater treatment plant is known as the FGD CPS wastewater treatment plant. The treatment system includes mercury removal equipment, with a goal to minimize the incremental pollutant loading from the existing fly ash pond (Outfall 005 discharge to Kyger Creek).

An FGD sludge (also referred to as coal combustion product or CCP) landfill of approximately 100 acres was constructed and includes both liner and leachate collection systems. Contact and non-contact runoff water in the FGD landfill area is routed to a series of settling treatment ponds to be discharged to NPDES permitted outfalls.

In March 2015, the facility had one TSS exceedance at outfall 001. In 2013 and 2014, the facility had low-level mercury exceedances at outfall 028 (three exceedances), at outfall 030 (eight) and at outfall 031 (four). All low-level exceedances were between January 2013 and September 2014. The facility personnel notified Ohio EPA about the nature of the violations and steps were taken to resolve them so no further action was required.

Gallia County Landfill, LLC (Ohio EPA Permit # 0IN00121; outfall 001)
The Gallia County Landfill (owned and operated by Waste Management) is located at 497 Roush Hollow Rd., Bidwell, Gallia County. The landfill is a municipal solid waste landfill that has a leachate collection system and holding tanks for off-site treatment of the leachate. Non-contact storm water is collected in a

sediment pond and discharged through outfall 001 into an unnamed tributary of White Oak Creek at RM 3.59. Between January 2013 and December 2015, the facility had no exceedances.

Inland Lakes

Ohio EPA has implemented a sampling strategy that focuses on evaluating chemical conditions near the surface and physical conditions in the water column of inland lakes. Physical profile measurements are summarized either for the entire water column or the epilimnion depending on the existence of thermal stratification. The sampling target consists of an even distribution of 10 sampling events divided over a two-year period and collected during the recreation season of May 1 through October 31. Key parameters analyzed in lakes include chlorophyll-*a*, ammonia, D.O., pH, total dissolved solids along with various metals for multiple beneficial use assessments. Other parameters used to evaluate lakes include secchi depth, total phosphorus and total nitrogen. Details of the sampling protocol used at the time of this sampling are outlined in Appendix E of the ***Ohio EPA Surface Water Field Sampling Manual***. Ohio EPA has revised those sampling protocols in Appendix I of ***the Ohio EPA Surface Water Field Sampling Manual in 2016***.

During 2015 and 2016, Ohio EPA sampled two recreational lakes, Veto and Forked Run Lakes, to determine the beneficial use attainments for each. Both lakes are man-made in-stream impoundments located in the WAP ecoregion.

Veto Lake

In 1954, the Ohio Department of Natural Resources constructed a dam for recreational purposes below the confluence of the Little Hocking River, Buffalo Run and Plum Run. The dam created Veto Lake which is contained within 160 surface acres of water and is surrounded by a 445-acre wildlife area. Veto Lake is located in Washington County on Veto Rd., east of St. Rte. 339. The 10 HP-limit lake has nine miles of shoreline with a maximum depth of 4.5 meters (*Figure 37*). Veto Lake is located in the upper third of the Little Hocking River mainstem and the dam is located at RM 13.8. The lake watershed is six percent developed, 68 percent forested, 26 percent agricultural, 0.01 percent wetland and 0.62 percent open water. Just outside the wildlife boundary are many small housing developments including the communities of Vincent and Veto.

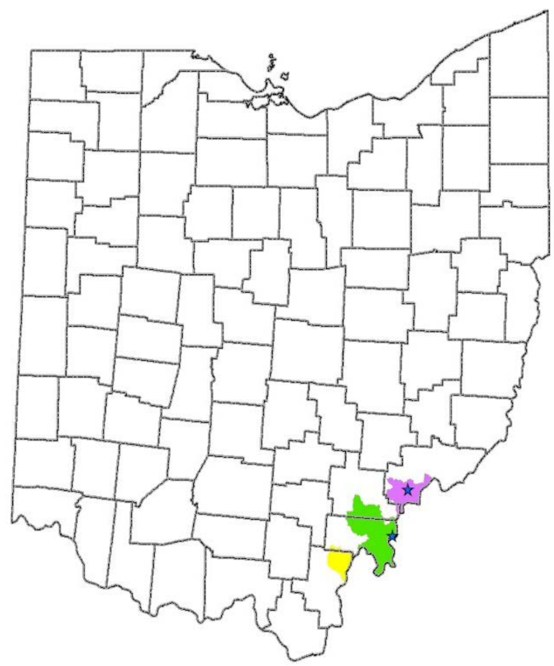

Figure 37 — Location of eastern Ohio River tributary lakes sampled in 2015 and 2016.

Lake Water Quality Assessment

Aquatic Life Use

The current aquatic life use (ALU) designation for all inland lakes in Ohio is exceptional warmwater habitat (EWH) except for upground reservoirs which are designated warmwater habitat (WWH). Important criteria for assessing lake condition include nutrient parameters (e.g. total phosphorus, total nitrogen) and biological response variables (e.g. chlorophyll-a). Currently in Ohio, no nutrient or biological criteria exists for inland lakes. Ohio EPA is currently evaluating data and methodologies to develop appropriate ALU criteria for inland lakes.

Lake samples were collected from near the surface of Veto Lake five times each during the 2015 and 2016 recreation seasons. Statewide Outside Mixing Zone Average (OMZA) water quality criteria listed in tables 35-1 through 35 of section 3745-1-35 of the OAC (Water Quality Standards) were used for most parameters to evaluate the existing EWH designated use for Veto Lake. Dissolved Oxygen is compared against the statewide Outside Mixing Zone Minimum (OMZM) criteria. If the statewide criterion was exceeded in more than 10 percent of the total samples tested for any parameter, the use is considered in non-attainment of the existing EWH use designation. Sampling results determined that Veto Lake was in not in attainment of the existing EWH use based on three exceedances of the OMZM criteria for D.O during the 2016 field season Table 14.

Where criteria do not exist, a common approach to assess relative lake condition is to compare lake water quality sampling data to a regionally derived percentile (e.g. 25th) of existing lake data. The lower 25th percentile generally represents minimally impacted conditions protective of designated uses. For Ohio EPA, inland lake aquatic life use benchmarks were calculated for total nitrogen (T-N), total phosphorus (T-P) and chlorophyll-a (Chl. a) based on the lower 25th percentile of lake median data and for secchi depth based on the upper 75th percentile of lake median data. All data used for benchmarks were collected by Ohio EPA from Ohio inland lakes between 1989 and 2006.

Assessment of other important lake parameters reveals that Veto Lake was greater than the regional 25th percentile benchmarks for T-P, Total T-N and Chl.a, and for transparency based on the 75th percentile Secchi data (Table 14). These results are indicative of nutrient enrichment and likely play an important role in the trophic dynamics, diel chemistry and associated biological functioning of Veto Lake.

Hypolimnion (bottom) samples can provide helpful information related to internal nutrient loading. The sources of nutrients in lakes can come from external sources such as lake tributaries or from lake sediments which act as a nutrient sink. The internal loading or regeneration of available phosphorus from sediments and within the hypolimnion is very complex, often occurring under hypoxic (D.O. <2 - 4 mg/L range) conditions. Through chemical, biological and physical processes, significant amounts of available phosphorus can be released into the water column (Great Lakes Environmental Assessment and Mapping Project, n.d.).

Table 15 — Summary of data collected in Veto Lake. Values in bold are exceeding the criteria or greater than the 25th – percentile target.

Parameter	Secchi (m)	Chl. a (µg/L)	T- N (µg/L)	T-P (µg/L)	D.O. (mg/L)	pH (SU)	NH_3-N (mg/L)
ALU Benchmarks	**≥2.16**	**≤6.2**	**≤350**	**≤14**	**≥5.0**	**6.5-9.0**	**WQS**
5/27/2015	0.697	22.6	910	10.9	8.64	8.09	<
6/11/2015	0.444	40.6	1050	14.4	7.88	8.01	<
7/7/2015	0.134	82.1	950	19	12.13	8.0	<
8/19/2015	0.429	47.95	1210	13.1	5.67	8.01	<
9/23/2015	0.420	58.9	1250	17.6	5.61	7.72	<
6/28/2016	0.523	111	1610	72	11.02	8.67	<
7/11/2016	0.395	89	1260	100	11.93	8.18	<
8/4/2016	0.495	31.7	1620	100	**4.05**	7.38	<
8/31/2016	0.370	246	1970	91	**4.24**	7.74	<
9/27/2016	0.330	111	1670	94	**4.08**	6.67	<
Median	**0.425**	**70.5**	**1255**	45.5	N/A	N/A	N/A

During the 2015 and 2016 sampling season, Veto Lake was stratified on all dates except in September 2016. Hypoxic conditions reached to within two meters of the surface signifying that the internal loading of nutrients in Veto Lake is a factor in understanding the nutrient function of this system. The hypolimnion sampling showed ammonia ranging from below detection to 2.55 mg/L. Hypolimnetic generation of ammonia during stratification can rapidly convert to nitrate (NO_2-NO_3) during autumnal mixing. Phosphorus can be released from as deep as 20 cm into the sediment under hypoxic conditions and can account for 30 to 40 percent of a lake's phosphorus load (Søndegarrd, Jenson, & Jeppesen, 2003). The sequestration of total phosphorus in Veto Lake sediment at 1,030 mg/kg, and the generation of orthophosphate during periods of hypoxia indicates significant internal loading. The median epilimnion total phosphorus concentration was 45.5 parts per billion (ppb) and the median hypolimnion total phosphorus level was 124 ppb for the two years of sampling. This internal nutrient load is likely the cause of elevated chlorophyll-*a* concentrations and is a likely nutrient source for blue-green algal blooms.

Sediment Contamination

A sediment sample was collected in June 2015 and analyzed for metals, nutrients and semivolatile organic compounds (s-VOCs). All s-VOCs parameters were reported as below detection. Nickel concentration was above the TEC, but below the PEC and Ohio SRV and is unlikely to cause any harmful effects. All other sediment metals sampled were below Ohio SRV, TEC and PEC values.

Recreation Use

The recreation use was evaluated by measuring levels of *E. coli* bacteria at the lake boat ramp. The site was sampled 13 times over the two-year assessment period and respective geometric mean values were compared to the bathing water criterion of 126 cfu (colony forming units). The recreation use was considered to be in full attainment.

Phytoplankton Assessment

The phytoplankton community in Veto Lake was characterized based on water samples collected using an integrated tube sampler deployed to either a maximum of two meters (m) or two times the secchi depth if <1 m. Samples were collected during May and September of 2015 and June, August and September of 2016. phytoplankton samples were preserved with Lugol's and submitted to a contract lab (BSA) for identification and enumeration analysis. The phytoplankton present in a representative aliquot was identified to at least genus level (usually species) and cell densities (cells/L) and bio-volumes (μm^3/L) were estimated using standard identification and enumeration methods.

Phytoplankton communities exhibit a seasonal succession when factors like water temperature, nutrients, transparency and photoperiod favor certain types. Grazing by larval fish and zooplankton also has an effect. Temperate lakes in Ohio are usually dominated by diatoms in the spring until micronutrients such as silica are depleted. At this time, blue green algae often predominate in the fall, possessing the ability to control buoyancy and fix nitrogen from the atmosphere giving certain types a competitive edge.

In general, the population seems diverse and balanced, with six different classes of algae represented through the summer months, but only four classes of algae were present later in the summer. Although cyanobacteria (blue green algae) represented less than five percent of the total biovolume (μm^3/L) of phytoplankton in 2015, blue green algae did represent as much as 55 percent during August of 2016.

A community dominated by cyanobacteria (blue green algae) is a concern when types that produce cyanotoxins are present. For public beaches, a Recreational Public Health advisory is posted at surface water levels ≥6 ppb and a No Contact advisory is posted at levels ≥ 20 ppb, if human or animal illness is documented. Veto Lake is considered a recreation lake, so Microcystin, Cylindrospermopsin and Saxitoxin samples were collected three times each year. Results for all samples for Microcystin, Cylindrospermopsin and Saxitoxin were near or below the reporting limit. Genera documented with the ability to produce toxin included: *Anabeana*; *Aphanizomenon*; *Aphanocapsa*; *Cylindrospermopsis*; *Microcystis*; *Planktonlyngbya*; *Anabaenopsis*; and *Pseudanabaena*.

Forked Run Lake

Construction of the 102-acre Forked Run State Park began in May of 1951 and was completed in October 1952. The lake was stocked with fish and opened to the public the following year. The lake is used mostly as a recreational fishing lake although there is a public beach. Forked Run State Park is located adjacent to Shade River State Forest, bordering the park on the eastern and northern boundary. Much of the forest's 2,601 acres is second growth pitch pine and Virginia pine. The area is also rich in hardwoods such as oaks and hickories. Hemlock and mountain laurel are found in some of the deep gorges. Forked Run Lake is 2.5 miles long with 8.5 miles of shoreline and has 102 surface acres of water. The Forked Run Lake watershed is 8.7 mi^2 with 76.3 percent forested, 13.6 percent agricultural, 2.4 percent open water, 0.3 percent wetlands and 7.4 percent developed areas. The developed areas consist of roads and the park infrastructure including a Frisbee golf course and a campground. Most of the agricultural activity is confined to the headwaters of Forked Run or downstream of the dam in the Ohio River floodplain.

Lake Water Quality Assessment

Aquatic Life Use

Lake samples were collected during the 2015-16 recreation seasons. Data collected from near the surface is summarized in **Table 14**. Forked Run Lake was in full support of the existing ALU EWH criteria based on this sampling effort. Assessment of other lake parameters revealed slight variance from Ohio EPA benchmarks where the T-N median value of 425 ug/L was greater than the 25th percentile target (350 ug/l). The median secchi reading was below the regional expectations (2.16 m) as well where a 2 year median transparency of 1.61 m existed. During all 2015 and 2016 sampling efforts, Forked Run Lake was fully stratified, forming distinct density layers. Hypoxic conditions reached to within two meters of the lake surface, but surface D.O. concentrations were still sufficient to meet existing EWH criteria.

Table 16 — Summary of collected in Forked Run Lake. Values in bold are exceeding the criteria or greater than the 25th – percentile target.

Parameter	Secchi (m)	Chl. a (µg/L)	T- N (µg/L)	T-P (µg/L)	D.O. (mg/L)	pH (SU)	NH_3-N (mg/L)
ALU Benchmarks	≥2.16	≤6.2	≤350	≤14	≥5.0	6.5-9.0	WQS
5/27/2015	0.89	5.1	810	9.7	7.35	7.15	<
6/11/2015	1.14	3.6	190	8.6	6.85	7.64	<
7/7/2015	1.32	16.9	260	6.3	10.3	7.77	<
8/19/2015	1.75	3.5	440	9.0	6.19	7.52	0.014
9/23/2015	2.28	4.0	360	4.1	8.05	7.45	<
6/28/2016	0.96		700	20	8.03	7.52	<
7/11/2016	1.47	6.0	410	2.5	8.35	7.73	<
8/4/2016	2.13	4.7	320	28	6.58	7.15	<
8/31/2016	2.95	4.8	410	11	6.38	7.31	<
9/27/2016	2.56	5.5	550	10	7.68	6.90	<
Median	**1.61**	4.8	**425**	9.35	N/A	N/A	N/A

Sediment Contamination

A sediment sample was collected in June 2015 and analyzed for metals, nutrients s-VOCs. All s-VOCs parameters were below detection. Similar to Veto Lake, nickel concentration was above the TEC, but below the PEC and SRV making it unlikely to cause any harmful effects. Another metal, barium, was above the Ohio SRV, but was determined unlikely to cause any harmful effects. All other sediment metals sampled were below Ohio SRV, TEC and PEC values.

Recreation Use

The recreation use was evaluated by measuring levels of *E. coli* bacteria at the L-1 station near the boat ramp. The site was sampled 12 times over the two-year assessment period and respective geometric mean values were compared to the bathing water criterion of 126 cfu (colony forming units). The recreation use was considered to be in full attainment.

Phytoplankton Assessment

The phytoplankton community in Forked Run Lake was assessed in a similar manner to Veto Lake. In general, the population appears diverse and balanced, with six or seven different classes of algae present during the summer months. The phytoplankton community shifted during late summer and fall when only four classes of algae were present. Cyanobacteria represented less than one percent of the total biovolume ($\mu m^3/L$) of phytoplankton in each sample.

Forked Run Lake is considered a recreation lake, so Microcystin, Cylindrospermopsin and Saxitoxin samples were collected three times each year. Results for all samples for Microcystin, Cylindrospermopsin and Saxitoxin were near or below the reporting limit in each sampled collected. Genera documented with the ability to produce toxin, within the phytoplankton collected, included *Anabeana*, *Aphanizomenon*, *Aphanocapsa*, *Microcystin*, *Planktonlyngbya*, and *Pseudanabaena*.

Fish Tissue Contamination

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 (for example, 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 a 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 ***epa.ohio.gov/dsw/fishadvisory/index.aspx***.

Prior to the 2015 sampling, the Shade River had no consumption advisories in place for any species.

The minimum data requirement for issuing a new fish advisory is three samples of a single species from within the past 10 years. After the 2015 sampling, for the Shade River, only one species (freshwater drum) met this requirement. As a result of the 2015 sampling, a one meal per month advisory was posted for freshwater drum in the Shade River due to mercury.

For all other species, the statewide advisories apply: two meals a week for sunfish (bluegill) and yellow perch; one meal a week for most other fish; and one meal a month for flathead catfish 23" and over, and northern pike 23" and over.

For a listing of fish tissue data collected from Shade River in support of the advisory program, and how the data compare to advisory thresholds, see Table 15 and Table 16.

Table 17 — Select fish tissue mercury data from 2015 Shade River sampling (mg/kg). The shading indicates the advisory category that each sample falls into. Blue = unrestricted; green = two meals per week; yellow = one meal per week; orange = one meal per month.

Site	River Mile	Sample Type	Species	Result
Shade R. dst. Chester at gage at Twp. Rd. 112	11.64	Fillet	Channel Catfish	0.097
Shade R. at Chester at St. Rte. 248	17.13	Fillet	Freshwater Drum	0.546
Shade R. at Chester at St. Rte. 248	17.13	Fillet	Freshwater Drum	0.549
Shade R. at Chester at St. Rte. 248	17.13	Fillet	Freshwater Drum	0.424

Table 18 — Select fish tissue PCB data from 2015 Shade River sampling (mg/kg). The shading indicates the advisory category that each sample falls into. Blue = unrestricted; green = two meals per week; yellow = one meal per week; orange = one meal per month.

Site	River Mile	Sample Type	Species	Result	Detected?
Shade R. dst. Chester at gage at Twp. Rd. 112	11.64	Fillet	Channel Catfish	0.02	No
Shade R. at Chester at St. Rte. 248	17.13	Fillet	Freshwater Drum	0.0199	No
Shade R. at Chester at St. Ret. 248	17.13	Fillet	Freshwater Drum	0.0199	No
Shade R. at Chester at St. Rte. 248	17.13	Fillet	Freshwater Drum	0.0199	No

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 2016 Integrated Report, Section E*** (***epa.ohio.gov/Portals/35/tmdl/2016intreport/SectionE.pdf***) for details of this conversion.].

To be considered in attainment of the water quality standards, the sport fish caught within a HUC12 watershed must have a weighted average concentration of the geometric means for all species below 1 mg/kg for mercury, and below 0.054 mg/kg for PCBs, within the Ohio River basin.

Within the Shade River study area, fish tissue data were not adequate to determine attainment status for the WAU that was sampled. At least two samples from each trophic level, 3 and 4, were needed for each WAU. Prior to the 2015 sampling, the Spruce Creek-Shade River WAU was considered impaired based on historical (outdated) information (attainment category 5h), but insufficient new data was collected to reevaluate this WAU during the upcoming assessment cycle, so this WAU remains impaired based on historical data. Table 17 below shows these details.

Table 19 — Updates to attainment status for the Shade River study area in Ohio's 2018 Integrated Report.

Unit	Name	Previous (2016) Status	Revised (2018) Status
5030202 03 04	Spruce Creek-Shade River	5h	5h

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.

Fish tissue had previously been collected from the Shade River in 1974, 1996, 1997 and 2002. Of the data collected in Shade River in the study intervals, mercury concentrations are shown in Figure 38 for those species that have been collected for at least two years. No clear trends emerge from the data, beyond what appears to be a general reduction in mercury levels since the 1974 sampling, with some up-and-down fluctuation between samples of a given species between years. Similar fluctuations are routinely observed for mercury results in Ohio's watersheds, especially when sample sizes are relatively small such as in the present case. All species averages in Figure 38 fall into the one meal per month advisory range (between 0.22 and 1 mg/kg) or better.

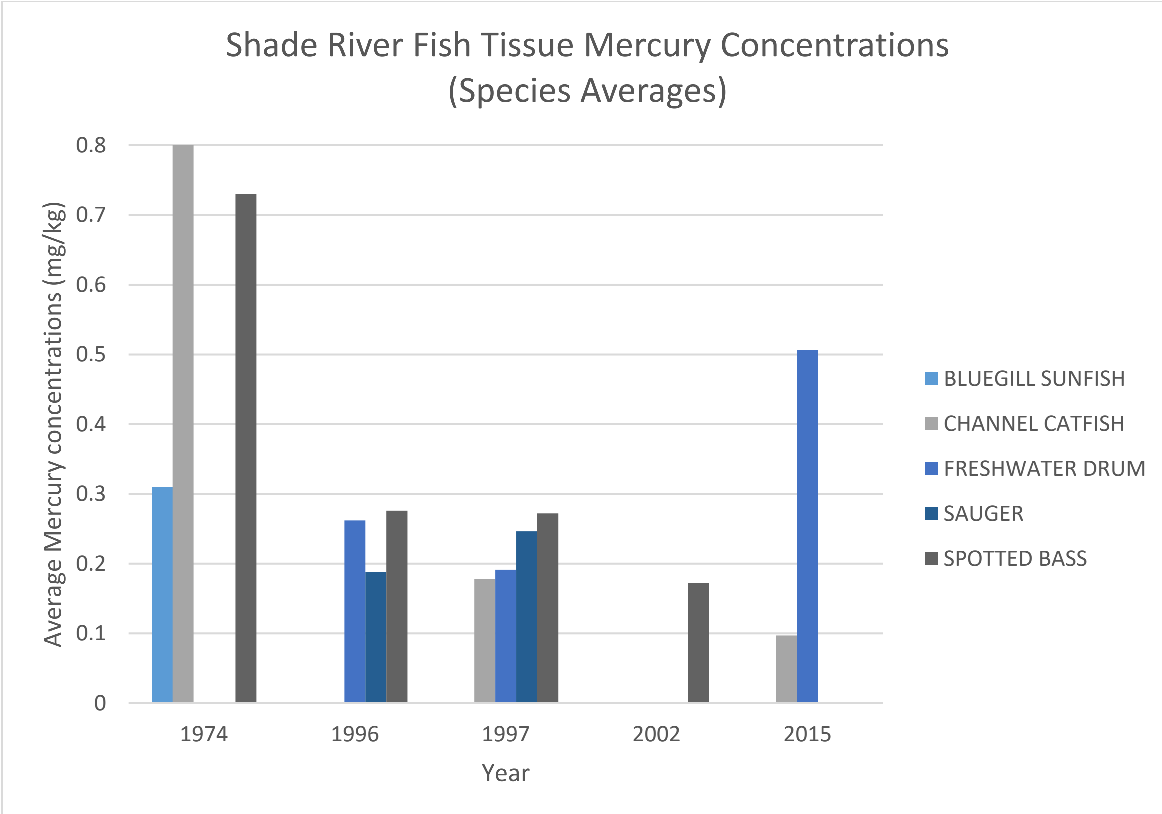

Figure 38 — Mercury concentrations in fish tissue in the Shade River, 1974-2015, showing only those species that had at least two years of data to compare.

The other major fish tissue contaminant of concern, polychlorinated biphenyls or PCBs, were detected at generally low concentrations (Figure 39) in the Shade River. Except for freshwater drum in 1996 and 1997, all species averages shown are below the 0.22 mg/kg threshold for issuing a one meal per month consumption advisory. Although the sample sizes were small, making any trends analysis challenging, PCB concentrations appear to be generally steady or decreasing since PCB monitoring began in 1996, except for an observed increase in spotted bass PCBs in 2002. The elevated species average for spotted bass in 2002 is the result of a single bass sample that had elevated levels of PCBs collected approximately seven miles upstream of the mouth at the Ohio River. Moderate levels of PCB contamination of sediments and fish are common in the Ohio River, and it is possible that spotted bass from the Ohio traveled up the Shade River and were sampled by the survey crew, leading to this anomalous result.

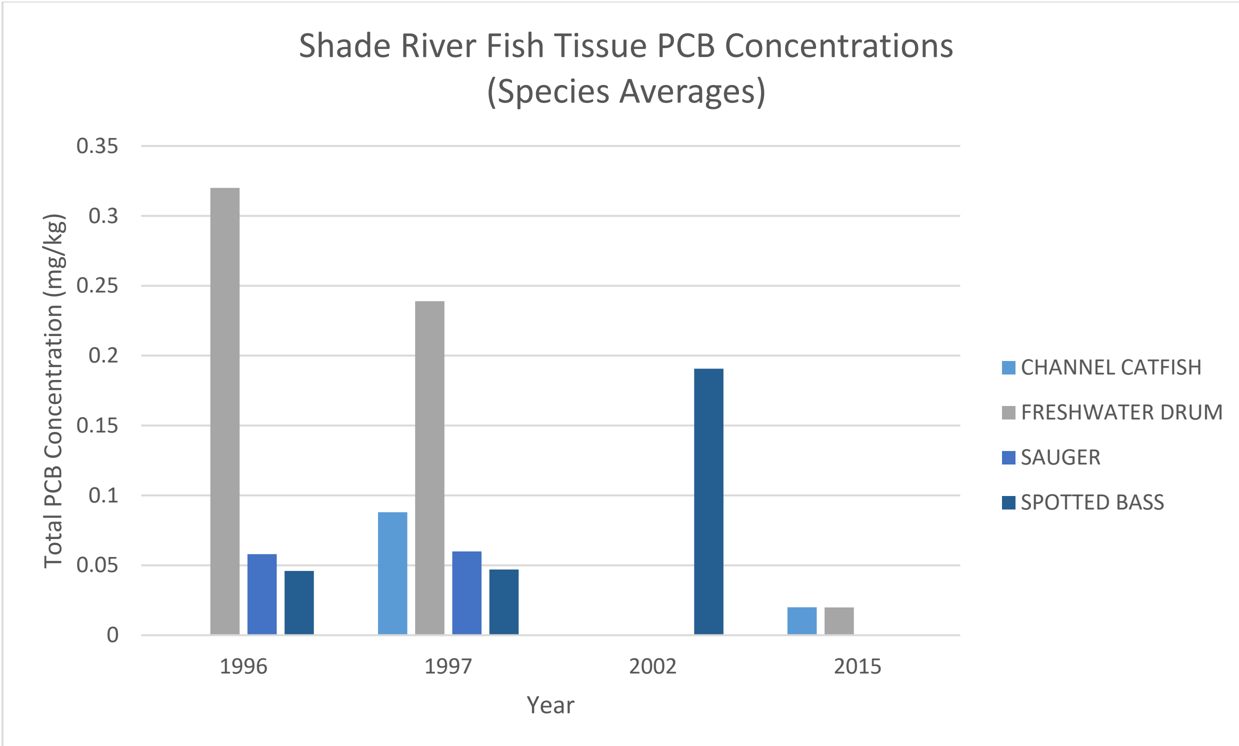

Figure 39 — Total PCB concentrations in fish tissue in the Shade River, 1996-2015, Showing only those species that had at least two years of data to compare. Values below 0.05 mg/kg represent non-detects for that species and year.

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