Biological and Water Quality Study of the East Fork Little Miami River and Select Tributaries, 2012

Brown, Clermont, Clinton, Highland and Warren Counties, Ohio

Ohio EPA Technical Report EAS/2014-05-05

Division of Surface Water
Ecological Assessment Section
May 16, 2014

Biological and Water Quality Study of the East Fork Little Miami River Watershed Brown, Clermont, Clinton, Highland, and Warren Counties

May 16, 2014

Ohio EPA Technical Report EAS/2014-05-05

Prepared by
State of Ohio Environmental Protection Agency
Division of Surface Water
Lazarus Government Center
50 West Town Street, Suite 700

Mail to:
P.O. Box 1049, Columbus, Ohio 43216-1049
Central District Office
Lazarus Government Center
50 West Town Street, Suite 700
Columbus, Ohio 43215

Southwest District Office
401 East Fifth Street
Dayton, Ohio 45402

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

John R. Kasich
Governor, State of Ohio
Craig W. Butler
Director, Ohio Environmental Protection Agency

Table of Contents

List of Tables

List of Figures

List of Appendices

ACKNOWLEDGEMENTS
Study Area Description – Hugh Trimble and Bob Miltner
Pollutant Loadings – Bob Miltner and Mary Mahr
Chemical Water Quality – Bob Miltner and Louise Snyder
Sediment Quality - Bob Miltner
Physical Habitat Quality – Bob Miltner
Biological Assessment - Bob Miltner
Recreational Assessment – Louise Snyder and Bob Miltner
Data Management - Bob Miltner and Dennis Mishne
Reviewers – Diana Zimmerman, Jeff DeShon, Holly Tucker and Paul Gledhill

Water chemistry analysis was provided by the Ohio EPA division of Environmental Services. Numerous college interns and district office staff assisted in the collection of field samples.

Landowners who granted permission for site access are duly appreciated.

Copies of this report are located on the Ohio EPA internet web page (www.epa.state.oh.us/dsw/document_index/psdindx.html) or may be available on CD from:

Ohio EPA
Division of Surface Water
Ecological Assessment Section
4675 Homer Ohio Lane
Groveport, Ohio 43125
(614) 836-8777

FOREWORD

What is a Biological and Water Quality Survey?
A biological and water quality survey, or "biosurvey", is an interdisciplinary monitoring effort coordinated on a waterbody specific or watershed scale. This effort may involve a relatively simple setting focusing on one or two small streams, one or two principal stressors, and a handful of sampling sites or a much more complex effort including entire drainage basins, multiple and overlapping stressors, and tens of sites. Each year Ohio EPA conducts biosurveys in 4-5 watersheds study areas with an aggregate total of 350-400 sampling sites.

The Ohio EPA employs biological, chemical, and physical monitoring and assessment techniques in biosurveys in order to meet three major objectives: 1) determine the extent to which use designations assigned in the Ohio Water Quality Standards (WQS) are either attained or not attained; 2) determine if use designations assigned to a given water body are appropriate and attainable; and 3) determine if any changes in key ambient biological, chemical, or physical indicators have taken place over time, particularly before and after the implementation of point source pollution controls or best management practices. The data gathered by a biosurvey is processed, evaluated, and synthesized in a biological and water quality report. Each biological and water quality study contains a summary of major findings and recommendations for revisions to WQS, future monitoring needs, or other actions which may be needed to resolve existing impairment of designated uses. While the principal focus of a biosurvey is on the status of aquatic life uses, the status of other uses such as recreation and water supply, as well as human health concerns, are also addressed.

The findings and conclusions of a biological and water quality study may factor into regulatory actions taken by Ohio EPA (e.g., NPDES permits, Director's Orders, the Ohio Water Quality Standards [OAC 3745-1], Water Quality Permit Support Documents [WQPSDs]), and are eventually incorporated into the biennial Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]) and Total Maximum Daily Load (TMDL) reports developed to address identified pollutants impairing Ohio waterbodies.

Hierarchy of Indicators
A carefully conceived ambient monitoring approach, using cost-effective indicators consisting of ecological, chemical, and toxicological measures, can ensure that all relevant pollution sources are judged objectively on the basis of environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach includes a hierarchical continuum from administrative to true environmental indicators (Figure i). The six "levels" of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination,

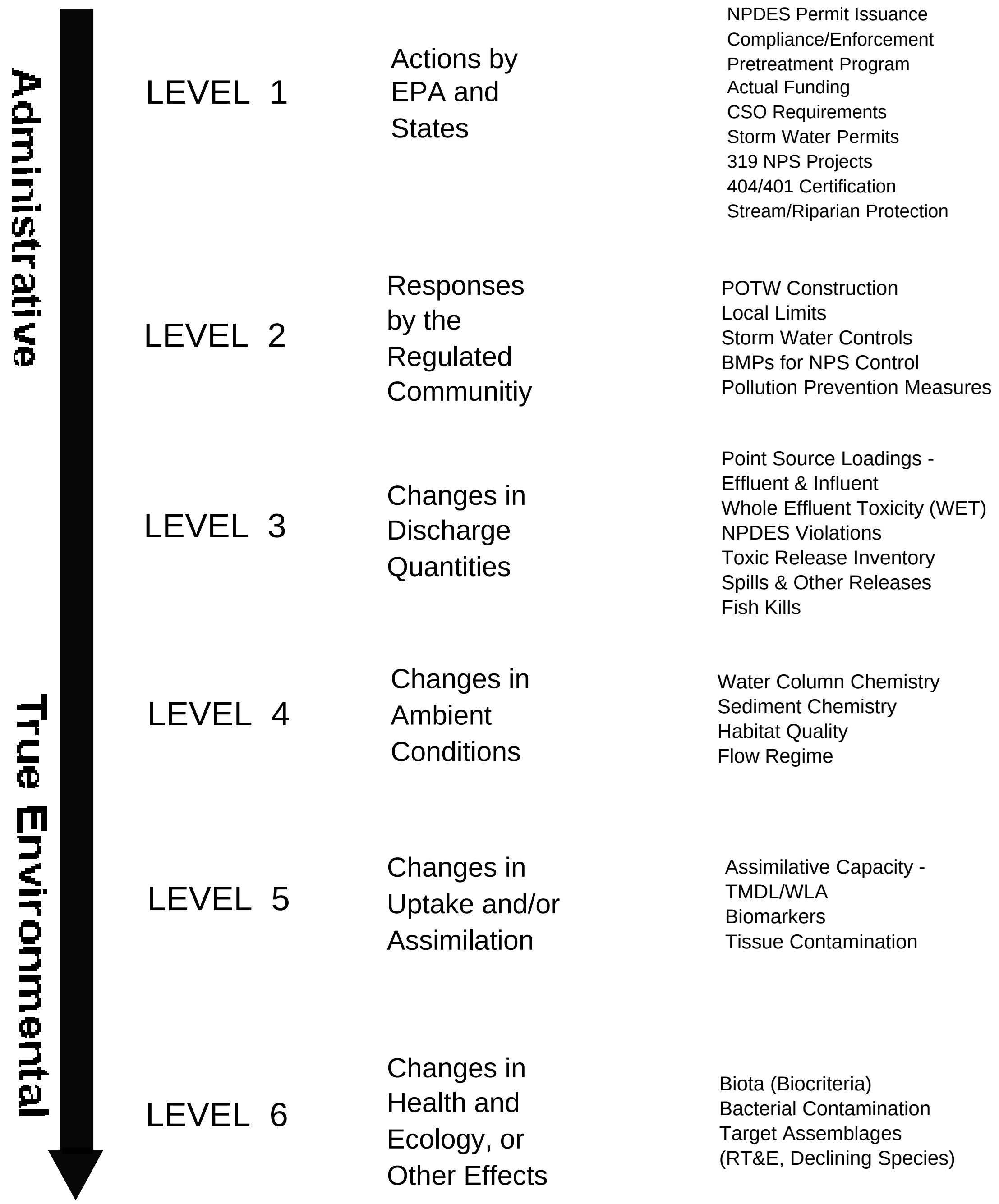


Figure i. Hierarchy of administrative and environmental indicators which can be used for water quality management activities such as monitoring and assessment, reporting, and the evaluation of overall program effectiveness. This is patterned after a model developed by the U.S. EPA.

biomarkers, wasteload allocation); and, 6) changes in health, ecology, or other effects (ecological condition, pathogens). In this process the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4, and 5) which should translate into the environmental results (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition. Superimposed on this hierarchy is the concept of stressor, exposure, and response indicators. Stressor indicators generally include activities which have the potential to degrade the aquatic environment such as pollutant discharges (permitted and unpermitted), land use effects, and habitat modifications. Exposure indicators are those which measure the effects of stressors and can include whole effluent toxicity tests, tissue residues, and biomarkers, each of which provides evidence of biological exposure to a stressor or bioaccumulative agent. Response indicators are generally composite measures of the cumulative effects of stress and exposure and include the more direct measures of community and population response that are represented here by the biological indices which comprise Ohio's biological criteria. Other response indicators could include target assemblages, i.e., rare, threatened, endangered, special status, and declining species or bacterial levels which serve as surrogates for the recreation uses. These indicators represent the essential technical elements for watershed-based management approaches. The key, however, is to use the different indicators within the roles which are most appropriate for each.

Describing the causes and sources associated with observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data, and biological response signatures within the biological data itself. Thus the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The principal reporting venue for this process on a watershed or subbasin scale is a biological and water quality report. These reports then provide the foundation for aggregated assessments such as the Integrated Water Quality Monitoring and Assessment Report (305[b] and 303[d]), the Ohio Nonpoint Source Assessment, and other technical bulletins.

Ohio Water Quality Standards: Designated Aquatic Life Use

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

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

2) Exceptional Warmwater Habitat (EWH) - this use designation is reserved for waters which support “unusual and exceptional” assemblages of aquatic organisms which are characterized by a high diversity of species, particularly those which are highly intolerant and/or rare, threatened, endangered, or special status (i.e., declining species); this designation represents a protection goal for water resource management efforts dealing with Ohio’s best water resources.

3) Cold-water Habitat (CWH) - this use is intended for waters which support assemblages of cold water organisms and/or those which are stocked with salmonids with the intent of providing a put-and-take fishery on a year round basis which is further sanctioned by the Ohio DNR, Division of Wildlife; this use should not be confused with the Seasonal Salmonid Habitat (SSH) use which applies to the Lake Erie tributaries which support periodic “runs” of salmonids during the spring, summer, and/or fall.

4) Modified Warmwater Habitat (MWH) - this use applies to streams and rivers which have been subjected to extensive, maintained, and essentially permanent hydromodifications such that the biocriteria for the WWH use are not attainable and where the activities have been sanctioned by state or federal law; the representative aquatic assemblages are generally composed of species which are tolerant to low dissolved oxygen, silt, nutrient enrichment, and poor quality habitat.

5) Limited Resource Water (LRW) - this use applies to small streams (usually <3 mi^2 drainage area) and other water courses which have been irretrievably altered to the extent that no appreciable assemblage of aquatic life can be supported; such waterways generally include small streams in extensively urbanized areas, those which lie in watersheds with extensive drainage modifications, those which completely lack water on a recurring annual basis (i.e., true ephemeral streams), or other irretrievably altered waterways.

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

Ohio Water Quality Standards: Non-Aquatic Life Uses

In addition to assessing the appropriateness and status of aquatic life uses, each biological and water quality survey also addresses non-aquatic life uses such as recreation, water supply, and human health concerns as appropriate. The recreation uses most applicable to rivers and streams are the Primary Contact Recreation (PCR) and Secondary Contact Recreation (SCR) uses. The criterion for designating the PCR use can be having a water depth of at least one meter over an area of at least 100 square feet or, lacking this, where frequent human contact is a reasonable expectation. If a water body does not meet either criterion, the SCR use applies. The attainment status of PCR and SCR is determined using bacterial indicators (e.g., fecal coliform, *E. coli*) and the criteria for each are specified in the Ohio WQS.

Attainment of recreation uses are evaluated based on monitored bacteria levels. The Ohio Water Quality Standards state that all waters should be free from any public health nuisance associated with raw or poorly treated sewage (Administrative Code 3745-1-04, Part F). Additional criteria (Administrative Code 3745-1-07) apply to waters that are designated as suitable for full body contact such as swimming (PCR- primary contact recreation) or for partial body contact such as wading (SCR- secondary contact recreation). These standards were developed to protect human health, because even though fecal coliform bacteria are relatively harmless in most cases, their presence indicates that the water has been contaminated with fecal matter.

Water supply uses include Public Water Supply (PWS), Agricultural Water Supply (AWS), and Industrial Water Supply (IWS). Public Water Supplies are simply defined as segments within 500 yards of a potable water supply or food processing industry intake. The AWS and IWS use designations generally apply to all waters unless it can be clearly shown that they are not applicable. An example of this would be an urban area where livestock watering or pasturing does not take place, thus the AWS use would not apply. Chemical criteria are specified in the Ohio WQS for each use and attainment status is based primarily on chemical-specific indicators. Human health concerns are additionally addressed with fish tissue data, but any consumption advisories are issued by the Ohio Department of Health.

Executive Summary

Fifty-two percent of the 88 stream sites sampled during the 2012 survey of the East Fork Little Miami River (LMR) basin were biologically impaired (Figure 1; Tables 1 and 2). The principal cause of impairment was low dissolved oxygen levels caused primarily by organic enrichment, and to a lesser extent nutrient enrichment, but frequently exacerbated in both cases by naturally occurring low stream flow, and less frequently by poor habitat. Sources of organic and nutrient enrichment included publicly owned treatment facilities, small package plants, and diffuse pollution from agriculture and on-site sewage systems. Soils in Clermont County are, without exception, ill-suited to supporting on-site sewerage. Native parent material is also a source of phosphorus, and given the low nitrogen to phosphorus ratios (median ratio of all sites ~ 4.5), autotrophic nitrogen fixation is likely. Poor habitat was the driver of impairment at three sites, and urban stormwater was responsible for impairing two sites.

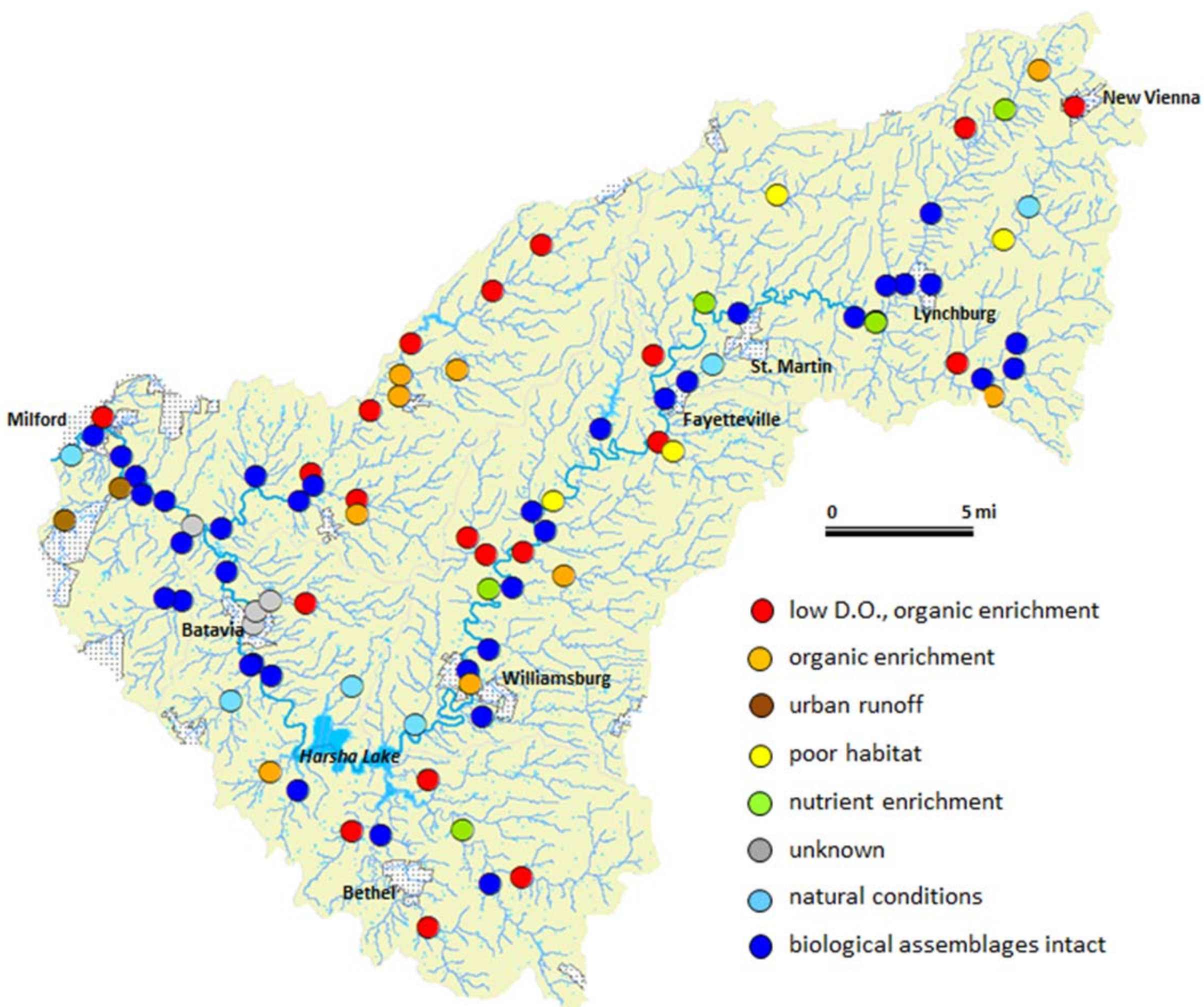


Figure 1. Locations sampled during the 2012 East Fork Little Miami River survey color-coded to condition status as arrayed by the most proximate cause (where applicable) of impairment (*n.b.*, low dissolved oxygen is typically a manifestation of organic enrichment, whereas organic enrichment is a more encompassing source of stress).

Twenty-three (of the 88) sampling locations were located on the East Fork LMR mainstem, 12 of which were impaired. For those impaired upstream from Harsha Lake (8 sites), most were due to low dissolved oxygen levels and poor habitat. However, for the 4 impaired sites located downstream from Harsha Lake, no pollutant could be associated as a cause. Relative to 1998, fish and macroinvertebrate assemblages in the East Fork LMR mainstem downstream from Harsha Lake showed no trend. For the watershed as a whole, the condition of fish and macroinvertebrate assemblages showed modest improvement.

Table 1. Attainment status by 12-digit hydrologic assessment unit.

HUC_12	NAME	Full	Non	Causes
050902021001	Turtle Creek	2	1	Nutrient Enrichment
050902021002	Headwaters East Fork Little Miami River	3	2	Organic Enrichment
050902021003	Headwaters Dodson Creek	2	1	Habitat
050902021004	Anthony Run-Dodson Creek	2	1	Nutrient Enrichment
050902021005	West Fork East Fork Little Miami River	1	1	Habitat
050902021006	Glady Creek-East Fork Little Miami River	5	3	Organic Enrichment
050902021101	Solomon Run-East Fork Little Miami River	5	2	Habitat, Low D.O.
050902021102	Fivemile Creek-East Fork Little Miami River	7	2	Organic Enrichment
050902021103	Todd Run-East Fork Little Miami River	1	1	Nutrient Enrichment
050902021201	Poplar Creek	1	2	Low D.O.
050902021202	Cloverlick Creek	1	3	Low D.O.
050902021203	Lucy Run-East Fork Little Miami River	4	3	Natural
050902021204	Backbone Creek-East Fork Little Miami River	4	2	Low D.O.
050902021301	Headwaters Stonelick Creek	0	3	Organic Enrichment
050902021302	Brushy Fork	1	2	Low D.O.
050902021303	Moores Fork-Stonelick Creek	3	2	Low D.O./Org. Enrich.
050902021304	Lick Fork-Stonelick Creek	3	0	
050902021305	Salt Run-East Fork Little Miami River	10	2	Low D.O.
Small Streams (<50mi2)		36	32	
Principal Streams (≥50mi2)		12	8	Unknown, Low D.O., Habitat

As for publicly owned treatment works or small package plants that were identified as sources of impairment, stream monitoring demonstrated high ammonia concentrations coincidental with low dissolved oxygen levels downstream from the New Vienna WWTP. Flows from the Batavia WWTP were frequently in excess of average design flow, but flows from that plant were recently directed to the Middle East Fork WWTP, where capacity exists to handle the flow. The Williamsburg WWTP (1PB00034) experienced numerous permit violations due to excessive ammonia, especially in 2010 and 2011. Recent improvements to the plant likely have remedied the problem. Lastly, the package plant serving the Locust Ridge Nursing Home (1PX00059) was under construction during 2012, and not discharging to Light Run. Light Run is a tributary to Cloverlick Creek (confluence at RM 4.37).

Table 2. Attainment status of sites sampled during the 2012 East Fork Little Miami River survey. The aquatic life use is Warmwater Habitat unless otherwise noted by an epsilon $^{\varepsilon}$ superscript denoting Exceptional Warmwater Habitat. Letters following drainage area denote sampling method used for fish: A – boat, D – Wading, E – Longline.

STORET	DA	RM	QHEI	IBI	MIWB	ICI	STATUS	Cause	Source
11-100-000	***East Fork Little Miami River***								
M04S17	3.0 E	84.1	58.5	38^{ns}		F	Partial	Low D.O., marginal habitat	Runoff from New Vienna
M04S35	5.4 E	82.4	76.8	34*		F	Non	Low D.O., organic enrichment	New Vienna
M04S16	12.8 E	80.4	67.5	50		42	Full	Threatened by nutrient enrichment - carry-over from upstream organic enrichment	
M04S15 $^{\varepsilon}$	26.2 D	75.3	69.8	51	9.9	42^{ns}	Full		
200506 $^{\varepsilon}$	48.0 D	72.8	77.5	52	9.8	42 ^{ns}	Partial		
M04S34 $^{\varepsilon}$	54.0 D	70.9	71.0	50	10.0	VG	Full		
M04S14 $^{\varepsilon}$	88.0 D	70.1	73.3	53	9.7	VG	Full		
200504 $^{\varepsilon}$	100.0 D	63.4	80.5	52	9.9	48	Full		
M04S13 $^{\varepsilon}$	151.0 D	56.3	78.3	47 ^{ns}	9.5	50	Full		
M04S12 $^{\varepsilon}$	165.0 D	54.4	68.8	45 *	8.7*	44 ^{ns}	Partial	Low D.O.; historic channelization	Agriculture, natural
301738 $^{\varepsilon}$	178.0 D	46.9	68.8	40*	7.9*	46	Partial	Historic Channelization	
M04S10 $^{\varepsilon}$	221.0 D	41.1	77.8	45 *	8.7*	46	Partial	Unknown	
M04S09 $^{\varepsilon}$	235.0 D	35.9	80.8	51	9.9	46	Full		
M04S08 $^{\varepsilon}$	237.0 D	34.9	70.5	46^{ns}	8.8*	50	Partial	Organic enrichment	Williamsburg

Table 2. Attainment status of sites sampled during the 2012 East Fork Little Miami River survey. The aquatic life use is Warmwater Habitat unless otherwise noted by an epsilon $^{\varepsilon}$ superscript denoting Exceptional Warmwater Habitat. Letters following drainage area denote sampling method used for fish: A – boat, D – Wading, E – Longline.

STORET	DA	RM	QHEI	IBI	MIWB	ICI	STATUS	Cause	Source
11-100-000	***East Fork Little Miami River***								
M04S06 $^{\varepsilon}$	352.0 D	15.6	82.8	49 ^{ns}	8.9 ^{ns}	46	Full		
M04S31 $^{\varepsilon}$	363.0 D	13.8	80.0	47 ^{ns}	8.7*	E	Partial	Unknown	
M04S05 $^{\varepsilon}$	364.0 D	13.2	81.0	44	8.7*	56	Partial	Unknown	
M04S04 $^{\varepsilon}$	375.0 D	11.5	85.0	46 ^{ns}	9.5	52	Full		
M04S03 $^{\varepsilon}$	380.0 D	9.1	87.0	45	8.6*	48	Partial	Unknown	
M04W34 $^{\varepsilon}$	484.0 D	5.6	83.3	47 ^{ns}	9.0	52	Full		
M04W38 $^{\varepsilon}$	491.0 D	4.3	83.0	49	9.3	52	Full		
M04S29 $^{\varepsilon}$	494.0 A	2.2	82.5	45 ^{ns}	10.2	52	Full		
610530 $^{\varepsilon}$	498.0 A	0.8	72.3	42*	9.4	50	Partial	Natural conditions	
11-100-003	***Trib. to E. Fk. L. Miami R. (RM 78.45)***								
M04P04	4.0 E	0.5	52.3	42		MG	Full		
11-100-007	***GLADY CREEK***								
301885	4.2 E	0.7	66.5	50		MG	Full		
11-101-000	***Hall Run***								
200481	3.1 E	2.3	58.0	26		F	Non	Low D.O., condition exacerbated by low flow	Urban runoff
M04P13	5.5 E	0.2	47.8	30		F	Non	Low D.O., condition exacerbated by low flow and poor habitat	Urban runoff

Table 2. Attainment status of sites sampled during the 2012 East Fork Little Miami River survey. The aquatic life use is Warmwater Habitat unless otherwise noted by an epsilon $^{\varepsilon}$ superscript denoting Exceptional Warmwater Habitat. Letters following drainage area denote sampling method used for fish: A – boat, D – Wading, E – Longline.

STORET	DA	RM	QHEI	IBI	MIWB	ICI	STATUS	Cause	Source
11-103-000	***Salt Run***								
M99Q10	6.4 E	0.4	65.8	48		MG	Full		
11-104-000	***Sugarcamp Run***								
M04P12	3.6 E	0.2	59.3	44		G	Full		
11-105-000	***Shayler Run***								
M04S38	4.9 E	5.2	71.5	48		MG	Full		
M04S37	12.1 E	1.7	67.5	44		G	Full		
11-105-001	***Trib. to Shayler Run (RM 4.40)***								
M04S40	4.4 E	0.4	63.8	40		MG	Full		
11-107-000	***Stonelick Creek***								
200492	4.9 E	20.0	57.3	38		F	Partial	Low D.O., organic enrichment, condition exacerbated by low flow	Unkown, Agriculture
M04S42	11.6 E	17.7	64.0	30		MG	Non	Low D.O., organic enrichment condition exacerbated by low flow	Stonelick Reservior backwaters
301905	23.0 E	13.4	73.0	32	5.6	F	Non	Low D.O., organic enrichment, condition exacerbated by low flow	Stonelick Reservior
M04S41	38.0 D	9.8	69.0	34	6.3	G	Partial	Low D.O., organic enrichment, condition exacerbated by low flow	Stonelick Reservior
301906	43.3 E	6.2	66.8	37	7.9	G	Full		
M99Q14	62.0 D	5.2	67.3	44	8.4	VG	Full		
M04P09	75.0 D	1.0	66.5	42	8.9	VG	Full	Threatened by nutrient enrichment, algae cover thick	

Table 2. Attainment status of sites sampled during the 2012 East Fork Little Miami River survey. The aquatic life use is Warmwater Habitat unless otherwise noted by an epsilon $^{\varepsilon}$ superscript denoting Exceptional Warmwater Habitat. Letters following drainage area denote sampling method used for fish: A – boat, D – Wading, E – Longline.

STORET	DA	RM	QHEI	IBI	MIWB	ICI	STATUS	Cause	Source
11-107-002	***Trib. to Stonelick Creek (RM 10.61)***								
301148	2.0 E	0.9	61.8	34		P	Non	organic enrichment, condition exacerbated bv low flow	Newtonsville
11-108-000	***Lick Fork***								
200466	6.3 E	0.6	72.0	56		VG	Full		
11-109-000	***Brushy Fork***								
301911	5.7 E	2.2	49.0	26		G	Non	Low D.O., condition exacerbated by low flow and bedrock habitat	
301912	14.8 E	0.3	55.8	46		MG	Full		
11-111-000	***Patterson Run***								
301913	4.2 E	0.1	57.3	20		MG	Non	Low flow, organic enrichment, condition exacerbated by marginal habitat	Clermont NE Local Schools
11-112-000	***Moores Fork***								
301909	4.6 E	2.9	63.0	38		MG	Full		HSTS
301910	10.6 E	0.7	66.5	38		MG	Full		HSTS
11-115-000	***Backbone Creek***								
301903	7.4 E	0.6	65.5	36		G	Partial		
11-115-001	***Trib to Backbone (1.36)***								
301904	3.8 E	0.9	62.8	28		G	Partial	Low D.O., condition exacerbated by low flow	Unknown, Natural
11-116-000	***Lucy Run***								
M04S44	3.7 E	1.9	63.5	30		G	Partial	Low flow, no riffle	Natural
M04S43	7.2 E	0.1	58.8	38		MG	Full	Threatened, enrichment indicators not elevated, but bio declining	

Table 2. Attainment status of sites sampled during the 2012 East Fork Little Miami River survey. The aquatic life use is Warmwater Habitat unless otherwise noted by an epsilon $^{\varepsilon}$ superscript denoting Exceptional Warmwater Habitat. Letters following drainage area denote sampling method used for fish: A – boat, D – Wading, E – Longline.

STORET	DA	RM	QHEI	IBI	MIWB	ICI	STATUS	Cause	Source
11-117-000	***Fourmile Run***								
M99Q15	3.5 E	0.2	76.8	52		VG	Full		
11-118-000	***Back Run***								
301902	2.4 E	1.2	73.0	34		F	Non	Low flow, no riffle	Natural, small package plant
11-119-000	***Ulrey Run***								
200497	3.5 E	1.3	61.5	38		G	Full		
11-120-000	***Slabcamp Run***								
M04S45	0.7 E	2.6	65.8	12		P	Non		
11-121-000	***Cloverlick Creek***								
301898	12.4 E	8.5	64.3	28		HF	Non	Low D.O., condition exacerbated by low flow	Unknown, Agriculture
200468	23.0 E	5.2	62.0	34	7.1	G	Partial	Low D.O. accompanied by D.O. swing >11 mg/l	Unknown, Agriculture
11-121-002	***TRIB TO CLOVERLICK CR (7.48)***								
301899	6.9 E	0.5	64.5	38		MG	Full		
11-122-000	***Barnes Run***								
200469	7.9 E	1.9	64.3	30		MG	Partial	Low D.O. - unknown source	Unknown, Agriculture
11-123-000	***Poplar Creek***								
301900	5.8 E	8.4	70.5	28		F	Non	Low D.O., condition exacerbated by low flow	Unknown, Agriculture
200499	17.5 E	2.1	66.0	44		VG	Full		
11-124-000	***Sugartree Creek***								
301901	3.6 E	1.0	58.8	34		F	Non	Low D.O., condition exacerbated by low flow	

Table 2. Attainment status of sites sampled during the 2012 East Fork Little Miami River survey. The aquatic life use is Warmwater Habitat unless otherwise noted by an epsilon $^{\varepsilon}$ superscript denoting Exceptional Warmwater Habitat. Letters following drainage area denote sampling method used for fish: A – boat, D – Wading, E – Longline.

STORET	DA	RM	QHEI	IBI	MIWB	ICI	STATUS	Cause	Source
11-132-000	***Kain Run***								
200471	5.9 E	0.3	64.0	30		G	Non	Bedrock, low flow, nutrient	Natural, Urban runoff
11-133-000	***Todd Run***								
200473	9.4 E	1.0	58.3	42		G	Full		
11-135-000	***Crane Run***								
301897	8.9 E	0.2	72.8	44		G	Full		
11-136-000	***Fourmile Creek***								
301896	5.5 E	0.3	60.0	46		G	Full		
11-137-000	***Pleasant Run***								
M04S22	5.3 E	1.4	67.5	42		MG	Full		
M04S46	7.8 E	0.4	62.5	38		HF	Full		
11-138-000	***Fivemile Creek***								
301895	8.3 E	2.3	54.3	32		F	Non	Organic enrichment, condition exacerbated by low flow and marginal habitat	Unknown, Agriculture
M04S49	10.6 E	0.5	51.5	36		MG	Partial	Low D.O., organic enrichment, condition exacerbated by low flow	Unknown, Agriculture
11-141-000	***Howard Run***								
301894	5.6 E	0.4	75.3	40		G	Full		
11-142-000	***Grassy Fork***								
301345	6.3 E	0.2	67.3	36		MG	Full		

Table 2. Attainment status of sites sampled during the 2012 East Fork Little Miami River survey. The aquatic life use is Warmwater Habitat unless otherwise noted by an epsilon $^{\varepsilon}$ superscript denoting Exceptional Warmwater Habitat. Letters following drainage area denote sampling method used for fish: A – boat, D – Wading, E – Longline.

STORET	DA	RM	QHEI	IBI	MIWB	ICI	STATUS	Cause	Source
11-143-000	***Glady Run***								
M04W08	5.3 E	0.8	61.0	38		G	Full		
11-144-000	***Saltlick Creek***								
301893	5.7 E	0.6	51.5	28		HF	Non	Marginal habitat, condition exacerbated bv low flow	Natural
11-147-000	***Solomon Run***								
M04W05	6.1 E	1.9	55.5	36		MG	Full	Low D.O., organic enrichment, condition exacerbated by low flow	Natural
11-147-001	***Murray Run***								
301927	3.2 E	0.1	68.0	42		MG	Full		
11-149-000	***Sycamore Creek***								
200474	6.6 E	0.8	56.8	40		Fair	Partial	Low D.O., marginal habitat, organic enrichment, condition exacerbated by low flow	
11-150-000	***West Fork East Fork Little Miami River***								
301891	8.2 E	7.5	39.5	26		F	Non	Poor habitat, condition exacerbated bv low flow	Natural
M04S50	28.3 E	0.1	71.8	44	7.8	G	Full	Wide D.O. swing, carry over from usptream conditions	Channelization
11-151-000	***Dodson Creek – EWH Existing/WWH Recommended***								
301886 $^{\varepsilon}$	5.1 E	7.5	53.8	44		G	Partial/Full		
301887 $^{\varepsilon}$	16.1 E	5.8	54.0	46		40	Partial/Full		
M04S51 $^{\varepsilon}$	32.5 E	0.1	63.0	46	9.1	44	Full/Full	Threatened, wide D.O. swing, loosing stream exacerbates condition	
11-151-001	***TRIB TO DODSON CREEK (4.52)***								
301890	4.9 E	0.6	72.3	50		P	Non		

Table 2. Attainment status of sites sampled during the 2012 East Fork Little Miami River survey. The aquatic life use is Warmwater Habitat unless otherwise noted by an epsilon $^{\varepsilon}$ superscript denoting Exceptional Warmwater Habitat. Letters following drainage area denote sampling method used for fish: A – boat, D – Wading, E – Longline.

STORET	DA	RM	QHEI	IBI	MIWB	ICI	STATUS	Cause	Source
11-153-000	***S. FK. DODSON CREEK***								
301888	2.3 E	0.9	44.5	34		P	Non	Organic enrichment, low D.O., condition exacerbated by poor habitat and low flow	Low-head dam at Roush Road
11-153-001	***TRIB TO S. FK DODSON CR (0.37)***								
301889	6.5 E	0.9	72.3	52		G	Full		
11-154-000	***Turtle Creek***								
301884	5.6 E	5.9	59.5	44		MG	Full		
200508	13.7 E	4.4	44.8	36		F	Partial	Habitat limited by bedrock	Quarry
M04S52	17.2 E	1.2	65.8	54		G	Full		
11-100-008	***Trib. to E. Fk. LMR @ RM 2.4***								
302121	2.6E	0.4	56.0	38		MG	Full		

	IBI		MIwb		ICI	
	WWH *ECBP/IP*	EWH	WWH *ECBP/IP*	EWH	WWH *ECBP/IP*	EWH
Headwaters	40/40	50	NA	NA	36/30	46
Wadeable	40/40	50	8.3/8.1	9.4	36/30	46
Boat	42/38	50	8.5/8.7	9.6	36/30	46

a- MIwb is not applicable to headwater streams with drainage areas < 20 mi^2.
b- Qualitative evaluation based on community composition, EPT taxa richness, and other community attriubutes are given letter scores (e.g., E – Exceptional, VG – Very Good, etc.).
c- Causes and Sources listed are considered to be a primary influence on water quality, but may not be the only issue leading to impairment. See text for discussion of additional causes that cumulatively have led to impairment.

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 of the waters surveyed within the study area. For those not presently designated, industrial water supply, agricultural water supply, and recreational use (Class B[1]) are appropriate designations. The village of Blanchester draws source water for its drinking water supply from Whitakers Run, Stonelick Creek, and the West Branch of the East Fork the Little Miami River. Atrazine levels in all three sources exceeded water quality standards in 2008, thus classifying the source water as impaired for atrazine. Samples collected in 2012 documented continued impairment for the Stonelick and West Branch sources, and samples collected in 2013 documented continued impairment for Whitakers Run. Elevated nitrate levels measured in 2008 from the West Fork resulted in that source being watch-listed for nitrate. Nitrate levels averaged less than 8.0 mg/l (i.e., the watch-list threshold) during 2012 and 2013, thus removing the West Branch from the watch-listed. Whitaker Run is added to the nitrate watch list, as concentrations as high as 16.4 mg/l were measured from there in 2013.

Clermont County operates a PWS intake in Harsha Lake. In 2010 Clermont County's raw water had a maximum atrazine concentration of 20.84 ug/L and a quarterly average concentration of 4.51 ug/L. Based on the 2010 data, the source water was placed on the atrazine watch list. In 2012, the cyanotoxin microcystin was detected above drinking water thresholds (1.0 ug/L) at two public beaches on Harsha Lake, with maximum concentrations of 4.5 ug/L. However, cyanotoxins were not detected in the raw or finished water taken from the supply. An on-going effort to assess the PDWS beneficial use in relation to cyanotoxins for Clermont County's source water will be summarized in the 2014 Integrated Water Quality Monitoring and Assessment Report.

EAST FORK LITTLE MIAMI RIVER (11-100-000)

Status of Aquatic Life Uses

The East Fork the Little Miami River, excluding Harsha Lake, was assessed from its confluence with the Little Miami River in Milford to its headwaters near New Vienna. The headwater reach to river mile 75 (Canada Road) is designated Warmwater Habitat (WWH), and from there downstream is designated Exceptional Warmwater Habitat (EWH). The Warmwater Habitat reach was impaired due to organic enrichment/low dissolved oxygen caused by the New Vienna WWTP. The EWH reach downstream from Fayetteville and bracketed by SR 131 and SR 286 was impaired primarily by marginal habitat quality and low dissolved oxygen. The use downstream from Williamsburg was impaired by ammonia loadings from the Williamsburg WWTP. Downstream from Harsha Lake, the EWH use was not consistently met, but no causative agent was identified.

[1] i.e., waters with occasional, as opposed to frequent, recreational use

Other Recommendations and Future Monitoring Concerns

Apart from treatment plant serving the village of New Vienna being upgraded to more advanced treatment, a reworking of present discharge conditions is warranted. Discharge should be restricted to non-critical periods (November-April) and the 5:1 (stream flow to effluent volume) condition may need to be reevaluated. The use attainability of the EWH designation between river miles 40 and 60 should be carefully considered pending remediation of diffuse sources of impairment in adjoining tributaries, namely Saltlick Creek and Fivemile Creek, and from upstream, specifically, the West Fork. The river downstream from Williamsburg should receive follow-up monitoring to determine if recent plant improvements have restored the use. Similarly, now that flows from the Batavia plant have been redirected to the Middle East Fork plant, follow-up monitoring in the reach near Batavia would help ascertain whether the Batavia plant was limiting potential in the reach downstream from Harsha Lake.

TURTLE CREEK (050902021001)

Status of Aquatic Life Uses

The Turtle Creek assessment unit was monitored at three locations, all located on Turtle Creek. Turtle Creek has a verified WWH designation, and the use was met at two of the three sampling locations (Table 2). The macroinvertebrate assemblage at the Bald Knob Road (200508) site did not meet the WWH use due primarily to lack of stream flow and monotonous bedrock habitat.

Other Recommendations and Future Monitoring Concerns

The possibility that a quarry immediately adjacent to the stream at the Bald Knob Road site is disrupting stream flow should be investigated.

HEADWATERS EAST FORK LITTLE MIAMI RIVER (050902021002)

Status of Aquatic Life Uses

This unit includes the mainstem reach through New Vienna, as previously discussed. It also includes an unnamed tributary (confluence at river mile 78.45). Biological assemblages monitored in the unnamed tributary at Forge Road (M04P04, river mile 0.5) fully demonstrated WWH as the appropriate aquatic life use. In total, 2 of the 5 monitoring locations were impaired by organic enrichment in the unit.

Other Recommendations and Future Monitoring Concerns

The Snow Hill Country Club (1PZ00029) routinely neglected monitoring requirements specified in its permit, and reported 33 numeric permit violations, many for ammonia. The unnamed receiving water body (unnamed tributary to the East Fork LMR at RM 82.28) should be monitored for condition status.

Headwaters Dodson Creek (050902021003)

Status of Aquatic Life Uses

Three sites were assessed within the unit, one on Dodson Creek, one on the South Fork Dodson, and one on an unnamed tributary to the South Fork. The mainstem of Dodson has an existing EWH use that was made based on data collected from one site near the confluence with the East Fork LMR. Based on current data from the mainstem reach within the assessment unit, a WWH designation is demonstrated and appropriate. Assemblages sampled in the unnamed tributary to the South Fork (at RM 0.37) demonstrated that a WWH use is appropriate. South Fork Dodson Creek has an existing WWH use, and the assemblages measured there did not meet the WWH biocriteria due primarily to poor habitat, and secondarily to organic enrichment (Figure 2).

Other Recommendations and Future Monitoring Concerns

Habitat restoration is needed in the lower mile of the South Fork Dodson Creek.

Anthony Run-Dodson Creek (050902021004)

Status of Aquatic Life Uses

Three sites were monitored in this unit, two on the mainstem of Dodson Creek, and one on an unnamed tributary (at RM 4.52). As previously discussed, the Dodson Creek mainstem was designated EWH based on one sampling location. In the context of all available information from the present survey, a WWH designation is clearly appropriate. Given this designation for the mainstem, and also for the unnamed tributary, biological assemblages fully demonstrated the use.

Other Recommendations and Future Monitoring Concerns

The site at the mouth of Dodson Creek showed clear signs of nutrient enrichment. Although this stress likely inhibits biological assemblages from reaching their full potential and represents a threat to the use, in the absence of the stress, the assemblages are not likely to meet EWH given the marginal habitat quality documented in the lower reach.

West Fork East Fork Little Miami River (050902021005)

Status of Aquatic Life Uses

Two sites were monitored in the West Fork assessment unit, both located on the West Fork mainstem. The site at Frazier Road (301891, RM 7.45) did not meet the existing WWH use due to poor habitat (Figure 2). The site near the mouth (M04S50) at SR 123 met WWH, but was clearly stressed by nutrient enrichment.

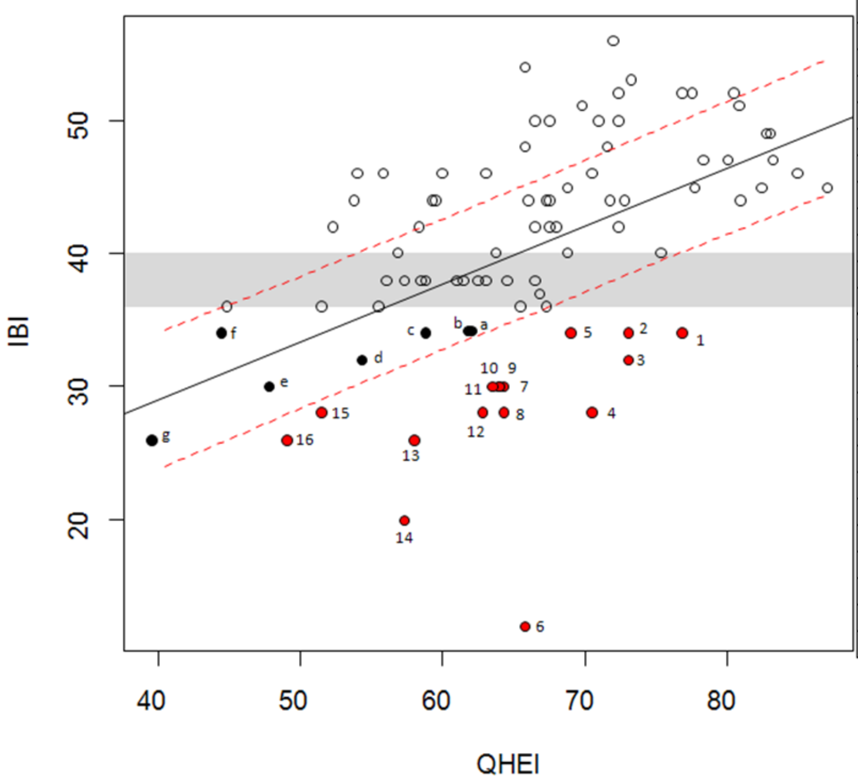
Other Recommendations and Future Monitoring Concerns

The stream gradient at the Frazier Road site (15 ft/mi) is steep enough to provide the power to rework the channel if given space and time.

Glady Creek-East Fork Little Miami River (050902021006)

Status of Aquatic Life Uses

Eight sites were sampled within this assessment unit, four on the mainstem of the East Fork and four on tributaries. Biological assemblages sampled in the mainstem met expectations for EWH; in fact, this is the only reach of the mainstem where the EWH use was fully demonstrated. Sites sampled from adjoining tributaries met expectations for WWH at three locations (Glady Creek, Murray Run, and Solomon Run), but fell short of WWH in Sycamore Creek due to organic enrichment and the exacerbating effect of low flow. For Solomon Run, note that although both assemblages met WWH, both did so within the range of non-significant departure, as the site was stressed by organic enrichment and low flow.



ID	Storet	Waterbody	RM
1	M04S35	East Fork LMR	82.4
2	301902	Back Run	1.2
3	301905	Stonelick Creek	13.4
4	301900	Poplar Creek	8.4
5	M04S41	Stonelick Creek	9.84
6	M04S45	Slabcamp Run	2.6
7	200469	Barnes Run	1.9
8	301898	Cloverlick Creek	8.5
9	M04S42	Stonelick Creek	17.7
10	200471	Kain Run	0.3
11	M04S44	Lucy Run	1.9
12	301904	Trib. to Backbone (1.36)	0.9
13	200481	Hall Run	2.3
14	301913	Patterson Run	0.1
15	301893	Saltlick Creek	0.60
16	301911	Brushy Fork	2.20
a	301148	Trib. to Stonelick (10.61)	0.89
b	200468	Cloverlick Creek	5.20
c	301901	Sugartree Creek	0.95
d	301895	Fivemile Creek	2.30
e	M04P13	Hall Run	0.23
f	301888	S. Fk. Dodson	0.90
g	301891	W. Fk. E. Fk. LMR	7.45

Figure 2. Index of Biotic Integrity (IBI) scores plotted on Qualitative Habitat Evaluation Index (QHEI) scores for sites sampled in the East Fork Little Miami River basin, 2012. The solid line is from ordinary least squares regression, and the dashed red lines show the 50th percentile prediction intervals (PI). Points falling below non-significant departure of the WWH biocriterion (gray-shaded region) are color-coded according to proximity to the lower PI. Red points are likely stressed beyond limitations imposed by local habitat quality; black-filled points are primarily limited by local habitat quality. Note that Slabcamp Run (point 6) functions as a primary headwater stream.

Downstream Solomon Run-East Fork Little Miami River (050902021101)

Status of Aquatic Life Uses

Of the seven stations sampled in this unit, three were impaired, including two sites on the East Fork where the existing use is EWH, and one on Saltlick Creek where the existing use is WWH. The cause of impairment to Saltlick was marginal habitat combined with low stream flow. The cause of impairment to the East Fork mainstem was low dissolved oxygen and marginal habitat.

Other Recommendations and Future Monitoring Concerns

As previously mentioned, given that habitat in the East Fork mainstem was simplified via historic channel modifications, use attainability needs to be evaluated following remediation of stress from adjoining tributaries.

Fivemile Creek-East Fork Little Miami River (050902021102)

Status of Aquatic Life Uses

This unit includes Fivemile Creek, Fourmile Creek, Crane Run, Pleasant Run, and a 10 mile reach of the East Fork mainstem through and upstream from Williamsburg. The Pleasant Run subcatchment contains the CECOS International facility. Detections of organic compounds were not any more frequent (nor were concentrations any higher) in Pleasant Run compared to any other site sampled in the East Fork basin during the 2012 survey. That said, biological assemblages in Pleasant Run were stressed by organic enrichment and sluggish flows. Similarly, Fivemile Creek had impaired biological assemblages due primarily to marginal habitat and low stream flow, and secondarily to enrichment. Crane Run and Fourmile Creek were in full attainment of the WWH biocriteria. The East Fork mainstem was impaired due to organic enrichment, presumably from the Williamsburg WWTP. All total, 4 of the 9 sites assessed in the unit were impaired.

Other Recommendations and Future Monitoring Concerns

Improvements to the Williamsburg WWTP completed during 2012 suggest that a follow-up sample is needed to confirm condition status downstream from the plant.

Todd Run-East Fork Little Miami River (050902021103)

Status of Aquatic Life Uses

Two sites were sampled within this assessment unit, one on Kain Run, the other on Todd Run. Biological assemblages sampled in Kain Run did not meet their respective biocriteria due mainly to natural limits imposed by monotonous bedrock habitat. Assemblages sampled from Todd Run were in full attainment.

Poplar Creek (050902021201)

Status of Aquatic Life Uses

Two of three sites sampled in the Poplar Creek assessment unit failed to meet biological standards, one site on Poplar Creek, the other on Sugartree Creek. In both cases, low dissolved oxygen levels brought on by anemic stream flow and organic enrichment appeared to be the cause.

CLOVERLICK CREEK (050902021202)

Status of Aquatic Life Uses

Three of four sites sampled within the Cloverlick assessment unit did not meet biological standards. Again, low dissolved oxygen levels brought on by organic and nutrient enrichment, and exacerbated by anemic stream flow was the primary cause.

Other Recommendations and Future Monitoring Concerns

Though not statutorily impaired, the unnamed tributary to Cloverlick (confluence at RM 7.48) appeared threatened by nutrient enrichment given marginal performance in both biological indicators coinciding with oxygen levels ranging from super-saturation to below standards.

LUCY RUN-EAST FORK LITTLE MIAMI RIVER (050902021203)

Status of Aquatic Life Uses

Seven locations were sampled in this assessment unit, of which three did not meet expectations set for respective use designations. Back Run was stressed beyond the limitations imposed by marginal habitat (Figure 2), likely due to frequent discharges of residual chlorine from the Holly Towne MHP. Slabcamp Run inexplicably holds a verified WWH designation. No historic data support such a designation, and data from the 2012 survey indicate that the stream functions as a primary headwater. Similarly, Lucy Run at Lucy Run Cemetery Road (M04S44) underperformed relative to available habitat (Figure 2); however, the condition appeared to be natural due to low flow, as many salamanders were present. Hence the site was likely transitional in function between a primary headwater and a warmwater habitat stream.

Other Recommendations and Future Monitoring Concerns

The cause of release of residual chlorine from the Holly Towne MHP needs to be investigated.

BACKBONE CREEK-EAST FORK LITTLE MIAMI RIVER (050902021204)

Status of Aquatic Life Uses

Three of four monitored sites on the East Fork mainstem did not attain EWH condition. No causative agent could be identified. The fish assemblage sampled in the unnamed tributary to Backbone Creek (301904) did not meet WWH, and underperformed relative to available habitat quality, though no identifiable source of stress could be isolated. The site sampled on Backbone Creek (301903) met WWH.

Other Recommendations and Future Monitoring Concerns

Flows from the Batavia WWTP have been redirected to the Middle East Fork plant. Follow-up sampling in the reach bracketing the former discharge would help resolve whether the river has not been realizing its full potential.

HEADWATERS STONELICK CREEK (050902021301)

Status of Aquatic Life Uses

None of the three sites sampled in this unit, all on Stonelick Creek, had biological assemblages fully meeting applicable WWH biocriteria. Organic enrichment was the cause of impairment.

BRUSHY FORK (050902021302)

Status of Aquatic Life Uses

Three sites were sampled in the Brushy Fork unit, two on Brushy Fork and one on Patterson Run. Assemblages sampled in Patterson Run were impaired beyond any limitations imposed by local habitat quality (Figure 2) due to organic and nutrient enrichment. Similarly, the site sampled on Brushy Fork at Brushy Fork Road (301911) narrowly underperformed relative to available habitat due to low dissolved oxygen levels attributed to low flow and enrichment.

Other Recommendations and Future Monitoring Concerns

The package plant serving Clermont Count N.E. Schools (1PT00077) reports occasional violations of the 30-day average limit for ammonia nitrogen (six in 2011, four in 2012). Follow-up monitoring downstream from the discharge is needed to ascertain if the plant is affecting water quality and biological condition.

MOORES FORK-STONELICK CREEK (050902021303)

Status of Aquatic Life Uses

Two sites sampled on Moores Fork had biological assemblages meeting WWH condition. The biological assemblages sampled in the unnamed tributary to Stonelick Creek (10.61) sampled at Cedarville Road (301148) narrowly missed expectations for WWH, but the fish community was consistent with the available habitat, especially given the small drainage area (2 mi^2), lack of flow, and limited pool depth. The macroinvertebrate community, however, appeared to be impaired by nutrient and organic enrichment beyond what could be explained simply due to low flow, as field dissolved oxygen showed extreme supersaturation (>200%) coincidental with the lowest recorded phosphorus levels at the site (i.e., an obvious sign of active uptake), and TKN and ammonia nitrogen were periodically elevated at the site. Two sites on the mainstem of Stonelick Creek were sampled in the assessment unit; one failed condition status for WWH, the other narrowly passed. Again, organic and nutrient enrichment and low flow were factors limiting the biological assemblages.

LICK FORK-STONELICK CREEK (050902021304)

Status of Aquatic Life Uses

Three sites were sampled in the assessment unit, two on the Stonelick mainstem, one on Lick Fork. Biological assemblages at all three sites demonstrated acceptable condition status for WWH, though the site on Stonelick Creek at US 50 (M04P09) appeared threatened by effects from nutrient enrichment given elevated levels of benthic chlorophyll and wide dissolved oxygen swings.

Other Recommendations and Future Monitoring Concerns

The observed manifestation of nutrient enrichment in the lower reach of Stonelick Creek is an extension of enrichment (both nutrient and organic) from upstream. Given that biological condition at the site appears to be deteriorating relative to historic condition, continued attainment of the WWH use may be threatened.

SALT RUN-EAST FORK LITTLE MIAMI RIVER (050902021305)

Status of Aquatic Life Uses

Thirteen sites were sampled in this assessment unit, including five on the East Fork LMR mainstem. Of the five mainstem sites, biological assemblages at two sites (RM 9.1, M04S03 & RM 0.77, 610530) did not have acceptable condition status for EWH due to local habitat quality (RM 0.77), and for an unknown reason at RM 9.1. Tributaries sampled included Shayler Run, Sugarcamp Run, Hall Run and an unnamed tributary (confluence with the mainstem at RM 1.62). Three sites sampled in the Shayler Run subcatchment had biological assemblages rated in acceptable condition, as did the site sampled on Sugarcamp Run. Hall Run is an urbanized stream, and biological assemblages failed applicable biocriteria for WWH at the two sampling locations. The unnamed tributary to the East Fork (RM 1.62) is also an urban stream; however, despite being highly urbanized and experiencing low dissolved oxygen levels and high conductivity readings (principally driven by chloride), the condition of the fish and macroinvertebrate assemblages were consistent with local habitat quality and WWH status, albeit marginally.

Table 3. Use designations for waterbodies in the East Fork Little Miami River drainage basin. Use changes or new streams with recommendations based on the results of the 2010 survey are noted by a delta (▲) symbol.

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 Miami river - North fork (RM 91.64) to RM 3.0 (downstream of Beechmont ave.)			+						+	+		+		
- all other segments		+							+	+		+		
Cluff creek (Clough creek)		+							+	+		+		
McCullough run		*							*	*		*		
Duck creek - downstream Red Bank road (RM 2.4) to the mouth		+							*	*		+		
- confluence of East fork and West fork to Red Bank road							+		*	*			+	Small drainageway maintenance
East fork							+		*	*			+	Small drainageway maintenance
Dry run							+		*	*			+	Small drainageway maintenance
		*							*	*		*		
East Fork LMR - headwaters to RM 75		+							+	+		*		
- at RM 22.6			+					+	+	+		+		PWS intake - Clermont county
- all other			+						+	+		+		
segments Hall run		+							+	+		*		
Wolfpen run		+							+	+		*		
Salt run		+							+	+		*		
Sugarcamp run		+							+	+		*		
Shayler run		+							+	+		*		
Unnamed tributary (Shayler run RM 4.4)		+												

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	
| | | | | | |														
| Dry run		+							+	+		*		
Stonelick creek - at RM 23.37		+						+	+	+		+		PWS intake - village of Blanchester
- all other segments		+							+	+		+		
Lick fork		+							+	+		*		
Brushy fork		+							+	+		*		
Rocky run		+							+	+		*		
Paterson run		+							+	+		*		
Moores fork		+							+	+		*		
Greenbush creek		+							+	+		*		
Hunter creek		+							+	+		*		
Backbone creek		+							+	+		*		
Lucy run		+							+	+		*		
Fourmile run		+							+	+		*		
Back run		+							+	+		*		
Ulrey run		+							+	+		*		
Slabcamp run		+							+	+		*		
Cloverlick creek - at RM 3.23		+						o	+	+		*		PWS intake - village of Bethel (formerly)

Water Body Segment	Use Designations													Comments
		Aquatic Li fe Habitat						Water Supply			Recreation			
	SRW	WWH	EWH	MWH	SSH	CWH	LRW	PWS	AWS	IWS	BW	PCR	SCR	
| | | | | | |														
| Barnes run		+							+	+		*		
Poplar creek		+							+	+		*		
Sugartree		+							+	+		*		
creek Town		+							+	+		*		
run Guest run		+							+	+		*		
Trible run		+							+	+		*		
Light run		+							+	+		*		
Snow run		+							+	+		*		
Polecat run		+							+	+		*		
Cabin run		+							+	+		*		
Kain run		+							+	+		*		
Todd run		+							+	+		*		
Indian Camp run		+							+	+		*		
Crane run		+							+	+		*		
Fourmile creek		+							+	+		*		
Pleasant run		+							+	+		*		
Fivemile 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	
| | | | | | |														
| Sixmile creek		+							+	+		*		
Howard run		+							+	+		*		
Grassy fork		+							+	+		*		
Glady run		+							+	+		*		
Saltlick creek		+							+	+		*		
Indian creek		+							+	+		*		
Little Indian creek		+							+	+		*		
Solomon run - at RM 3.33		+						+	+	+		*		PWS intake (formerly)
- all other segments		+							+	+		*		
Murray run		+							+	+		*		
Sycamore creek		+							+	+		*		
Unnamed tributary (Sycamore creek RM 1.13)							+		*	*			+	Irretrievable flow modification
West fork - at RM 4.62		+						+	+	+		*		PWS intake - village of Westboro (formerly)
- all other segments		+							+	+		*		
Dodson creek		▲	+						+	+		*		
Anthony run		+							+	+		*		
South fork		+							+	+		*		

Study Area

The East Fork Little Miami River watershed analyzed in this study includes the region from the headwaters in Clinton and Highland counties to the confluence with Little Miami River at the Hamilton county line. The drainage area of the East Fork Little Miami covers 499 mi^2. Along its course the river drops from an elevation of 1118 feet to 494 feet with an average gradient of 7.6 ft. /mile. Major tributaries include Dodson Creek, Solomon Run, Five Mile Creek, Stonelick Creek, and West Fork East Fork Little Miami River. Impoundments in the watershed include East Fork Reservoir (2,160acres), Stonelick Lake (160 acres), and Lake Lorelei (171 acres).

The 2011 East Fork Little Miami River study area included four 10-digit Hydrologic Unit Code watersheds (HUCs) and eighteen 12-digit Watershed Assessment Units (WAUs) as presented in Table 4. The study area included portions of Clinton, Highland, Brown, Clermont and a small part of Warren counties (Figure). The most upstream 10-digit HUC is labeled Headwaters East Fork Little Miami River which begins in southern Clinton County. Other 10-digit HUCS include the Fivemile Creek, Cloverlick Creek, and Stonelick Creek subwatersheds.

The topography of the East Fork Little Miami River watershed has been influenced by glaciation which left distinctive land forms and thick deposits of silt, sand, and gravel. The upper portion of the watershed is within the Eastern Corn Belt Plains (ECBP) ecoregion which is characterized by level to gently sloping land, and relatively low gradient streams. At approximately river mile 70 on the East Fork mainstem the river enters the Interior Plateau ecoregion. This is a transitional zone between the ECBP and the Western Allegheny Plateau. The upper reaches of the watershed include glacial till plains similar to the ECBP with more rolling topography and slightly higher gradient streams (Omernik and Gallant, 1988). The lower watershed includes dissected plateaus with more pronounced elevation changes along with limestone outcrops. An example is the greater than 200' change in elevation between Williamsburg and Batavia. (ftp://ftp.epa.gov/wed/ecoregions/in/ohin_front.pdf).

The East Fork Little Miami River is designated Exceptional Warmwater Habitat (EWH) from the mouth to river mile 75. The other stream in the watershed with a EWH designation is Dodson Creek. The remaining streams in the watershed have an aquatic life use designation of Warmwater Habitat (WWH). East Fork is also designated Public Water Supply (PWS) at river mile 22.6 due to the Clermont County Water intake in the William H. Harsha reservoir. Stonelick Creek, Whitaker Run and West Branch LMR also have a PWS designation, as the village of Blanchester maintains a water intake at river mile 23.37. With a few exceptions the streams in the watershed are also designated for Agricultural and Industrial water supply and Primary Contact Recreation.

Data from the 2006 National Land Classification Dataset (NLCD) show that land uses in the watershed are principally rural and agricultural. Overall 44.78% of the watershed is used for cultivated crops and if hay/pasture is included then 53.95% of the watershed is used for agriculture. Six of the 18 WAUs have more than 60% of their land area dedicated to cultivated crops, and if pastures and hay fields are included, then these same WAUs all exceed 70% of their area used for agriculture. All of the referenced WAUs are within the Headwaters East Fork Little Miami River HUC-10. The majority of this HUC is within the ECBP ecoregion. Deciduous forest is the second most common landuse in the watershed with the distribution also reflecting the ecoregions. Overall deciduous forests cover 31.11% of the area with two WAUs, Lucy Run-East Fork Little Miami River (12-03) and Lick Fork-Stonelick Creek (13-04) exceeding 50%. Urban land uses are confined to the areas within cities and villages and are most dense in the WAUs closest to the I-275 corridor near Cincinnati. Only one WAU, Salt Run- East Fork Little Miami River has more than 10% impervious surface.

CECOS International Facility is located at 5092 Aber Road, in Jackson Township, Clermont County. The State of Ohio granted approval to this facility to operate as a sanitary landfill in 1972. In 1979, approval to dispose of polychlorinated biphenyls (PCBs) was obtained from USEPA. In November 1980, a Part A [RCRA Application] was filed and interim status was granted to operate this site as a hazardous waste landfill. In 1984, CECOS filed a Part B permit application. In April of 1988, both Ohio EPA and USEPA notified CECOS of their intent to deny this permit and in April 1990, CECOS discontinued all hazardous waste business aspects. CECOS has not accepted any off-site waste since September 1988.

All land disposal units have been closed. On September 23, 1994, Ohio EPA approved a Modified Closure/Post-Closure Plan for Selected Hazardous Waste Management Units and Operations Support Facilities. The Clermont County Board of Commissioners entered an appeal before the Environmental Board of Review on October 21, 1994 requesting that the closure plan approval be vacated. Additionally, in December 2010, Clermont County Commissioners filed a petition requesting modification to the approved Post-Closure Plan. This petition was denied by the Director of Ohio EPA in July of 2012. In a final attempt to end the long-standing dispute between Clermont County and CECOS, Ohio EPA requested that both parties enter into direct negotiation to try and resolve their differences. These direct negotiations resulted in a supplemental agreement in which CECOS would provide the County with items that were over and above what was required by the regulations. This agreement includes additional monitoring and better communication with the facility. This agreement was also contingent upon the County not appealing an amended Post-Closure Plan which was submitted to Ohio EPA in January 2012. This amended plan was approved by Ohio EPA in July 2012 without appeal. The site is currently in its 30-year post-closure care period which is scheduled to end in 2027. This post-closure period may be extended by the Director of Ohio EPA should it be deemed necessary to protect human health and the environment.

Significant development is still occurring in the eastern portion of the watershed. Clermont County and the communities of Batavia, Milford, Bethel, Williamsburg, Owensville and others are trying to keep pace with the pressures that attend growth including provision of water and sewage services. Development seems to follow the transportation corridors along SRs 32, 125 and US 50. The county has instituted an effective stormwater management program for new development but significant problems were created prior to activation of the program. After development there is usually more impervious surface which increases the rate and volume of runoff. The lower reaches of small streams show the effects of excess runoff as evidenced by down-cutting and widening of the channel. Streams with interbedded limestone and shale bedrock bottoms are especially vulnerable, as they erode very rapidly when disturbed. While most developing areas in the East Fork Little Miami watershed are not immediately adjacent to the river, the impacts of development are still a potential problem. Already developed areas contribute different types of pollutants to the watershed (oil & grease, lawn chemicals, polycyclic aromatic hydrocarbons [PAHs]).

There are only a few significant reservoirs in the watershed. The largest reservoir is the William H. Harsha Lake which is owned and operated by the US Army Corps of Engineers. It is used for flood control, navigation augmentation, and recreation. The size during summer pool is 2160 acres. The Clermont County Water Department maintains a primary drinking water intake in Harsha Lake. ODNR leases part of the property and operates East Fork State Park, which is 4,870 acres in size. ODNR also owns Stonelick Lake within the 1058 acre Stonelick Lake State Park. Lake Lorelei is a privately owned residential development of vacation and year-round homes. Harmful algal blooms (HABs) have been documented in both Harsha and Stonelick lakes. These blooms are fueled by excess nutrients and have resulted in warnings against contact with the water.

There are several environmental organizations active in the East Fork Little Miami River watershed. The oldest of these is Little Miami Incorporated (LMI) which has been active for 45 years. Most of LMI’s activities have involved the purchase of conservation easements or property purchases in the riparian zone of the river. Clermont County and SWCDs in Clermont, Brown, Highland, and Clinton counties formed the East Fork Watershed Collaborative to take advantage of ODNR’s Watershed Coordinator Program. As a result there are now watershed action plans available for each of the five sub-watersheds. This group has also been very active in a number of water quality improvement projects including removal of the Solomon Run dam and the Avey’s Run Restoration. Avey’s Run was restored on the property of the Cincinnati Nature Center which is also active in education projects relative to water quality. The Collaborative has also been active in the proposed removal of the Batavia low head dam.

Several research projects have been initiated in the East Fork watershed and Harsha Lake by USEPA’s National Exposure Research Laboratory in Cincinnati and the U. S. Army Corps of Engineers. Among other topics research and monitoring are examining HABs and nutrients, impacts on the Clermont County water intake, carbon sequestration, methane release, nutrient trading, environmental tipping points, and fish population genetics. At this time seven different projects are conducting monitoring in Harsha Lake.

Table 4 Watershed Assessment Units (WAUs) in the 2012 East Fork Little Miami River study area.

10-Digit HUC: 05090202-10 Headwaters East Fork Little Miami River		
12-digit WAU	Description	Acreage / mi^2 [Total: 96,614 / 150.9]
05090202-10-01	Turtle Creek	11,661 / 18.22
05090202-10-02	Headwaters East Fork Little Miami River	19,210 / 30.02
05090202-10-03	Headwaters Dodson Creek	10,320 / 16.1
05090202-10-04	Anthony Run-Dodson Creek	10,407 / 16.26
05090202-10-05	West Fork East Fork Little Miami River	18,486 / 28.88
05090202-10-06	Glady Creek-East Fork Little Miami River	26,530 / 41.45
10-Digit HUC: 05090202-11 Fivemile Creek-East Fork Little Miami River		
12-digit WAU	Description	Acreage/mi^2 [Total: 68,187 / 106.5]
05090202-11-01	Solomon Run-East Fork Little Miami River	27,498 / 42.97
05090202-11-02	Fivemile Creek-East Fork Little Miami River	27,241 / 42.56
05090202-11-03	Todd Run-East Fork Little Miami River	13,448 / 21.01
10-Digit HUC: 05090202-12 Cloverlick Creek-East Fork Little Miami River		
12-digit WAU	Description	Acreage / mi^2 [Total: 78,427 / 122.5]
05090202-12-01	Poplar Creek	15,796 / 24.68
05090202-12-02	Cloverlick Creek	27,085 / 42.32
05090202-12-03	Lucy Run-East Fork Little Miami River	22,233 / 34.74
05090202-12-04	Backbone Creek-East Fork Little Miami R.	13,313 / 20.8
10-Digit HUC: 05090202-13 Stonelick Creek-East Fork Little Miami River		
12-digit WAU	Description	Acreage / mi^2 [Total: 76,389 / 119.36]
05090202-13-01	Headwaters Stonelick Creek	15,527/ 24.26
05090202-13-02	Brushy Fork	9,547 / 14.92
05090202-13-03	Moores Fork-Stonelick Creek	12,396 / 19.36
05090202-13-04	Lick Fork-Stonelick Creek	11,724 / 18.31
05090202-13-05	Salt Run-East Fork Little Miami River	27,195 / 42.49

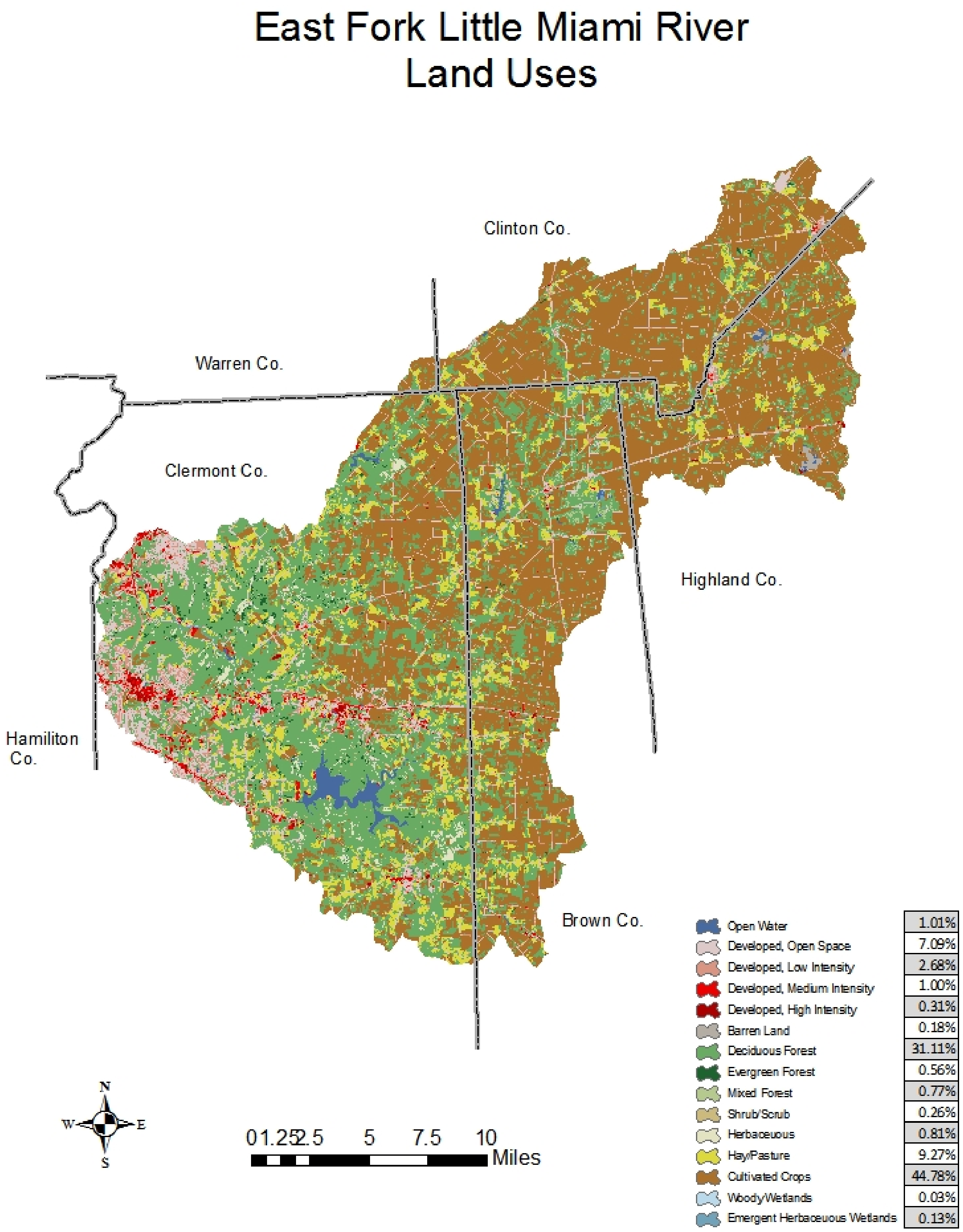


Figure 3. Land uses in the East Fork Little Miami basin classified from 2006 satellite imagery (NLCD 2006).

METHODS

All chemical, physical, and biological field, EPA laboratory, data processing, and data analysis methods and procedures adhere to those specified in the Manual of Ohio EPA Surveillance Methods and Quality Assurance Practices (Ohio EPA 2006b), Biological Criteria for the Protection of Aquatic Life, Volumes II - III (Ohio Environmental Protection Agency 1987b, 1989b, 1989c, 2008a, 2008b), The Qualitative Habitat Evaluation Index (QHEI); Rationale, Methods, and Application (Rankin 1989), and Methods for Assessing Habitat in Flowing Waters: Using the Qualitative Habitat Evaluation Index (Ohio EPA 2006a)[2].

Determining Use Attainment Status

Use attainment status is a term describing the degree to which environmental indicators are either above or below criteria specified by the Ohio Water Quality Standards (WQS; Ohio Administrative Code 3745-1). Assessing aquatic use attainment status involves a primary reliance on the Ohio EPA biological criteria (OAC 3745-1-07; Table 8-15). These are confined to ambient assessments and apply to rivers and streams outside of mixing zones. Numerical biological criteria are based on multimetric biological indices including the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb), indices measuring the response of the fish community, and the Invertebrate Community Index (ICI), which indicates the response of the macroinvertebrate community. Three attainment status results are possible at each sampling location - full, partial, or non-attainment. Full attainment means that all of the applicable indices meet the biocriteria. Partial attainment means that one or more of the applicable indices fails to meet the biocriteria. Non-attainment means that none of the applicable indices meet the biocriteria or one of the organism groups reflects poor or very poor performance. An aquatic life use attainment table (Table 2) is constructed based on the sampling results and is arranged from upstream to downstream and includes the sampling locations indicated by river mile, the applicable biological indices, the use attainment status (i.e., full, partial, or non), the Qualitative Habitat Evaluation Index (QHEI), and a sampling location description.

Habitat Assessment

Physical habitat was evaluated using the Qualitative Habitat Evaluation Index (QHEI) developed by the Ohio EPA for streams and rivers in Ohio (Rankin 1989, 1995, Ohio EPA 2006a). Various attributes of the habitat are scored based on the overall importance of each to the maintenance of viable, diverse, and functional aquatic faunas. The type(s) and quality of substrates, amount and quality of in-stream cover, channel morphology, extent and quality of riparian vegetation, pool, run, and riffle development and quality, and gradient are some of the habitat characteristics used to determine the QHEI score which generally ranges from 20 to less than 100. The QHEI is used to evaluate the characteristics of a stream segment, as opposed to

---

[2] The manuals referenced in this paragraph are periodically updated. The latest updates can be found at: http://www.epa.ohio.gov/dsw/bioassess/BioCriteriaProtAqLife.aspx

the characteristics of a single sampling site. As such, individual sites may have poorer physical habitat due to a localized disturbance yet still support aquatic communities closely resembling those sampled at adjacent sites with better habitat, provided water quality conditions are similar. QHEI scores from hundreds of segments around the state have indicated that values greater than 64 are generally conducive to the existence of warmwater faunas whereas scores less than 45 generally cannot support a warmwater assemblage consistent with the WWH biological criteria. Scores greater than 75 frequently typify habitat conditions which have the ability to support exceptional warmwater faunas.

Sediment and Surface Water Assessment
A total of 18 surficial sediment samples were collected from the East Fork Little Miami River and its tributaries. Samples were analyzed for total analytical list inorganics (i.e., metals), volatile organic compounds, semi-volatile organic compounds, polychlorinated biphenyls (PCBs), pesticides, and ammonia and phosphorus. Sediment collection involves looking for freshly deposited sediment in the stream bed with a bias toward fine grained material (<60 microns, silt, clay, muck,). Depositional zones on both sides of the stream channel are sampled in an attempt to get a composite sample representing the segment of the stream. Samples are collected with a stainless steel scoop and composited in a stainless steel bucket. The samples are placed in the appropriate containers and placed in a cooler at 4^{O} C.

Hierarchical guidelines are used to evaluate organic compounds. Sediment organic samples were evaluated using the guidelines developed by McDonald et al. (2000) and the USEPA Region 5 RCRA Ecological Screening Levels (ESL)[3]. The MacDonald (2000) are consensus-based sediment guidelines designed to evaluate ecotoxic effects. The USEPA Region 5 RCRA Ecological Screening Levels (ESL) are considered protective benchmarks. The most contaminated organics will use the MacDonald Probable Effect Concentration (PEC) to indicate adverse effects are likely to occur in benthic sediments. The lesser contaminated sediment results will use the RCRA Ecological Screening Levels (ESL) to determine if the level of contamination meets or exceeds the protective benchmark.

Sediment metal samples are evaluated using the Ohio Sediment Reference Value (SRV) for the ecoregion and the MacDonald Sediment Quality Guidelines. Sediment metals detected between the MacDonald TEC and PEC, but beneath the Ohio SRV will defer to Ohio's SRV. This will apply to arsenic, cadmium, copper and nickel.

Surface water samples were collected, preserved and delivered in appropriate containers to either an Ohio EPA contract lab or the Ohio EPA Division of Environmental Services. Surface water samples were evaluated using comparisons to Ohio Water Quality Standards criteria, reference conditions, or published literature.

[3] http://epa.gov/region5/waste/cars/pdfs/ecological-screening-levels-200308.pdf

Macroinvertebrate Community Assessment

Macroinvertebrates were collected from artificial substrates and from the natural habitats. The artificial substrate collection provided quantitative data and consisted of a composite sample of five modified Hester-Dendy multiple-plate samplers colonized for six weeks. At the time of the artificial substrate collection, a qualitative multihabitat composite sample was also collected. This sampling effort consisted of an inventory of all observed macroinvertebrate taxa from the natural habitats at each site with no attempt to quantify populations other than notations on the predominance of specific taxa or taxa groups within major macrohabitat types (e.g., riffle, run, pool, and margin). Detailed discussion of macroinvertebrate field and laboratory procedures is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989c, Ohio EPA 2008b).

Fish Community Assessment

Fish were sampled using pulsed DC electrofishing methods. Fish were processed in the field, and included identifying each individual to species, counting, weighing, and recording any external abnormalities. Discussion of the fish community assessment methodology used in this report is contained in Biological Criteria for the Protection of Aquatic Life: Volume III, Standardized Biological Field Sampling and Laboratory Methods for Assessing Fish and Macroinvertebrate Communities (Ohio EPA 1989c, Ohio EPA 2008b).

Causal Associations

Using the results, conclusions, and recommendations of this report requires an understanding of the methodology used to determine the use attainment status and assigning probable causes and sources of impairment. The identification of impairment in rivers and streams is straightforward - the numerical biological criteria are used to judge aquatic life use attainment and impairment (partial and non-attainment). The rationale for using the biological criteria, within a weight of evidence framework, has been extensively discussed elsewhere (Karr et al. 1986; Karr 1991; Ohio EPA 1987a,b; Yoder 1989; Miner and Borton 1991; Yoder 1991; Yoder 1995). Describing the causes and sources associated with observed impairments relies on an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, land use data, and biological results (Yoder and Rankin 1995). Thus the assignment of principal causes and sources of impairment in this report represent the association of impairments (based on response indicators) with stressor and exposure indicators. The reliability of the identification of probable causes and sources is increased where many such prior associations have been identified, or have been experimentally or statistically linked together. The ultimate measure of success in water resource management is the restoration of lost or damaged ecosystem attributes including aquatic community structure and function. While there have been criticisms of misapplying the metaphor of ecosystem "health" compared to human patient "health" (Suter 1993), in this document we are referring to the process for evaluating biological integrity and causes or sources associated with observed impairments, not whether human health and ecosystem health are analogous concepts.

Pollutant Loadings

Overview

Effluent concentrations and respective calculated loads were collated from data reported by permit holders between 1995 and 2012, screened for permit compliance, and further analyzed for trends in magnitude and variability over time. Relative to the baseline 5-year window between 1995 and 1999, the total daily effluent flow from NPDES dischargers during the recent time period (2008-2012) increased from 10.22 mgd to 11.68 mgd. Most of the increase in flow is accounted for by the Lower East Fork Regional WWTP (approximately 1.04 mgd), followed by the Middle East Fork WWTP (0.38 mgd) and the New Vienna WWTP (0.35 mgd). Despite the increased effluent flow, pollutant loads of ammonia nitrogen, 5-day biochemical oxygen demand, and total suspended solids have trended down significantly when the recent time period is compared to the baseline (Table 5; Figures 4-9).

A tally of permit compliance indicators (Table 6), and inspection of distributions of effluent flows and concentrations in relation to plant design flow and concentration limits (Appendix A-5) suggests that for the recent time period, the Middle East Fork WTTP and the Lower East Fork WWTP, two of the seven largest publicly owned treatment works[4], were generally in compliance with the terms of their permits, and were operated within respective design capacities. However, testing of the Middle East Fork effluent revealed acute toxicity (9.52 TU_a) to *Ceriodaphnia dubia* in a sampling event conducted 5/20/2008. An effluent compliance sample collected on 5/20/2008 showed levels of metals at concentrations potentially toxic to aquatic life, though within water quality standards for inside mixing zones. Acute toxicity to *C. dubia* was also noted in effluent samples collected from the Lower East Fork WWTP in 3 of 15 sampling events conducted between 2004 and 2008, with 2 of the events occurring in 2008 (6/16 and 7/21). Coincidentally, an effluent compliance sample collected on 6/17/2008 also showed levels of metals at concentrations potentially toxic to aquatic life, though within water quality standards for inside mixing zones.

Four of the remaining larger dischargers, Batavia, Lynchburg, Milford and New Vienna, experienced occasional permit violations, but rarely, with the exception of Lynchburg, during the third quarter (i.e., the period of critical flows). The majority of violations from the Lynchburg plant was for dissolved oxygen, and occurred during July and August of 2011. Dissolved oxygen concentration reported at less than the permit limit of 6.0 mg/l averaged 4.9 mg/l (± 0.5 SD). Third quarter flows from the Batavia WWTP frequently exceeded design capacity. Flows from the Batavia plant have been recently diverted to the Middle East Fork plant. Given that the design capacity of the Middle East Fork plant is 7.2 mgd, and has been operating well under capacity (90^{th} percentile 1^{st} quarter flows < 6 mgd), the addition from the Batavia plant (~0.3 mgd) should be easily handled. Daily flows during the third quarter from the Milford and Lynchburg plants average about half that of respective design capacities, and most reported flows (i.e., 2 standard deviations from the mean) were less than the respective design capacities for average daily flows, suggesting that those plants are not overly taxed by inflow and infiltration.

[4] Defined here as having a design capacity of >0.2 mgd average daily flow.

The last of the larger dischargers, the village of Williamsburg WWTP, tallied 119 violations comprising several parameters, notably ammonia, CBOD5, TSS and TP. Coincidentally, the Williamsburg WWTP also had a high number of sampling frequency violations. That said, the Village has completed a significant overhaul of the treatment plant that should eliminate the compliance problems.

Several mobile home parks (MHP), a nursing home and Clermont County Northeastern Local Schools discharge to East Fork LMR tributaries. Each of these dischargers have design flows of less than 50,000 gpd. Locust Ridge Nursing Home reported 197 limit violations between 2008 and 2012. Most of the violations were for ammonia nitrogen, suspended solids, dissolved oxygen, cBOD5 and chlorine, with the worst of the violations occurring in 2012; however, the samples reported in 2012 (Figure13) were from land-applied effluent, as the plant was under construction in 2012 and did not discharged to Light Run.

The Orchard Lake MHP reported 64 numeric limit violations, most occurring in 2008 and 2009. Most of the violations were for ammonia nitrogen, followed by TSS, cBOD5 and dissolved oxygen. The Orchard Lake MHP also had a high number of sampling frequency violations (230), mostly for failure to report turbidity, color and odor. Orchard Lake MHP discharges (indirectly) to an unnamed tributary to the East Fork LMR at RM 0.1. Royal Hills MHP also discharges to this unnamed tributary. Numeric violations from the Royal Hills MHP were, however, infrequent.

Clermont County Northeastern Local Schools discharges to Patterson Run. The facility reported 65 numeric limit violations between 2008 and 2012, mostly for ammonia nitrogen, and most frequently during 2008 and 2009 (49 of the 65). Reporting of turbidity, color and odor was, apparently, neglected as a matter of routine. The facility has an average design flow of 0.040 mgd. Maximum flows reported by the plant have never exceeded the design flow.

The Holly Towne MHP has a design flow of 0.035 mgd, but plant flows frequently exceed that level (mean flow 0.031± 0.012 SD). Forty-eight numeric violations were reported, most for residual chlorine. The Holly Towne MHP discharges to Back Run. The Forest Creek MHP discharges to Ulrey Run, and has a design flow of 0.040 mgd. The plant has operated below that capacity (mean flow 0.012± 0.007 SD) since 2006. Of the 25 numeric violations listed, none occurred during the 3rd quarter, and most occurred in the months of January and February.

The Rolling Acres WWTP discharges to a tributary to Dodson Creek, and has a design flow of 0.010 mgd. The plant generally operates under that capacity, but experiences episodically high flows, especially in the fourth quarter. Despite the potential hydraulic stress, only 4 numeric limit violations were reported for the plant.

Several other dischargers that merit a passing mention include the Snow Hill Country Club, St. Martin WWTP, and the Stonelick State Park WWTP. The Snow Hill Country Club discharges to an unnamed tributary to the East Fork LMR at RM 82.28 (i.e., the confluence is in the reach downstream from New Vienna). They failed to report observations for turbidity, color and oder, flow, and CBOD5 as a matter of routine, and reported 33 numeric violations, mostly for ammonia nitrogen and suspended solids. The St. Martin WWTP is now routed to the Fayetteville WWTP. The Stonelick State Park WWTP discharges sparingly and intermittently, and reported no 3rd quarter flows between 2008 and 2012.

Table 5. Median daily effluent flows and loadings for dischargers in the East Fork Little Miami River basin, 1995-1999 and 2008-2012. Significant directional trends are highlighted (blue shading for decreasing trend; orange shading for increasing trend); comparisons made using the Kruskal-Wallis nonparametric ANOVA.

PERIOD	Flow	N	NH3-N	N	BOD	N	TP	N	TSS	N	NOx	N
Batavia WWTP - 1PB00001												
1995-1999	0.285	1765	16.982	149	18.051	405	4.464	61	36.887	461	.	0
2008-2012	0.238	1796	9.500	141	16.527	460	4.040	59	18.731	482	.	0
Clermont Northeast Local Schools WWTP - 1PT00077												
1995-1999	0.018	948	0.086	68	0.846	112	.	0	0.751	90	.	0
2008-2012	0.003	1048	0.039	74	0.120	151	.	0	0.158	167	.	0
CECOS International Inc. - 1IN00123												
1995-1999	0.269	45	.	0	.	0	.	0	.	0	.	0
Forest Creek MHP - 1PV00034												
1995-1999	0.020	1808	0.013	120	0.175	233	.	0	0.188	236	.	0
2008-2012	0.015	1757	0.002	115	0.220	234	.	0	0.217	234	.	0
Huhtamaki Plastics Inc. - 1IQ00016												
2008-2012	0.033	90	.	0	.	0	.	0	4.477	77	.	0
Locust Ridge Nursing Home Inc - 1PX00059												
2008-2012	0.004	1796	0.033	51	0.138	51	0.129	5	0.459	64	0.070	5
Clermont County - Lower East Fork Regional WWTP - 1PK00009												
1995-1999	5.130	1795	29.467	893	233.838	955	122.315	405	141.955	985	436.392	400
2008-2012	6.165	1796	13.594	136	136.447	272	121.926	235	92.429	354	786.318	60
Lynchburg Wastewater Plant - 1PB00105												
1995-1999	0.134	1825	0.614	85	5.374	291	.	0	7.569	456	.	0
2008-2012	0.142	1796	0.310	343	5.291	290	3.206	60	3.388	385	24.086	60
Middle East Fork WWTP - 1PK00010												
1995-1999	2.680	1673	23.028	492	91.142	790	60.838	296	105.719	877	397.067	214
2008-2012	3.060	1796	9.862	224	91.081	619	68.352	262	101.288	681	353.010	88
City of Milford Wastewater Treatment Plant - 1PC00005												
1995-1999	0.600	1515	1.787	304	20.926	382	15.868	75	38.101	390	66.051	52
2008-2012	0.667	1796	1.425	430	19.605	586	14.824	233	23.542	681	87.259	59
New Vienna Wastewater Treatment Plant - 1PA00005												
1995-1999	0.128	267	8.892	28	64.564	38	.	0	69.434	39	.	0
2008-2012	0.480	428	19.723	35	102.147	55	10.151	6	120.224	57	.	0
Orchard Lake Mobile Home Park - 1PV00009												
1995-1999	0.035	1795	0.108	120	1.397	205	.	0	1.460	189	.	0
2008-2012	0.020	1755	0.056	101	0.267	150	.	0	0.451	199	.	0

Table 5. Median daily effluent flows and loadings for dischargers in the East Fork Little Miami River basin, 1995-1999 and 2008-2012. Significant directional trends are highlighted (blue shading for decreasing trend; orange shading for increasing trend); comparisons made using the Kruskal-Wallis nonparametric ANOVA.

PERIOD	Flow	N	NH3-N	N	BOD	N	TP	N	TSS	N	NOx	N
Rolling Acres WWTP - 1PG00100												
1995-1999	0.010	1063	0.167	51	1.085	46	.	0	1.252	59	.	0
2008-2012	0.006	1796	0.064	10	0.186	22	0.079	52	0.187	14	0.796	1
Royal Hills MHP - 1PV00074												
1995-1999	0.024	1489	0.025	115	0.250	231	.	0	0.300	237	.	0
2008-2012	0.008	1779	0.001	115	0.090	233	.	0	0.075	233	.	0
Snow Hill Country Club - 1PZ00029												
2008-2012		0		0		0		0		0		0
Stonelick State Park WWTP - 1PP00020												
1995-1999	0.190	5	51.533	1	26.638	1	.	0	145.877	1	.	0
2008-2012	0.030	24	0.245	24	3.630	16	.	0	5.132	19	.	0
USEPA Experimental Stream Facility - 1IN00116												
1995-1999	0.450	634	.	0	.	0	.	0	.	0	.	0
2008-2012	0.517	1743	.	0	.	0	.	0	.	0	.	0
village of Williamsburg WWTP - 1PB00034												
1995-1999	0.249	1427	1.779	399	12.564	380	2.226	48	9.464	387	6.746	45
2008-2012	0.289	1756	1.016	407	8.539	386	4.354	52	9.308	460	14.695	55
Lynchburg Wastewater Plant - 1PB00105												
2008-2012	0.703	305	11.582	18	23.887	22	14.175	17	29.976	28	.	0

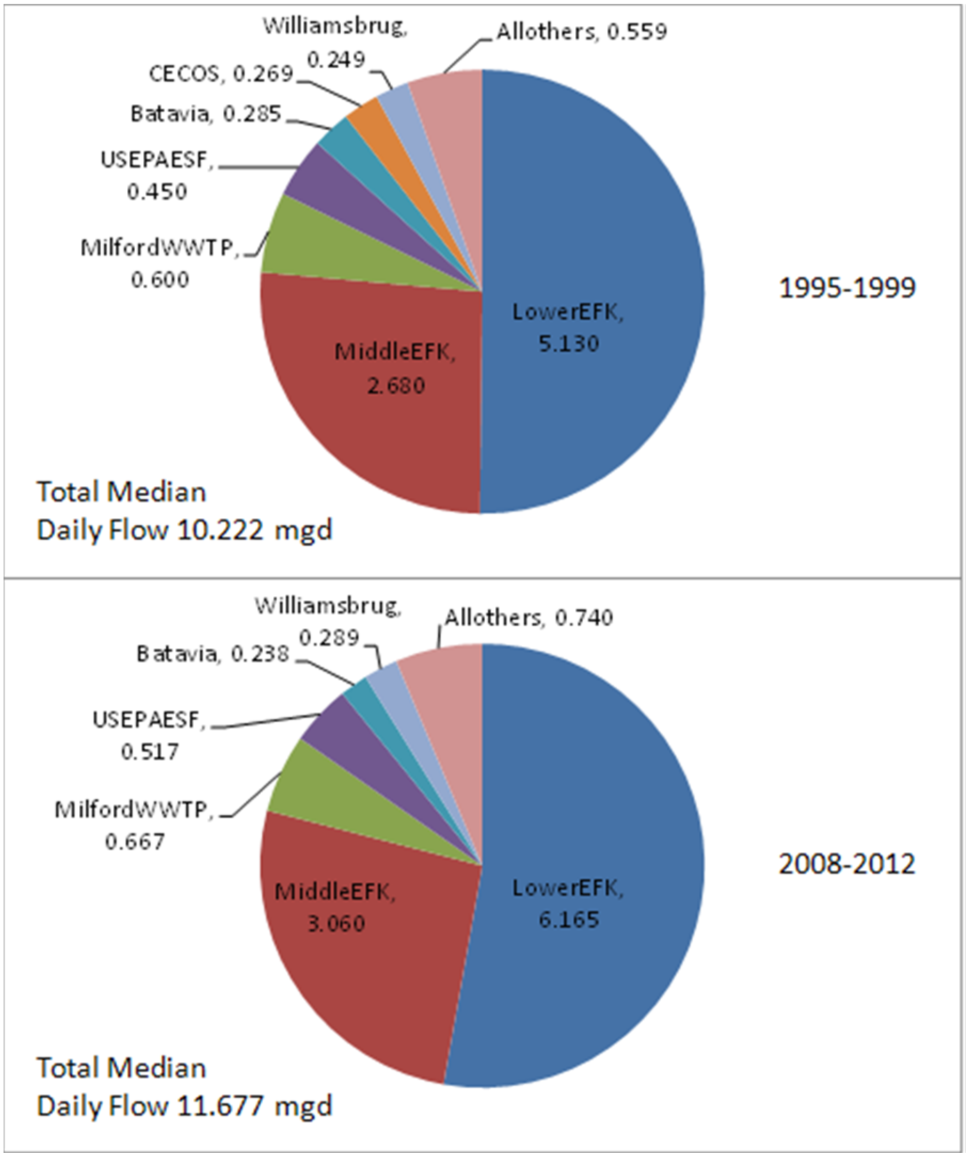


Figure 4. Median daily flows for East Fork LMR basin permitted dischargers apportioned by discharger and stratified by time period.

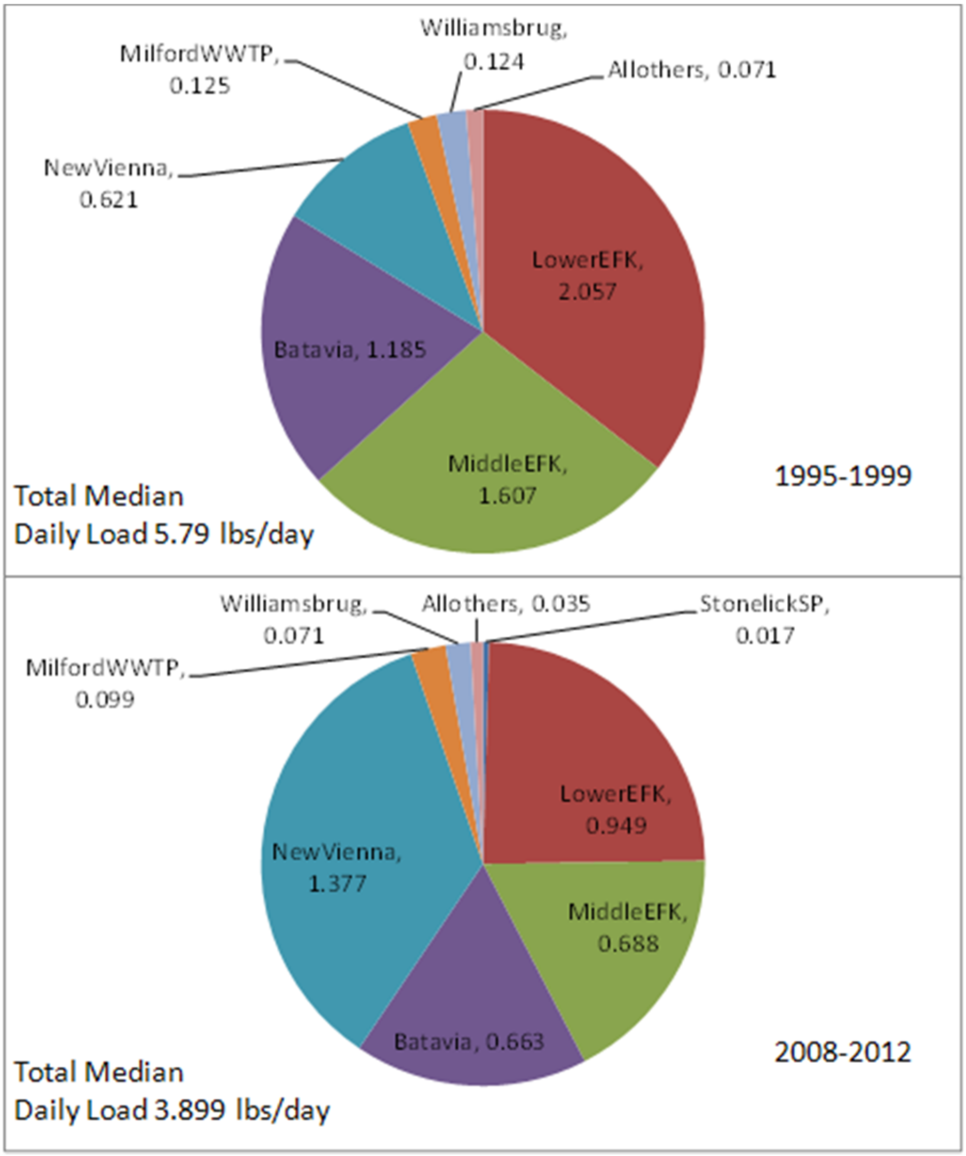


Figure 5. Median daily ammonia nitrogen loads from East Fork LMR basin permitted dischargers apportioned by discharger and stratified by time period.

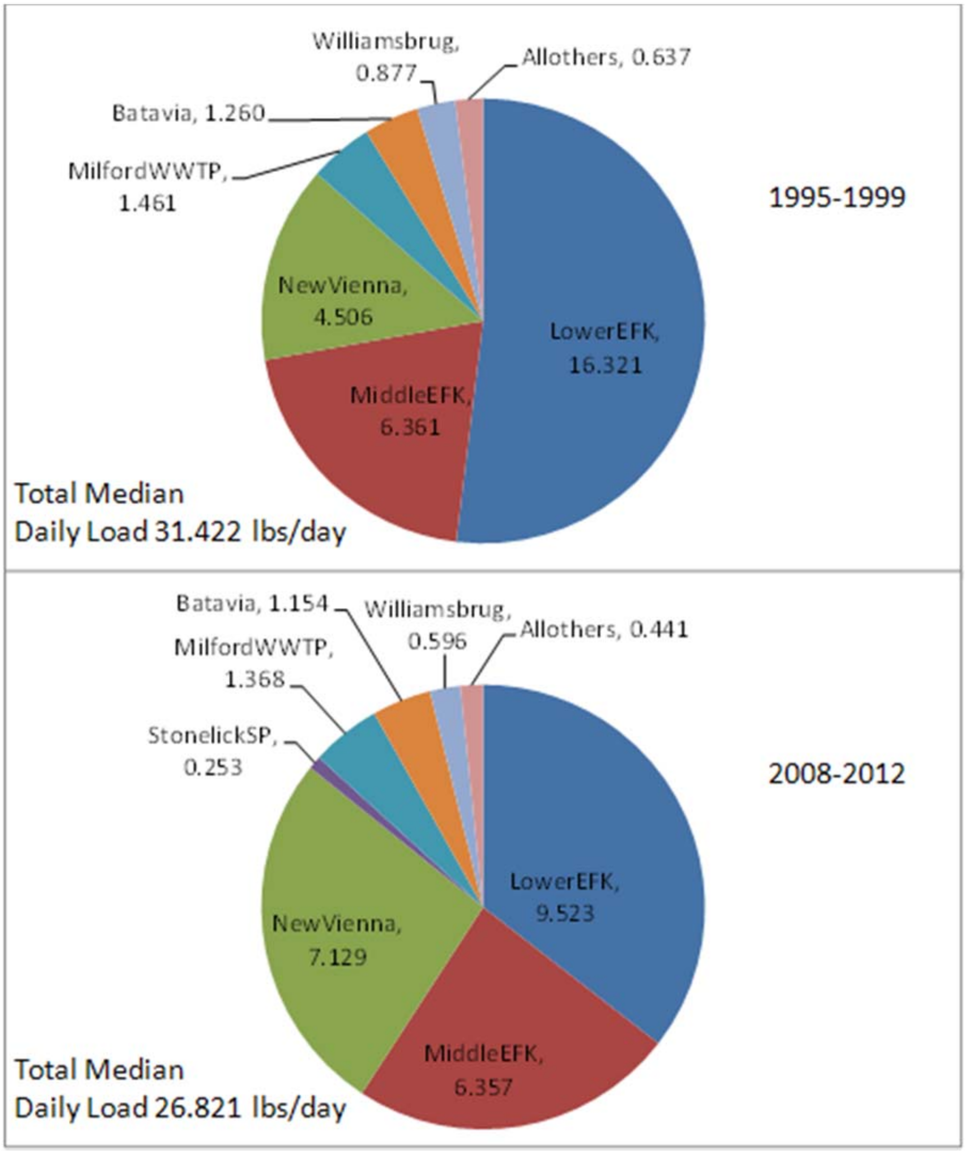


Figure 6. Median daily cBOD5 loads from East Fork LMR basin permitted dischargers apportioned by discharger and stratified by time period.

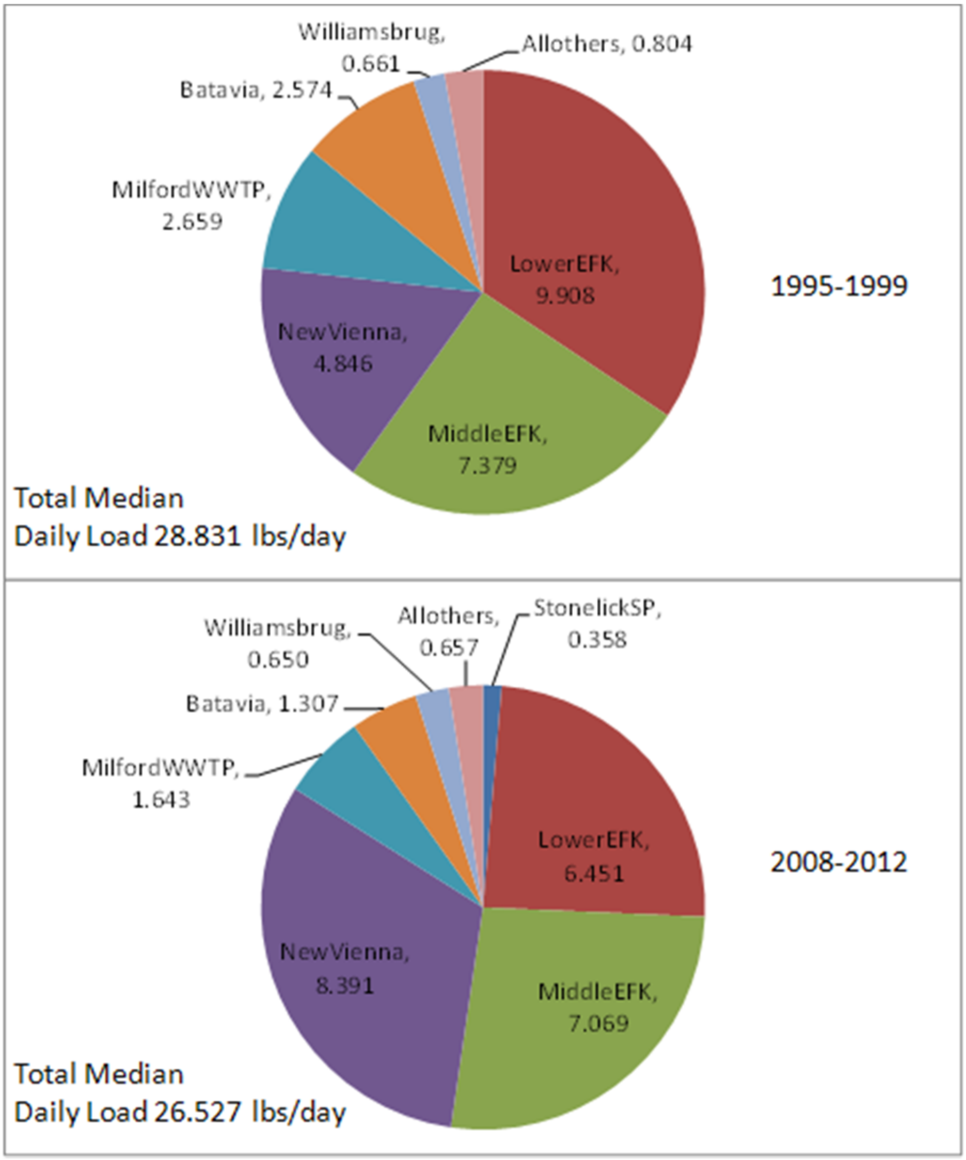
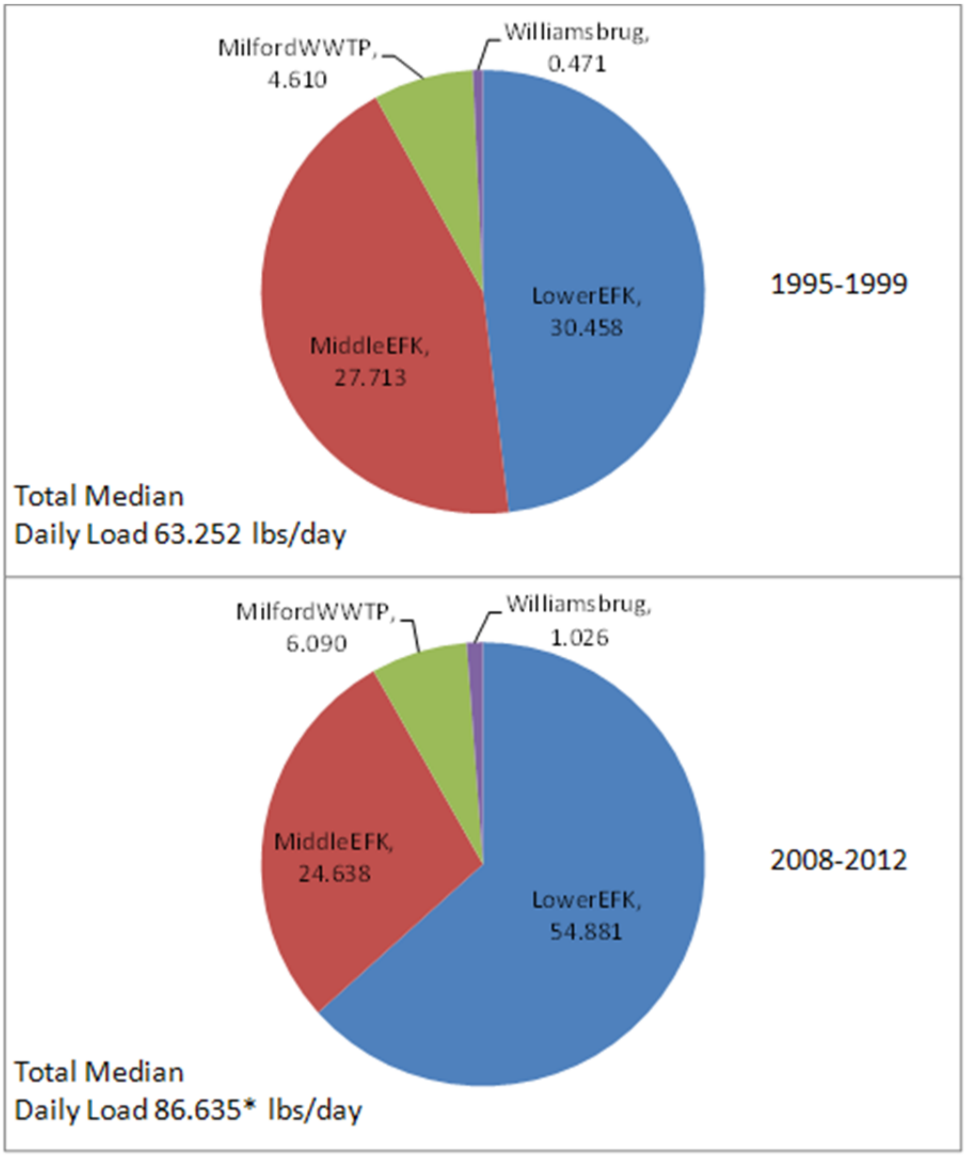


Figure 7. Median total suspended solids loads from East Fork LMR basin permitted dischargers apportioned by discharger and stratified by time period.



*Addition of loads from Locust Ridge Nursing Home, Rolling Acres MHP and Lynchburg WWTP increases the total load to 88.376 lbs/day

Figure 8. Median daily nitrate-nitrite loads from East Fork LMR basin permitted dischargers apportioned by discharger and stratified by time period.

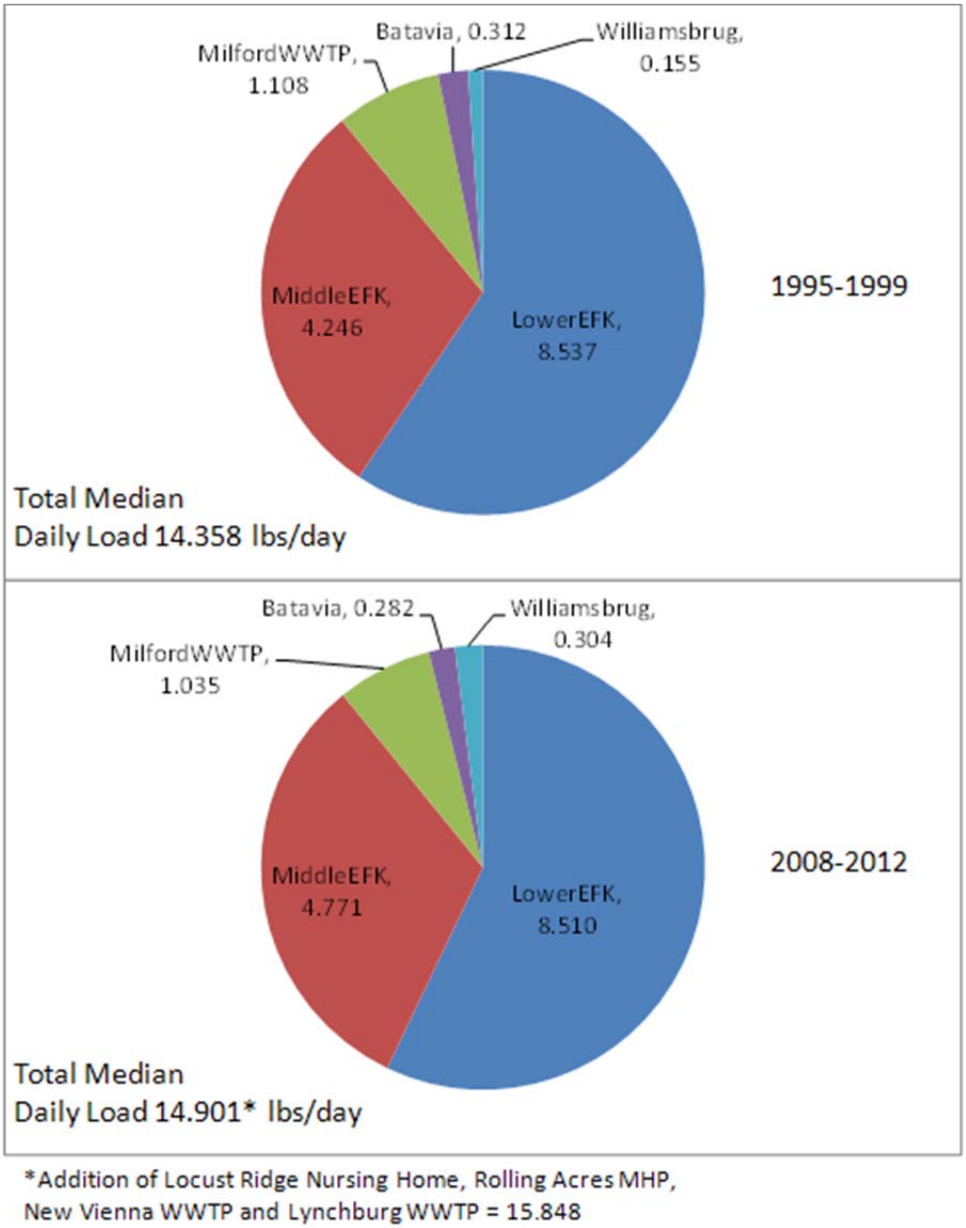


Figure 9. Median daily total phosphorus loads from East Fork LMR basin permitted dischargers apportioned by discharger and stratified by time period.

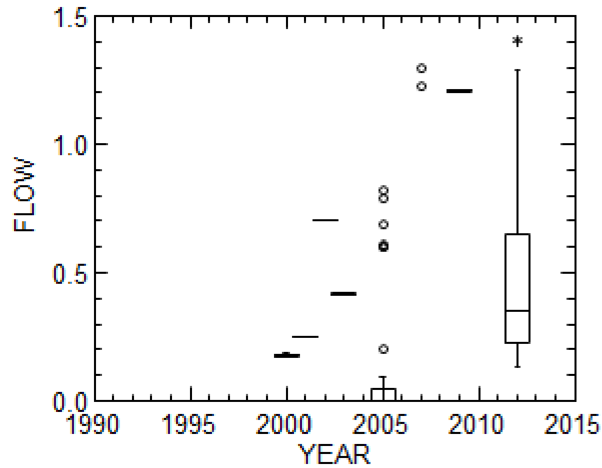
Table 6. NPDES permit compliance indicators for dischargers in the East Fork LMR basin compiled for January 2008 – October 2012. Limit violations are exceedences of concentration-based limits. Frequency violations denote unfulfilled monitoring requirements.

Discharger	Number of Limit Violations	Parameters Exceeded	Number of Frequency Violations	Neglected Parameters	Code Violations†			
					AB	AD	AF	AK
Batavia 1PB00001								
001	40	TSS, CBOD						
Clermont County N.E. Schools 1PT00077								
001	65	NH3, Cl, D.O.	1522	Temp, Flow, TCO	9			
Fayetteville Perry Twp. Sewer District 1PD00024								
001	31	D.O., NH3	75	Temp, D.O., pH				
801			31	Flow				
Forest Creek MHP 1PV00034								
001	25	NH3, D.O., TSS, CBOD	68	Temp, TCO		5		
Holly Towne MHP 1PV00002								
001	48	Cl, TSS	124	TCO, Cl		1		1
Huhtamaki Plastics Inc. 1IQ00016								
001	21	TSS	25	Temp, TSS, TDS, pH, O&G			48	
Locust Ridge Nursing Home Inc 1PX00059								
001	197	NH3, TSS, D.O., CBOD, Cl	4	Temp, D.O.				1
Clermont County - Lower East Fork Regional WWTP 1PK00009								
001	3	Cu	40	Cl				
901			8					
Lynchburg Wastewater Plant 1PB00105								
001	42	D.O.	2		5			
Middle East Fork WWTP 1PK00010								
001	2	NH3, O&G	8					
901			6					
City of Milford Wastewater Treatment Plant 1PC00005								
001	25	NH3, TSS, Fecals	5					
003	2	Flow						

Discharger	Number of Limit Violations	Parameters Exceeded	Number of Frequency Violations	Neglected Parameters	Code Violations†			
					AB	AD	AF	AK
New Vienna Wastewater Treatment Plant 1PA00005								
001	15	CBOD	103	Temp, pH, D.O., TCO	1			3
New Vienna WTP 1IY00122								
001	25	TSS, pH	34	pH	1			
Ohio Asphaltic Limestone Corporation 1IJ00060								
002	3	TSS						
Orchard Lake Mobile Home Park 1PV00009								
001	64	NH3, TSS, D.O., CBOD, Cl	230	TCO, Temp				1
Rolling Acres WWTP 1PG00100								
001	4	TSS						
Royal Hills MHP 1PV00074								
001	12	D.O., Cl	3			13		
Snow Hill Country Club 1PZ00029								
001	33	NH3, TSS	4150	TCO, Flow, CBOD				
St. Martin WWTP 1PA00100								
001	101	TSS, CBOD, NH3, D.O.	93	TCO				
Stonelick State Park WWTP 1PP00020								
001			24	D.O., CBOD, TSS				
village of Williamsburg WWTP 1PB00034								
001	119	NH3, TP, TSS, CBOD	469	Cl, pH, D.O., Flow				

†AB – Paper or electronic records of analytical results were lost; AD – Automatic analyzer out of service; AF – Sample site inaccessible due to flooding or freezing; AK - Number of bacterial colonies too numerous to count (i.e., each dilution tested exceeds the acceptable number of colonies given by the analytical method).

Figure 10. Distributions of annual flows from the New Vienna WWTP,2000-2012.



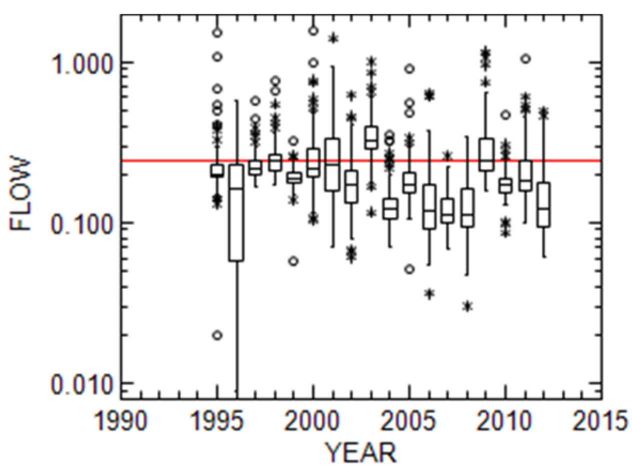
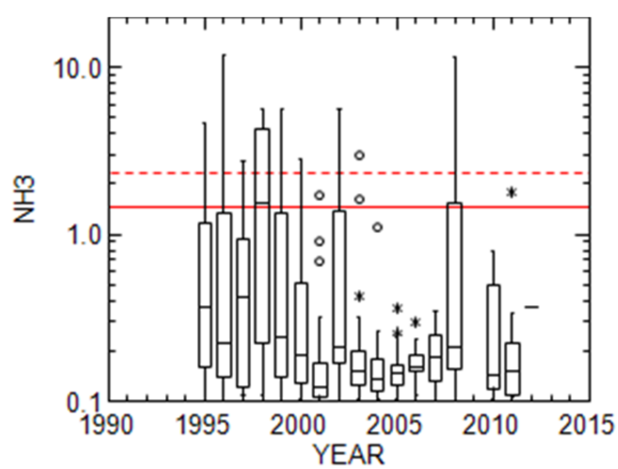


Figure 11. Distributions of third quarter flows from the Batavia WWTP 1995-2012 in relation to the average design flow (0.236 mgd, red line in plot).

Figure 12. Distributions of third quarter ammonia nitrogen concentrations measured in the Middle East Fork WWTP effluent 1995-2012 in relation to weekly (dashed red line) and monthly (solid red line) permit limits.



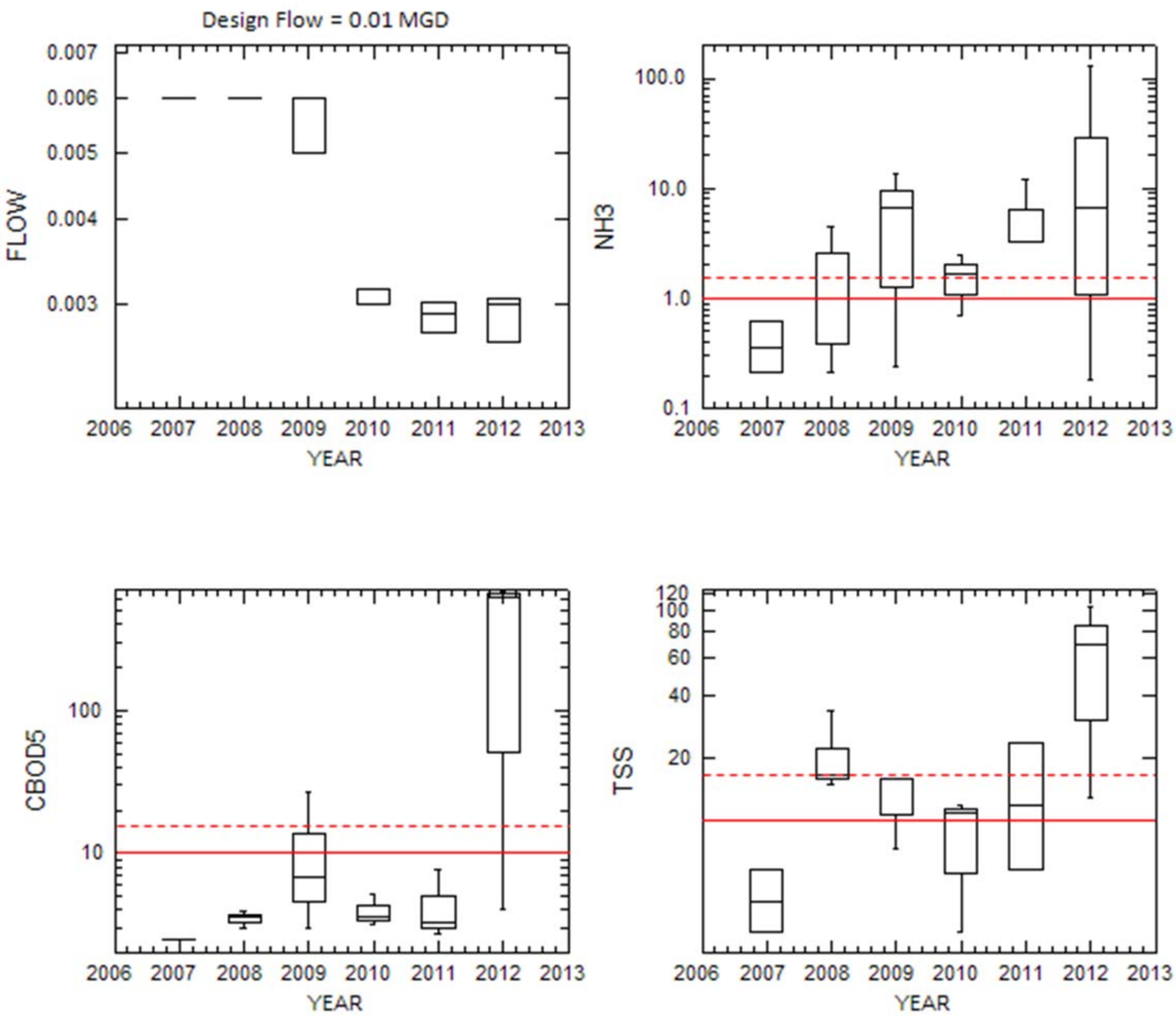


Figure 13. Third quarter plant flows and concentrations of ammonia nitrogen, CBOD5 and TSS reported by the Locust Ridge Nursing Home, 2007-2012. Note that samples reported for 2012 were for land-applied effluent. The plant was under construction in2012 and did not discharge to Light Run.

Surface Water Quality

Overview

Water quality in the East Fork Little Miami River basin during 2012 can be described as a function of stream flow and organic enrichment. Sites with either intermittent or interstitial flow tended to have lower dissolved oxygen concentrations and higher organic nitrogen (including ammonia nitrogen) concentrations compared to sites with continuous flow (Figure 14). Ammonia nitrogen (NH3-N) concentrations can be effectively modeled (Figure 14.d) by a combination of minimum observed dissolved oxygen and total Kjeldahl nitrogen (TKN). When parsed for sites lacking continuous flow, this relationship holds, which suggests that observed inter relationships between dissolved oxygen, NH3-N and TKN is not simply an artifact of stream flow, and that loadings are helping to force low dissolved oxygen. Curiously, whether low dissolved oxygen contributes to internal loading via remineralization of nitrogen (thus making nitrogen more available for microbial uptake) is untested, but is at least plausible given the quadratic nature of the relationship between NH3-N, TKN and dissolved oxygen (that is, NH3-N increases exponentially with high TKN concentrations and low dissolved oxygen).

The preceding interpretation aside, chronically low dissolved oxygen was associated with readily identified, direct sources of organic enrichment in a few cases, notably the New Vienna WWTP, and an impounded (or formerly so) reach on the South Fork Dodson Creek at Roush Road. Otherwise, episodically low dissolved oxygen was noted in tributaries throughout the catchment (Figure 15; Table 7), reflecting enrichment tied to diffuse sources. Organic enrichment/low dissolved oxygen was collectively most evident in the following hydrologic units:

HUC12	Name
050902021002	East Fork LMR Headwaters
050902021003	Dodson Creek Headwaters
050902021301	Stonelick Creek Headwaters
050902021303	Stonelick Creek including Moores Fork
050902021005	West Fork East Fork LMR
050902021102	Fivemile Creek, Fourmile Creek, Pleasant Run

Within these hydrologic units, the coincidence of elevated ammonia, TKN and low dissolved oxygen was most evident in the East Fork headwaters, the headwaters of Stonelick Creek, the headwaters of Dodson Creek, and Fivemile Creek (Figure 16). Dissolved oxygen concentrations in the West Fork unit were not critically low, but TKN concentrations there were among the highest compared to other units. Additionally, wide dissolved oxygen swings and high pH values suggested that the enrichment in the West Fork unit was related more directly to nutrients than organic matter.

No site had concentrations of metals (As, Cd, Cr, Cu, Ni, Se, Pb, and Zn) above WQS for the protection of aquatic life; however, sites in the northern quarter of the basin tended to have more frequent detections (Figure 17), especially for arsenic. Natural sources likely explain the detections, given that arsenic concentrations (as well as the other metals) were positively associated with barium and manganese. However, arsenic was historically used as a broadcast insecticide, especially for potatoes and in orchards.

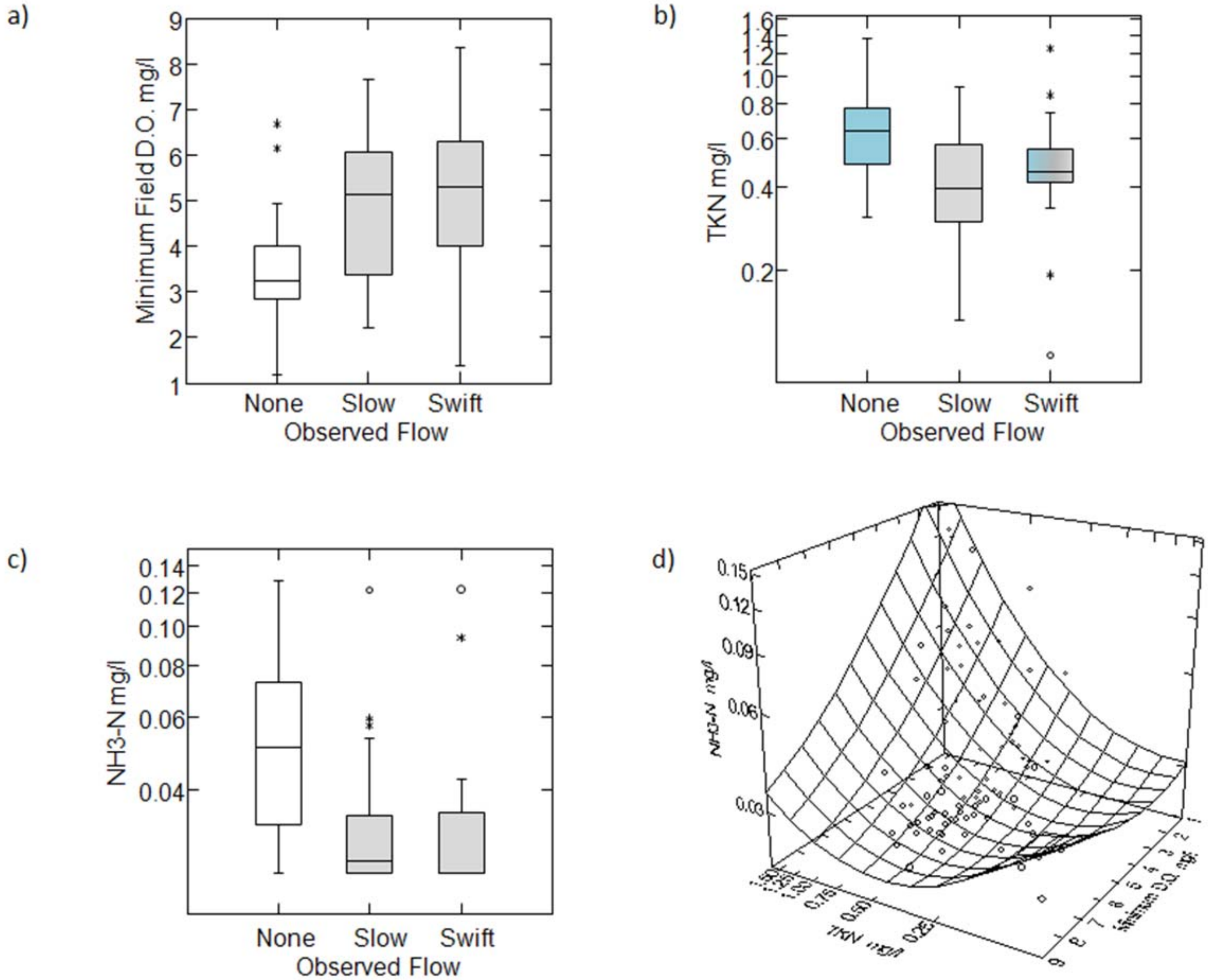


Figure 14. Distributions of (a) minimum field dissolved oxygen, (b) total Kjeldahl nitrogen (TKN) and (c) ammonia nitrogen (NH3-N) in relation to categorical levels of observed stream flow, and (d) a 3-dimensional scatter plot of the relationship between minimum dissolved oxygen, TKN and NH3-N. In this representation, 61% of the variance in NH3-N is explained. Data are from sites sampled in the East Fork LMR, 2012.

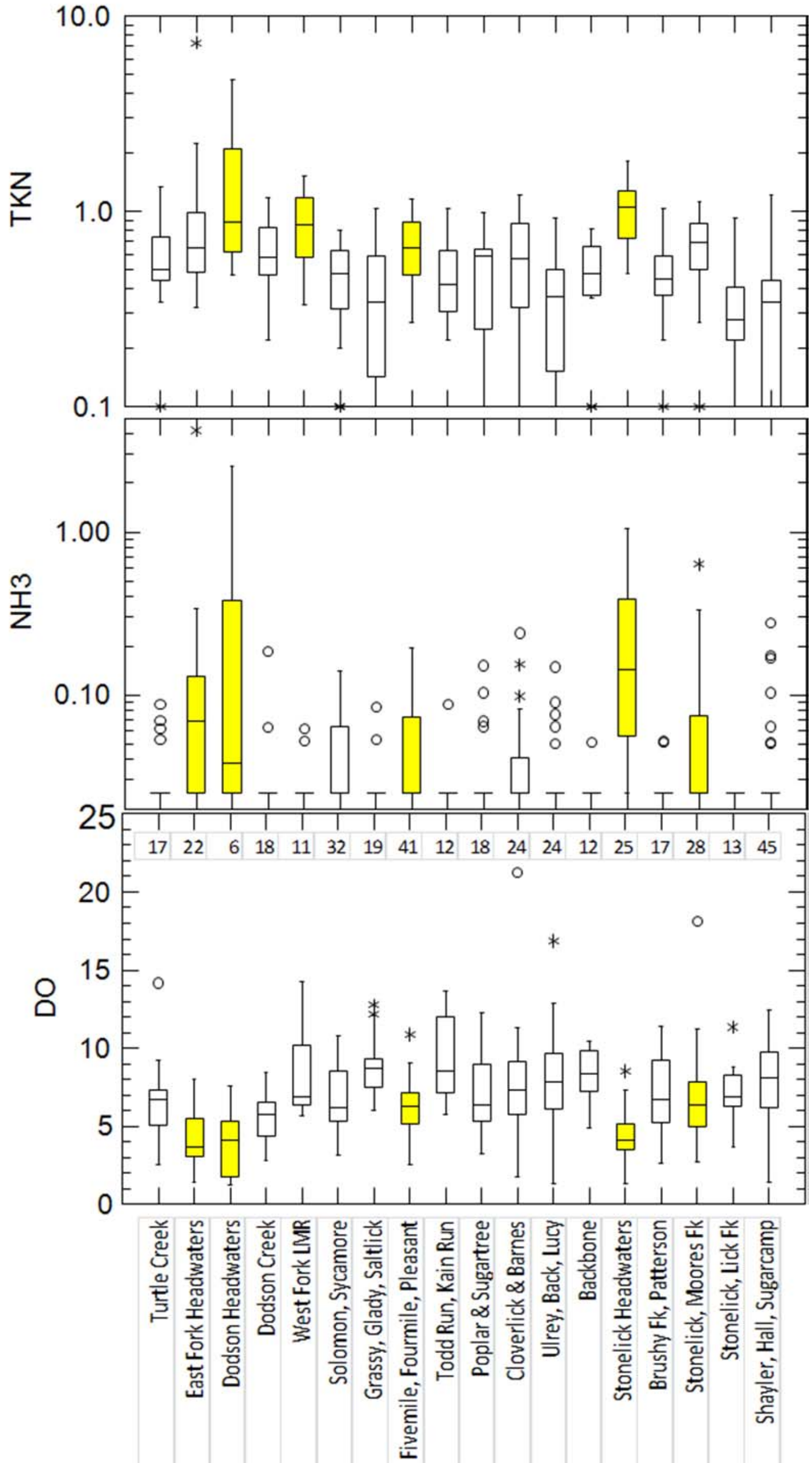


Figure 15. Distributions of total Kjeldahl nitrogen, ammonia nitrogen and dissolved oxygen stratified by 12-HUCs within the East Fork LMR basin. Yellow-shaded boxes show distributions containing values that are potentially stressful to aquatic life. Data from the East Fork mainstem downstream from Fayetteville are excluded.

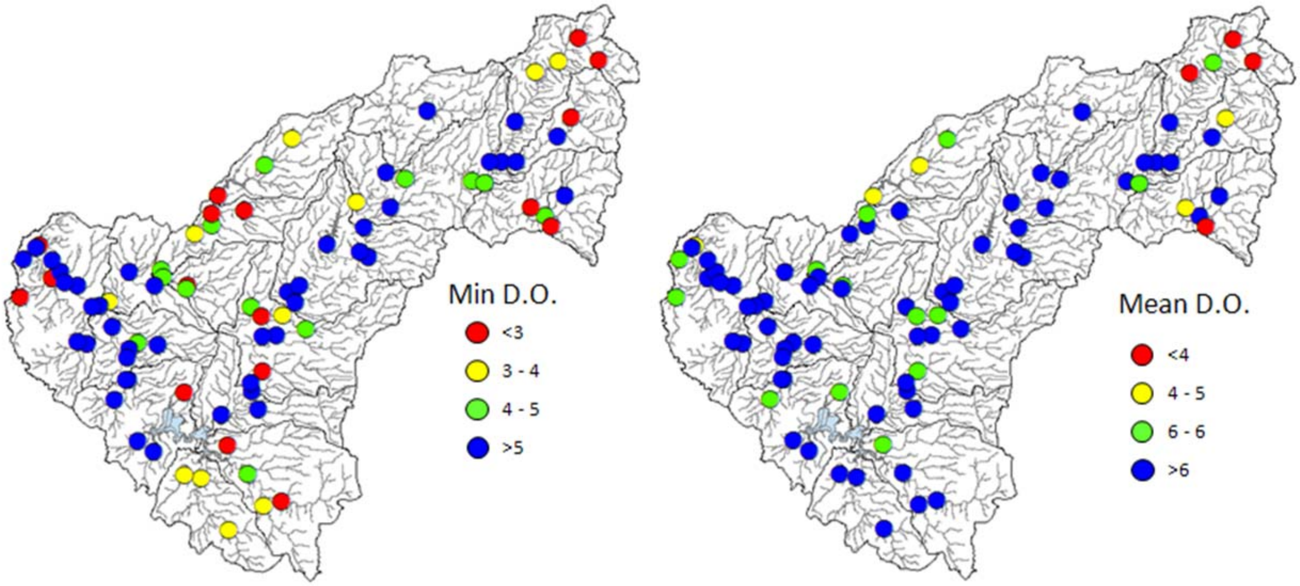


Figure 16. Minimum and mean field dissolved oxygen concentrations measured during the 2012 survey of the East Fork Little Miami River basin.

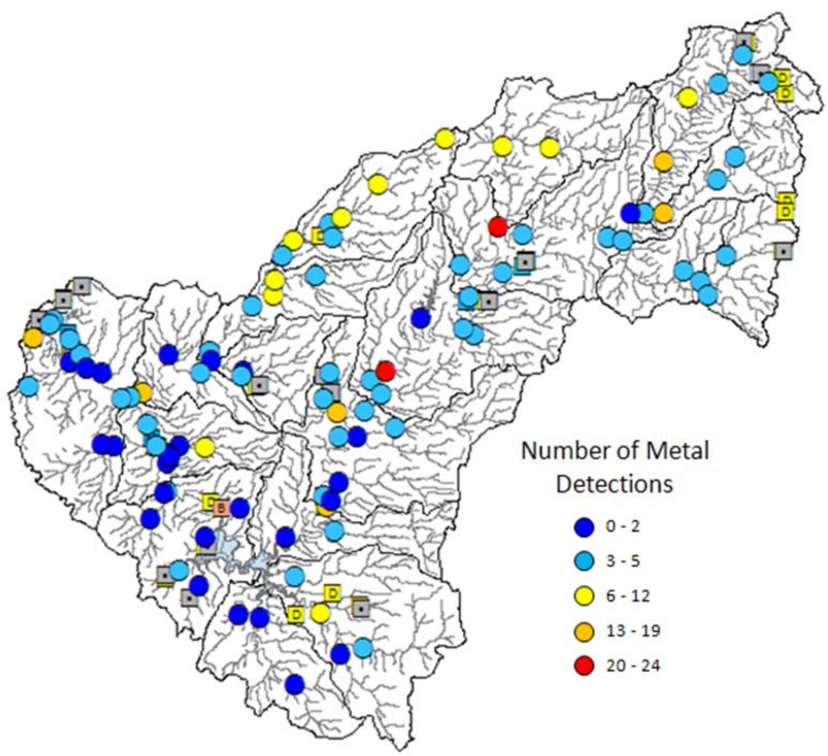


Figure 17. The number of times metals (As, Cd, Cr, Cu, Pb, Se, and Zn) were detected in water quality samples collected from the East Fork LMR basin, 2012. Note that no single concentration exceeded established WQS criteria for the protection of aquatic life.

Table 7 Exceedances of Ohio EPA Water Quality Standards criteria (OAC 3745-1) (and other chemicals not codified for which toxicity data is available) for chemical/physical water parameters measured in grab samples taken from the East Fork Little Miami River study area during the summer of 2012 (units are µg/l for metals and organics, C° for temperature, SU for pH, µmhos/cm for specific conductivity, and mg/l for all other parameters).

Stream (*use designation* [b])		**Parameter (value)**
12-digit HUC[a]	**River Mile**	
East Fork Little Miami River *[(WWH from headwaters to RM 75, all other segments EWH) PCR, AWS, IWS]*		
10-02	84.1	Dissolved oxygen (4.66[‡], 1.49[‡‡], 2.35[‡‡], 3.05[‡‡], 3.37[‡‡])
10-02	82.35	Dissolved oxygen (1.38[‡‡], 2.59[‡‡], 3.20[‡‡], 3.24[‡‡], 2.82[‡‡]) Ammonia-N (4.25*)
10-02	80.44	Dissolved oxygen (4.91[‡], 4.00[‡])
10-02	75.33	Dissolved oxygen (4.98[‡], 4.97[‡], 3.81[‡‡], 4.38[‡])
10-06	72.8	Dissolved oxygen (4.40[‡‡], 4.68[‡‡], 4.72[‡‡], 5.34[‡])
10-06	70.9	Dissolved oxygen (5.57[‡], 5.90[‡], 5.31[‡])
10-06	70.12	Dissolved oxygen (5.11[‡], 4.45[‡‡])
10-06	63.4	Dissolved oxygen (4.79[‡‡], 5.19[‡], 5.63[‡], 5.01[‡])
11-01	56.25	Dissolved oxygen (5.01[‡], 5.24[‡])
11-01	54.42	Dissolved oxygen (5.49[‡])
11-02	41.07	Dissolved oxygen (5.89[‡])
11-02	35.87	Dissolved oxygen (4.56[‡‡], 4.96[‡‡], 5.40[‡], 5.69[‡])
11-02	34.91	Dissolved oxygen (5.69[‡])
13-05	2.2	Dissolved oxygen (5.92[‡])
13-05	0.77	Dissolved oxygen (5.99[‡], 5.55[‡], 5.36[‡], 5.18[‡], 5.64[‡])
Tributary to East Fork Little Miami River (RM 78.45) *(undesignated-WWH apply)*		
10-02	0.46	Dissolved oxygen (3.57[‡‡], 3.29[‡‡], 3.84[‡‡], 3.92[‡‡])
Turtle Creek *(WWH, PCR, AWS, IWS)*		
10-01	5.9	Dissolved oxygen (4.00[‡], 2.58[‡‡], 3.35[‡‡,], 3.54[‡‡])
10-01	4.4	Temperature (28.37*) pH (9.01[Δ], 9.38[Δ])
Dodson Creek *(EWH [WWH Recommended], PCR, AWS, IWS)*		
10-04	5.83	Dissolved oxygen (4.36[‡‡], 5.43[‡])
10-04	0.05	Dissolved oxygen (4.06[‡‡], 4.86[‡‡], 5.15[‡])

Stream (*use designation* [b])		**Parameter (value)**
12-digit HUC[a]	**River Mile**	
South Fork Dodson Creek *(WWH PCR, AWS, IWS)*		
10-03	0.9	Dissolved oxygen (4.65[‡], 1.20[‡‡], 1.79[‡‡], 3.57[‡‡]) Ammonia-N (2.56*)
Tributary to Dodson Creek (RM 4.52) *(undesignated-WWH apply)*		
10-04	0.6	Dissolved oxygen (4.69[‡], 2.76[‡‡], 2.86[‡‡], 3.40[‡‡])
West Fork East Fork Little Miami River *(WWH PCR, AWS, IWS)*		
10-05	7.45	Temperature (28.42*, 28.35*) pH (9.45[Δ])
Sycamore Creek *(WWH, PCR, AWS, IWS)*		
10-06	0.8	Dissolved oxygen (3.14[‡‡], 4.06[‡])
Solomon Run *(WWH, PCR, AWS, IWS)*		
10-06	1.86	Dissolved oxygen (1.94[‡‡])
Fivemile Creek *(WWH, PCR, AWS, IWS)*		
11-02	2.3	Dissolved oxygen (4.74[‡])
11-02	0.5	Dissolved oxygen (3.11[‡‡], 4.12[‡])
Pleasant Run *(WWH, PCR, AWS, IWS)*		
11-02	2.7	Dissolved oxygen (3.32[‡‡], 4.56[‡])
11-02	1.35	Dissolved oxygen (4.96[‡])
11-02	0.42	Dissolved oxygen (2.79[‡‡])
Crane Run *(WWH, PCR, AWS, IWS)*		
11-02	0.20	Dissolved oxygen (2.52[‡‡], 4.35[‡])
Todd Run *(WWH PCR, AWS, IWS)*		
11-03	1.00	Temperature (28.80*)
Cloverlick Creek *(WWH PCR, AWS, IWS)*		
12-02	8.5	Dissolved oxygen (1.78[‡‡])
12-02	4.59	Dissolved oxygen (4.55[‡])

Stream (*use designation* [b])		**Parameter (value)**
12-digit HUC[a]	**River Mile**	
Tributary to Cloverlick Creek (RM 7.48) *(undesignated-WWH apply)*		
12-02	0.5	Dissolved oxygen (3.68[‡‡])
Poplar Creek *(WWH PCR, AWS, IWS)*		
12-01	8.4	Dissolved oxygen (3.25[‡‡])
12-01	2.1	Dissolved oxygen (3.43[‡‡])
Sugartree Creek *(WWH PCR, AWS, IWS)*		
12-01	0.95	Dissolved oxygen (3.39[‡‡])
Barnes Run *(WWH PCR, AWS, IWS)*		
12-02	1.9	Dissolved oxygen (2.50[‡‡], 4.98[‡])
Slabcamp Run *(WWH PCR, AWS, IWS)*		
12-03	2.6	Dissolved oxygen (4.14[‡], 3.79[‡‡], 1.29[‡‡])
Backbone Creek *(WWH PCR, AWS, IWS)*		
12-04	0.6	Dissolved oxygen (4.92[‡])
Stonelick Creek *(WWH PCR, AWS, IWS)*		
13-01	20.0	Dissolved oxygen (4.12[‡], 3.18[‡‡], 4.71[‡])
13-01	17.72	Dissolved oxygen (4.11[‡], 4.24[‡], 2.20[‡‡], 4.34[‡], 4.94[‡])
13-01	13.4	Dissolved oxygen (4.48[‡], 4.58[‡], 2.99[‡‡], 4.96[‡])
13-03	9.84	Dissolved oxygen (3.63[‡‡])
13-03	6.2	Dissolved oxygen (4.02[‡], 4.90[‡])
13-04	5.2	Dissolved oxygen (4.54[‡])
13-04	1.00	Dissolved oxygen (3.71[‡‡])
Locust Creek *(undesignated-WWH apply)*		
13-01	0.32	Dissolved oxygen (3.6[‡‡], 3.77[‡‡], 3.53[‡‡], 4.08[‡], 3.17[‡‡])
Tributary to Stonelick Creek (RM 16.56) *(undesignated-WWH apply)*		
13-01	0.35	Dissolved oxygen (2.22[‡‡], 3.83[‡‡], 1.32[‡‡], 3.97[‡‡], 2.94[‡‡])
Moores Fork *(WWH PCR, AWS, IWS)*		
13-03	2.9	Dissolved oxygen (2.84[‡‡])
13-03	0.7	Dissolved oxygen (4.45[‡], 2.69[‡‡], 4.97[‡])
Tributary to Stonelick Creek (RM 10.61) *(undesignated-WWH apply)*		
13-03	0.89	Dissolved oxygen (4.94[‡])
Brushy Fork *(WWH PCR, AWS, IWS)*		
13-02	2.2	Dissolved oxygen (3.25[‡‡], 2.62[‡‡])

Stream (*use designation* [b])		Parameter (value)
12-digit HUC[a]	River Mile	
13-02	0.3	Dissolved oxygen (4.36‡)
Paterson Run *(WWH PCR, AWS, IWS)*		
13-02	0.1	Dissolved oxygen (4.98‡)
Hall Run *(WWH PCR, AWS, IWS)*		
13-05	2.3	Dissolved oxygen (2.58‡‡, 3.29‡‡)
13-05	0.23	Dissolved oxygen (2.90‡‡)
Tributary to East Fork Little Miami River (RM 1.62) *(undesignated-WWH apply)*		
13-05	0.1	Dissolved oxygen (4.07‡, 3.04‡‡, 1.43‡‡, 4.58‡, 4.91‡)

a See Table 3

b Use designations:

Aquatic Life Habitat	Water Supply	Recreation
MWH - modified warmwater habitat	IWS - industrial water supply	PCR - primary contact
WWH - warmwater habitat	AWS - agricultural water supply	SCR - secondary contact
EWH - exceptional warmwater habitat	PWS- public water supply	BWR -bathing water

Undesignated [WWH criteria apply to 'undesignated' surface waters.]

* exceedance of numerical criteria for prevention of chronic toxicity (CAC).
∆ exceedance of the pH criteria (6.5-9.0).
‡ value is below the EWH minimum 24-hour average D.O criterion (6.0 mg/l) or value is below the WWH minimum 24-hour average D.O criterion (5.0 mg/l) or value is below the MWH minimum 24-hour average D.O criterion (4.0 mg/l) as applicable.
‡‡ value is below the EWH minimum at any time D.O. criterion (5.0 mg/l) or value is below the WWH minimum at any time D.O. criterion (4.0 mg/l) or value is below the MWH minimum at any time D.O. criterion (3.0 mg/l) as applicable.

East Fork Little Miami River

As previously mentioned, concentrations of ammonia nitrogen, total Kjeldahl nitrogen and total dissolved solids were elevated in the headwater reach of the East Fork mainstem due to organic enrichment from the New Vienna WWTP and nonpoint loadings. The ensuing effect on dissolved oxygen concentrations was profound, as evidenced by ambient concentrations routinely less than the instantaneous WQS criterion of 4.0 mg/l at stations M04S35 (RM 82.35) and M04S17 (RM 84.1; Figure 18; Table 7). A secondary manifestation was suggested by elevated dissolved oxygen swings (6.87 mg/l) and elevated benthic chlorophyll levels (257 mg/m2) measured upstream from SR 28 (M04S16; RM 80.44).

Nitrate-nitrite nitrogen concentrations dropped to near or below analytical detection limits in the reach between river miles 65 and 40, with nitrogen to phosphorus ratios tracking this and averaging less than 1 (Figure 19.c). Phosphorus concentrations in this reach, however, remained steady, and elevated relative to less enriched systems[5]. This pattern suggests nitrogen was being actively taken up, given its status as the apparently limiting nutrient. Coincidentally this was the only reach that had 5-day biological oxygen demand (BOD5) concentrations above detection limits[6] (albeit, BOD5 was not measured upstream from RM 60). The continuous dissolved oxygen profile recorded from M04S13 (RM 56.25) on 8/14/2012 revealed a wide swing in dissolved oxygen (8.73 mg/l) that appeared driven mostly by microbial respiration (i.e., bacteria and fungi) given that the daytime maximum (10.05 mg/l) was neither particularly high nor coincident with super saturation. Benthic chlorophyll levels averaged less than 100 mg/m^2 (essentially a background level), and sestonic chlorophyll was not particularly elevated in this reach (1.9 and 3.5 :g/l at RMs 56.25 & 54.42, respectively), at least on the day measurements were taken[7] (7/11/2012).

Downstream from Harsha Lake, water quality parameters gave no indication of organic enrichment, and despite highly elevated nutrient concentrations, nutrient enrichment was not apparent given that dissolved oxygen swings were less than 6 mg/l and benthic chlorophyll levels averaged less than 183 mg/m^2.

Organic Contaminants

Pesticides, herbicides, industrial solvents and lubricants, flame retardants, by-products of petroleum combustion, plasticizers, and chlorine disinfection by-products are examples of organic (carbon-based) compounds that can contaminate surface waters. Organic contaminants are of concern because they can be directly toxic to aquatic life at low concentrations, as is the case for legacy pesticides like DDT, aldrin and chlordane, or cause sublethal effects as endocrine mimics (i.e., can act as hormones), as in the case of plasticizers like phthalates. Additionally, these contaminants pose a risk to humans as many bioaccumulate (i.e., they build-up in the body over time) and are neurotoxic and/or carcinogenic. Because the sources of organic

[5] i.e., for Ohio.
[6] i.e., anything above detection is telling.
[7] The dissolved oxygen profile collected with the sestonic and benthic chlorophyll samples did not show an appreciable swing.

contaminants are various and many, these pollutants are ubiquitous in the environment. However, their concentrations in surface waters are typically trace amounts, and though consequential at the population level (i.e., detectable as an increase in the incidence of cancer, birth defects, or developmental disorders in very large samples), the level of overt risk posed to any given individual from casual contact with waters in the study area is astronomically remote.

Water samples for analysis of organic contaminants were collected between three and seven times from 14 stream sampling locations in the East Fork study area for a total of 810 sampling events. Organic compounds were detected in 196 of the 810 samples (24.2%), with herbicides collectively being the most frequently detected compounds (78% of detections), followed by insecticides (12% of detections) and plasticizers (10% of detections). Four WQS criteria exceedances were noted for legacy pesticides (Table 8). In all four cases, concentrations were very near the detection limits.

Samples collected from three sites along Pleasant Run in the vicinity of the CECOS landfill had a lower frequency of detections compared to other sites in the study area (15.5% of samples compared to 24.2%), and showed no longitudinal pattern in detections from upstream to downstream from the landfill. Similarly, Shayler Run had a lower frequency of detections relative to the entire sample. No assessment unit stood out as having an unusually high frequency of detections relative to the frequency in the entire sample, though detections in the mainstem, West Fork and Turtle Creek units were slightly elevated by comparison (Table 8).

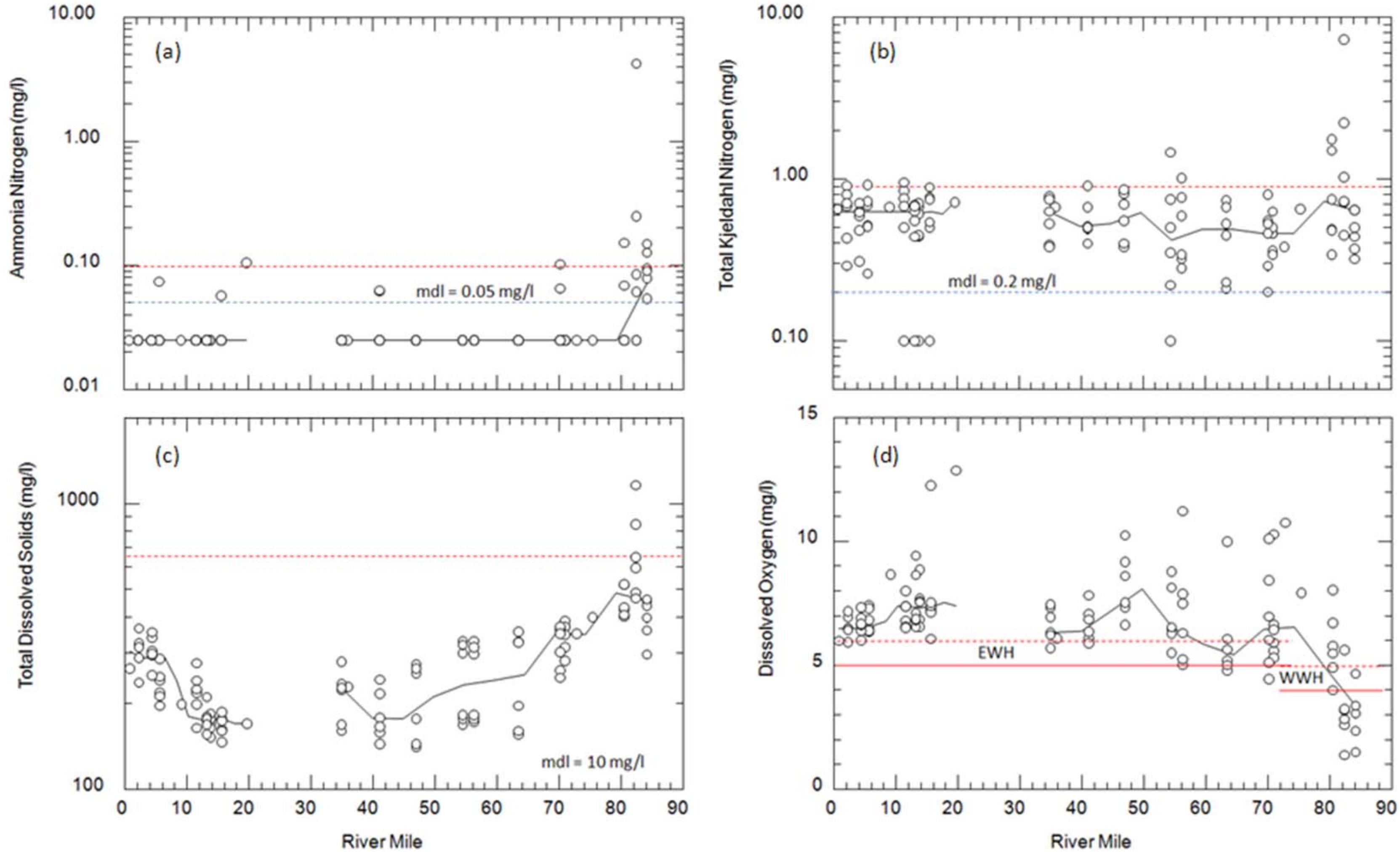


Figure 18. Longitudinal profiles of (a) ammonia nitrogen, (b) total Kjeldahl nitrogen, (c) total dissolved solids, and (d) dissolved oxygen measured in samples collected from the East Fork Little Miami River, 2012. Dashed red lines in plots (a), (b) and (c) suggest elevated levels. The blue lines in (a) and (b) indicate analytical detection limits. The red lines in (d) depict water quality criteria: dashed lines are 24 h average criteria, solid lines are instantaneous.

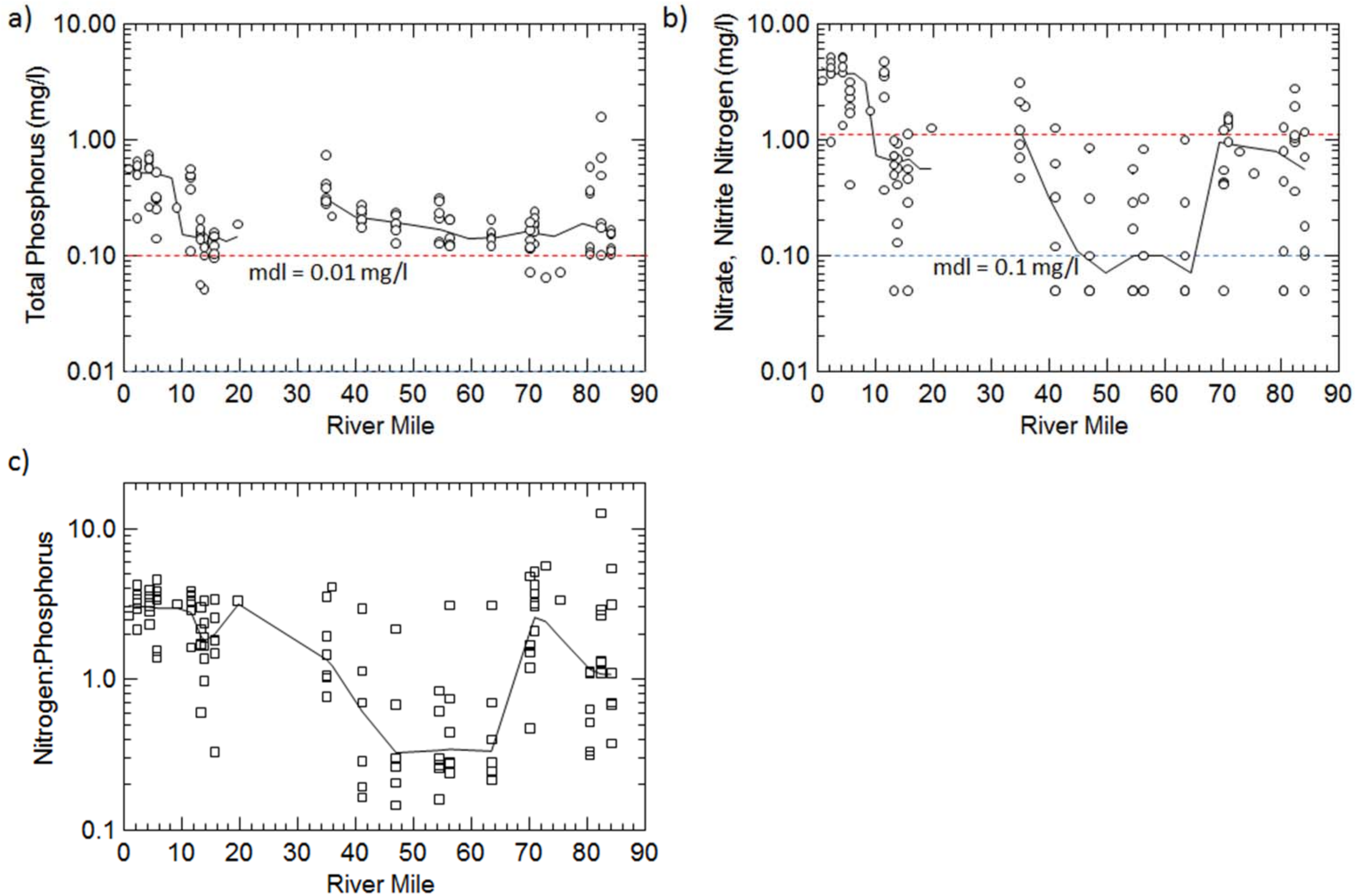


Figure 19. Longitudinal profiles of (a) total phosphorus and (b) nitrate, nitrite nitrogen measured in water samples collected from the East Fork Little Miami River, 2012. Dashed red lines in plots (a) and (b) suggest elevated levels, and the blue lines indicate analytical detection limits. Nitrogen to phosphorus ratio are given in (c); note the strong tendency towards nitrogen limitation.

Table 8. Frequency of organic compounds detected in stream water samples in the East Fork Little Miami River watershed during 2012. (Number of water quality criteria exceedences[a] / Number of detections).

Parameter	**East Fork LMR mainstem** RMs 75.33, 46.92, 34.91, 19.65, 9.10, and 0.77	East Fork Little Miami River Watershed (WAU 05090202-__-__)[b] 10-01 **Turtle Creek** RM 1.2	10-05 **W. Fk. E. Fk** RM 0.12	11-05 **Pleasant Run** RMs 12.70, 1.35, and 0.42	12-02 **Cloverlick Cr** RM 4.59	13-04 **Stonelick Cr** RM 1.00	13-05 **Shayler Run** RM 1.71	**TOTAL**
Acetochlor* (herbicide)	*/7	*/2	*/3	*/1	-	*/1	-	***/14**
Aldrin (banned pesticide)	-	1/1	-	-	-	-	-	**1/1**
Atrazine* (herbicide)	*/12	*/2	*/3	*/11	*/2	*/2	-	***/32**
α-Hexachlorocyclohexane (Lindane isomer)	0/1	0/1	-	0/1	0/1	0/1	-	**0/5**
γ-Hexachlorocyclohexane (Lindane)	0/6	0/1	0/1	0/2	0/2	0/2	-	**0/14**
Bis(2-Ethylhexyl)adipate* (plasticizer)	*/1	-	-	-	-	-	-	***/1**
Bis(2-Ethylhexyl)phthalate (plasticizer)	0/9	0/2	0/1	0/6	-	-	0/1	**0/19**
Cyanazine* (banned herbicide)	*/4	-	*/1	*/2	-	*/1	-	***/8**
Dicamba* (herbicide)	-	-	-	*/1	-	-	-	***/1**
Dieldrin (pesticide - Aldrin degradate)	1/1	-	-	-	-	-	-	**1/1**
Heptachlor epoxide (pesticide)	-	1/1	1/1	-	-	-	-	**2/2**
Metolachlor* (herbicide)	*/10	*/2	*/3	*/12	*/3	*/3	-	***/33**
Metribuzin* (herbicide)	*/9	*/1	*/3	*/4	*/1	*/2	-	***/20**
Simazine* (herbicide)	*/12	*/3	-	*/7	*/1	*/2	-	***/25**
2,4-D* (herbicide)	*/9	*/2	*/2	*/2	*/2	*/2	*/1	***/20**
Exceedences/Detections	**1/81**	**2/18**	**1/18**	**0/49**	**0/12**	**0/16**	**0/2**	**4/196**
Total possible detections[c]	**270**	**45**	**45**	**315**	**45**	**45**	**45**	**810**
Observed/Expected	**81/68**	**18/12**	**18/12**	**49/71**	**12/11**	**16/12**	**2/9**	
Cell Π^2	**2.33**	**2.67**	**2.67**	**6.77**	**0.07**	**1.43**	**5.59**	

* Parameter was detected but no applicable water quality criteria are available.
[a] Concentrations exceeding water quality were as follows: Aldrin 0.0066 ug/l; Dieldrin 0.0022 ug/l; Heptachlor epoxide 0.0053 & 0.0030
[b] See **Table 4.**
[c] Parameters x sites x number of samples

Sediment Chemistry

Sediments were collected from 18 stream locations for the analysis of contaminants during the East Fork LMR survey (Table 9). Analyses were ran for organic compounds at all 18 locations, and for metals at 14 locations. Concentrations of metals and organic compounds detected in samples were compared to effect levels published in McDonald et al. (2000). A threshold effect level is a level at which deleterious effects to one or more organisms have been observed in either field or laboratory studies, but not likely to adversely impact benthic assemblages as a whole (McDonald et al. 2000). A probable effect level is, obviously enough, a level at which deleterious effects are likely to be experienced frequently and by a range of taxa. Metals were detected at all 14 locations; however, only four locations had one detection exceeding a threshold effect level, and none exceeding a probable effect level. Polycyclic aromatic hydrocarbons (PAHs) were detected at 3 of the 18 locations sampled. None exceeded a threshold effect level. No pesticide or pesticide degragdate was detected. Otherwise, only one organic compound, acetophenone, a personal care by-product (and naturally occurring compound), was present above analytical detection limits.

Table 9. Frequency of metal and PAH detections in sediment samples collected during the East Fork LMR survey, 2012.

Station	River Mile	Number of Metals Detected	Number Exceeding Threshold Effect Level	Number of PAHs Detected	Number Exceeding Threshold Effect Level
East Fork LMR					
M04S15	75.33	7	0	0	0
301738	46.92	NA	NA	0	0
M04S10	41.07	8	0	0	0
M04S09	35.87	7	0	0	0
M04S08	34.91	7	1	0	0
M04S06	15.6	NA	NA	1	0
M04S05	13.18	NA	NA	0	0
M04S04	11.5	NA	NA	0	0
M04S03	9.1	7	0	0	0
M04W38	4.3	8	1	2	0
610530	0.77	8	1	1	0
Shayler Run					
M04S37	1.71	7	0	0	0
Stonelick Creek					
M04P09	1.0	7	0	0	0
Cloverlick Creek					
200468	5.2	NA	NA	0	0
Fivemile Creek					
M04S49	0.5	7	0	0	0
West Fork East Fork LMR					
M04S50	0.12	8	1	0	0
Dodson Creek					
M04S51	0.05	8	0	0	0
Turtle Creek					
M04S52	1.2	NA	NA	0	0

Public Drinking Water Supplies
The public drinking water supply (PDWS) beneficial use in the WQS (OAC 3745-1-33) currently applies within 500 yards of drinking water intakes and for all publicly owned lakes. Ohio EPA has developed an assessment methodology for this beneficial use which focuses on source water contaminants not effectively removed through conventional treatment methods, especially atrazine and nitrate. The 2010 Integrated Water Quality Report describes this methodology and is available on OEPA's website:
http://www.epa.state.oh.us/dsw/tmdl/OhioIntegratedReport.aspx.

Impaired source waters may contribute to increased human exposure or treatment costs. For the cases where stream water is pumped to a reservoir, the stream and reservoir sources are evaluated separately. These assessments are designed to determine if the quality of source water meets the standards and criteria of the Clean Water Act. Monitoring of the safety and quality of treated finished drinking water is regulated under the Safe Drinking Water Act and evaluated separately from this assessment. For those cases when the treatment plant processes do not specifically remove a source water contaminant, the finished water quality data may be considered representative of the raw source water directly feeding into the treatment plant.

There are two public water systems (Blanchester and Clermont County) directly served by surface water sources within the study area. Blanchester has three intakes on three different source waters: Whitakers Run (RM 1.4), Stonelick Creek (RM 23.4), and the West Branch of the East Fork the Little Miami River (RM 4.6). Clermont County has an intake structure on Harsha (East Fork) Lake. Table 15 provides a summary of exceedances for the PDWS use. For raw water quality analytical results see Appendices A1 and A2.

Village of Blanchester
The village of Blanchester operates a community public water system that serves a population of approximately 4,500 people through 1,735 service connections. The water treatment system obtains its water from Whitakers Run, Stonelick Creek, and the West Branch of the East Fork the Little Miami River. The Whitakers Run drainage area covers 1.1 mi^2, the Stonelick Creek drainage area covers 1.2 mi^2, and the West Fork the East Fork Little Miami River covers 20.2 mi^2. Raw water is stored in four up-ground reservoirs and by impounding Whitakers Run. The water system's treatment capacity is approximately 1.15 million gallons per day, but current average production is 520,000 gallons per day. The village of Blanchester's treatment processes include a clarifier and solids contact unit, rapid sand filtration, and chlorine disinfection. They also have the capacity to feed permanganate and carbon for taste and odor control.

The village of Blanchester participated in the Syngenta Crop Protection's Atrazine Monitoring Program (AMP). The raw and finished water sampling locations for this monitoring program do not differentiate between the three separate source waters. In 2005, the annual average of the AMP samples was 4.63 µg/L and exceeded the water quality criterion for atrazine in finished water. Ohio EPA conducted two sampling runs in 2008 and detected atrazine concentrations greater than four times the water quality criterion at all three sources (maximum 71.1 ug/L). Based on those data, Ohio EPA elected to conservatively apply the PDWS impairment listing to all three assessment units. The impairment listing will remain until adequate source water sampling is conducted to confirm the water source is no longer impaired. One sample collected at West Fork in 2008 had a nitrate value of 9.09 mg/L, which places that source on the nitrate watch list.

Ohio EPA collected five or six samples at each of the public water system's three source waters in 2012, and two samples at each location in 2013. To assess the PDWS beneficial use, samples were analyzed for nitrate and pesticides. Nitrate concentrations in the West Fork samples ranged from 0.87 mg/L to 6.29 mg/L and averaged 2.79 mg/L. Nitrate concentrations in Stonelick Creek samples ranged from 0.37 mg/L to 4.26 mg/L and averaged 1.88 mg/L. Nitrate concentrations in Whitakers Run samples ranged from 0.13 mg/L to 16.4 mg/L and averaged 2.68 mg/L. Based on these data, Whitaker Run will be added to the nitrate watch list, and West Fork will be taken off.

Atrazine concentrations measured in samples collected from the West Fork and Stonelick Creek, and Whitaker Run exceeded the WQC, with maximum concentrations of 89.5 ug/L, 102 ug/L, and 71.2 ug/l, respectively. Samples were not collected during the last quarter of 2012, but assuming a winter quarter average for atrazine concentration of zero, the annual average atrazine concentration for the West Fork and Stonelick Creek source waters would exceed the water quality criterion. Based on the 2012 and 2013 atrazine data, the West Fork and Stonelick Creek source waters will remain impaired for the PDWS beneficial use. The Whitakers Run source water, however, only had a maximum atrazine concentration of 0.52 ug/L which is a substantial improvement over concentrations detected in2008 where the maximum was 28.2 ug/L. These improvements may be attributed to recent efforts by Syngenta and the water system to educate producers in the smaller Whitakers Run watershed about herbicide best management practices and potential use restrictions if atrazine continued to exceed the water quality criterion in the drinking water source. However, 2013 sampling resulted in an atrazine concentration of 71.2 ug/l. Therefore, the Whitaker Run source will continue to be listed as impaired for atrazine for the PDWS beneficial use.

Table 10. Summary of available water quality data for parameters of interest at sampling sites near/at PWS intakes collected during 2012 and 2013.

Location(s)	PDWS Parameters of Interest					
	Nitrate-Nitrite WQC = 10 mg/L[1]		**Atrazine WQC = 3.0 ug/L[2]**			
	Average (sample count)[4]	Maximum (# samples >WQC)	Average (sample count)	Maximum Quarterly Average (2012)[3]	Maximum Quarterly Average (2012-13)[4]	Maximum Single Detection
West Fork the East Fork Little Miami River Upstream of Blanchester's Intake	2.79 mg/L n=7	6.29 mg/L (0)	36.38 ug/L n=8	15.7 ug/L	10.78 ug/L	89.5 ug/L
Stonelick Creek at Westboro Road	1.88 mg/L n=7	4.26 mg/L (0)	20.53 ug/L n=7	9.34 ug/L	10.13 ug/L	102 ug/L
Whitacre Run at Fancy Street	2.68 mg/L n=7	16.4 mg/L (1)	9.17 ug/L n=8	0.21 ug/L	17.80 ug/L	71.2 ug/L

1 Nitrate Water Quality Criteria (WQC) evaluated as maximum value not to be exceeded, impaired waters defined as having two or more excursions about the criteria.

2 Atrazine WQC evaluated as annual average of the quarterly averages.

3 Data was only collected during the first three quarters of 2012. Since spring results were so high, the annual average would be exceeded even if atrazine was not detected in the source water during the last quarter (annual average determined assuming zero atrazine in fourth quarter). Bold text indicates impairment of the PDWS beneficial use.

4 Data was only collected for the first two quarters of 2013. Maximum quarterly average taken from the first two quarters of 2013 and the last two quarters of 2012 (annual average determined assuming zero atrazine in fourth quarter of 2012). Bold text indicates impairment of the PDWS beneficial use.

Clermont County

Clermont County operates a community public water system that serves a population of approximately 117,097 people. The water supply sells water to the village of Batavia, village of Williamsburg, and New Richmond Robin-Grays water system. Clermont County operates two ground water plants and one surface water plant. The BMW surface water plant draws water from an intake structure on Harsha (East Fork) Lake. The system's treatment capacity is approximately 27.5 million gallons per day, but current average production is 12.5 million gallons per day. Clermont County's BMW water treatment plant incorporates coagulation, flocculation, sedimentation, rapid sand filtration, carbon adsorption (GAC) and chlorine disinfection. The water system can also pre-oxidize with either chlorine dioxide or permanganate to assist with manganese removal.

As the BMW plant does not blend sources and treatment does not remove nitrate, finished water nitrate concentrations are representative of the Harsha Lake source water. From 2006 through 2010, 59 samples of finished water were analyzed for nitrate. The average nitrate concentration was 0.57 mg/L and the maximum concentration detected was 1.4 mg/L. Based on these data, the source water is not impaired due to the nitrate concentrations. Because Clermont County's new granular activated carbon (GAC) treatment is capable of removing pesticides, finished water data are not considered representative of source water quality. Clermont County participated in the Syngenta Crop Protection's Atrazine Monitoring Program (AMP). In 2010, Clermont County's raw water had a maximum atrazine concentration of 20.84 ug/L and a quarterly average concentration of 4.51 ug/L. Based on the 2010 data, the source water was placed on the atrazine watch list.

The 2009 public water system algae survey indicated that algae blooms occur on Harsha Lake all summer. The blooms are one of the reasons for the recent plant upgrades and the new GAC treatment facility. In the spring of 2012, the first cyanotoxin-producing harmful algae bloom was documented on Harsha Lake. The cyanotoxin microcystin was detected above drinking water thresholds (1.0 ug/L) at Harsha's two public beaches, with maximum concentrations of 4.5 ug/L. Cyanotoxins were not detected in the raw or finished water. Since Clermont County's intake structure enables the water system to pull from multiple depths, this flexibility reduces their vulnerability to surface blooms (assuming deeper water is of sufficient quality).

Since 2010 USEPA and local partners have been intensively monitoring Harsha Lake and its watershed as part of the East Fork Watershed Water Quality Monitoring and Modeling Cooperative, including routinely sampling the water quality at Clermont County's intake structure. Data from this effort will be used to assess the PDWS beneficial use for Clermont County's source water for the 2014 Integrated Water Quality Report.

Recreational Use Assessment

Water quality criteria for determining attainment of the recreation use are established in the Ohio Water Quality Standards (Table 8-13 in OAC 3745-1-07) based upon the quantities of bacteria indicators (*Escherichia coli*) present in the water column. *E. coli* bacteria are present in large numbers in the feces and intestinal tracts of humans and other warm-blooded animals. *E. coli* typically comprises approximately 97 percent of the organisms found in the fecal coliform bacteria of human feces (Dufour, 1977), but there is currently no simple way to differentiate between human and animal sources of bacteria in surface waters, although methodologies for this type of analysis are becoming available. These microorganisms can enter water bodies where there is a direct discharge of human and animal wastes, or may enter water bodies along with runoff from soils where these wastes have been deposited.

Although not necessarily agents of disease, fecal coliform bacteria and *E. coli* may indicate the presence of pathogenic organisms that enter the environment through the same pathways. Pathogenic organisms are typically present in the environment in such small amounts that it is impractical to monitor them directly, hence the use of fecal bacteria as indicators. Fecal coliform bacteria, including *E. coli*, by themselves are usually not pathogenic, though some strains of *E. coli* can be toxic and cause serious illness, especially those emanating from cattle raised on a grain diet. That aside, associations have been documented between proximity of wastewater outfalls, fecal bacteria counts, and gastrointestinal illness at swimming beaches (Cabelli et al. 1982, Wade et al. 2006. Wade et al. 2010; see also the literature review in the 2011 draft Recreational Water Quality Criteria document (Office of Water 820-D-11-002). However, these studies failed to use true controls (i.e. a placebo), calling into question both the causal mechanism of reported illnesses, and the level of certainty of the study results. The near real-time counts used in the Wade et al. (2006) study showed increasing concentrations of fecal bacteria during the course of the day, suggesting that the bathers themselves were the source of contamination, and therefore the disease vector. More importantly, none of the studies reviewed in the draft Recreational Water Quality Criteria document (Office of Water 820-D-11-002) reported how recall bias was addressed. Recall bias, as reported in the literature, typically causes from 3 to 5 percent absolute difference in agreement between cases and controls (Coughlin 1990). Wade et al. (2010) conceded that recall bias may have obviated some of the results of their study, but suggested that the increase in reported gastrointestinal disturbances with increasing levels of fecal indicators was unlikely to have been confounded by recall bias.

Another important caveat in using fecal indicators as surrogates for pathogen exposure is that *E. coli*, and other bacteria, are found in soils (Fujioka et al. 1999), and can persist in sediments for several weeks (Solo-Gabriele 2000), thereby obfuscating both source identification and association with potential pathogens. Clearly, this last caveat is especially important when assessing upland streams. Collectively, the studies reviewed in the draft Recreational Water Quality Criteria document make the case for a causal dose-response association between recreational exposure to contaminated water and illness. It is important to note, however, aside from the aforementioned caveats, that the strongest associations were found where contamination was of *human origin, and untreated*. Where the source of contamination was less well-defined (i.e, a mix of treated effluent and diffuse runoff), the differences in illness rates between contact and non-contact groups, though statistically significant, were slight (Figure 20). In other words, the chance of experiencing a gastro-intestinal (GI) disturbance resulting from swimming at a beach when pathogen indicators are comparatively elevated is roughly 3 to 5 percent higher[8] than simply sitting on the beach.

Table 11 lists results for *E. coli* by location and in relation to the Primary Contact Recreation (PCR) Class A and Class B use assessment. These data suggest that the assigned PCR use was fully supported at four locations, but potentially compromised at twenty-one locations. Apart from two highly elevated *E. coli* counts, one in a sample from the Lynchburg WWTP effluent, and one from the Batavia WWTP, no definitive links to direct sources of human origin were apparent.

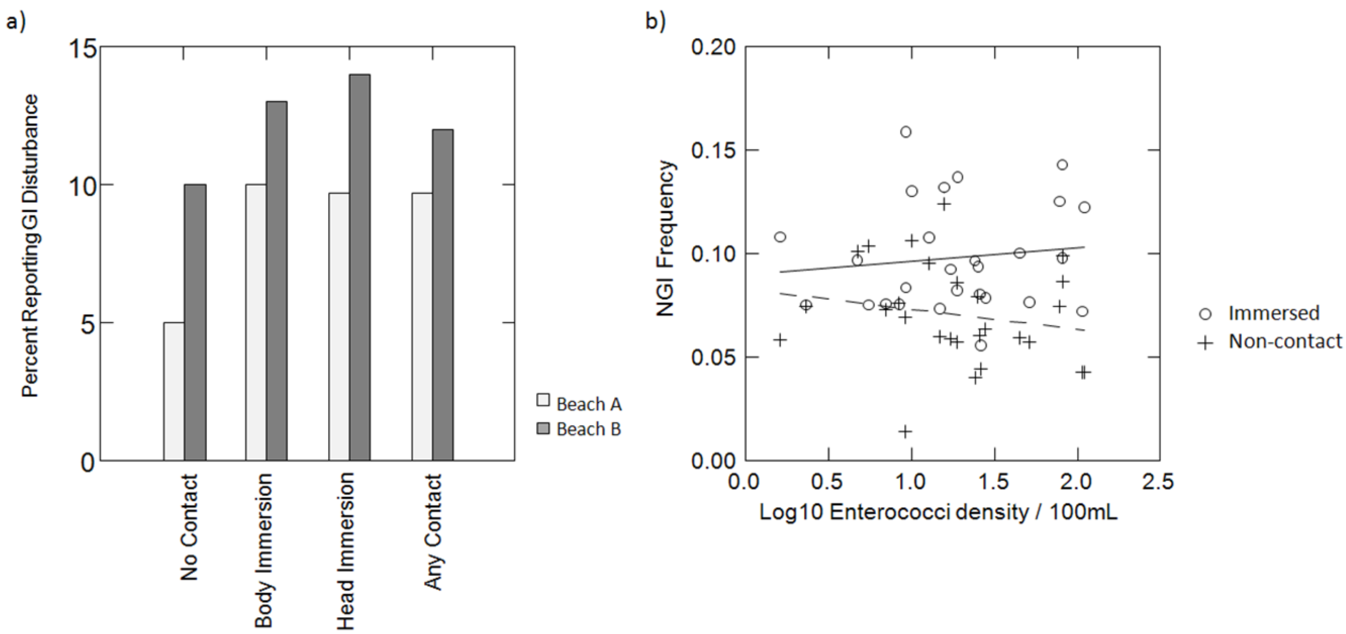


Figure 20. Incidence of reported gastro-intestinal (GI) disturbances for non-contact and contact (i.e., swimmers and bathers) beach goers. a) Incidence by level of recreational activity reported from two Great Lakes beaches with sources of treated municipal effluent in relatively close proximity. b) Incidence of GI disturbances as a function of pathogen indicator levels for non-contact and immersion beach goers. Data used for (a) are from Wade et al. (2006), and data for (b) are from the draft Recreational Water Quality Criteria document (U.S. EPA Office of Water 820-D-11-002; the most recent version can be found at: http://water.epa.gov/scitech/swguidance/standards/criteria/health/recreation/)

[8] coincidentally, within the margin of recall bias

Table 11. Ohio EPA bacteriological (*E. coli*) sampling results in the East Fork Little Miami River study area during 2012. All values are expressed as colony forming units (cfu) or most probable number (MPN) per 100 ml of water. Values from wastewater treatment plants (final effluent) are *italicized*. Values above Primary Contact Recreation (PCR) are highlighted in red. *

Stream **RM**	**AU** [a]	**Location**	**Samples (#)**	***E. coli*** **Geometric Mean**	**Max Value**	**Condition Status**
East Fork Little Miami River *– PCR Class A from SR 131 (RM 54.42) west of Chasetown to mouth; all other segments PCR Class B*						
82.35	10-02	Thornbird Rd, Dst New Vienna	7	392	7100	Not Supported
75.33	10-02	Canada Rd, Upst Lynchburg	8	308	960	Not Supported
72.55	*10-06*	*Lynchburg WWTP Final Effluent*	*8*	*38*	*130000*	*na*
70.9	10-06	SW Of Lynchburg, Upst Dodson Creek	8	439	2900	Not Supported
56.25	11-01	US 50 at Fayetteville	8	266	1000	Not Supported
46.92	11-01	SR 286, near Marathon	10	249	1600	Not Supported
35.87	11-02	Mckeever Rd at Williamsburg	8	406	11000	Not Supported
35.25	*11-02*	*Williamsburg WWTP Final Effluent*	*7*	*22*	*350*	*na*
34.91	11-02	Main St	10	351	8500	Not Supported
19.65	12-03	Adj Elk Lick Rd, Upst Batavia	10	24	70	**Supported**
13.8	12-04	SR 32 at Batavia	8	187	700	Not Supported
13.45	*12-04*	*Batavia WWTP Final Effluent*	*8*	*25*	*9500*	*na*
12.6	*12-04*	*Middle E Fk WWTP Final Effluent*	*7*	*23*	*60*	*na*
9.1	12-04	Olive Branch Stonelick Rd	10	127	2200	Not Supported
5.6	13-05	Adj US 50, Dst Wolfpen Run	8	346	4000	Not Supported
4.85/0.17	*13-05*	*Lower E Fk Regional WWTP Final Effluent*	*8*	*9*	*30*	*na*
1.61	*13-05*	*Milford WWTP Final Effluent*	*8*	*5*	*5*	*na*
0.77	13-05	S Milford Rd Nr Terrace Pk Country Club	10	640	6800	Not Supported
Turtle Creek *– PCR Class B*						
1.2	10-01	Rammel Rd	9	319	9500	Not Supported
Dodson Creek *– PCR Class B*						
0.05	10-04	Near mouth	8	360	14000	Not Supported
West Fork East Fork Little Miami River *– PCR Class B*						
0.12	10-05	SR 123	10	199	410	Not Supported
Glady Run *– PCR Class B*						
0.75	11-01	Dst SR 131	5	357	4600	Not Supported

Stream RM	AU [a]	Location	Samples (#)	*E. coli* Geometric Mean	*E. coli* Max Value	Condition Status
***Pleasant Run** – PCR Class B*						
0.42	11-02	Glancy Corner Marathon Rd	10	354	7600	Not Supported
***Cloverlick Creek** – PCR Class B*						
4.59	12-02	SR 133	10	166	9300	Not Supported
***Stonelick Creek** – PCR Class B*						
17.72	13-01	Adj SR 133, Upst Stonelick Lake	7	127	1000	**Supported**
13.4	13-01	SR 727, Dst Stonelick Lake	7	93	530	**Supported**
6.2	13-03	Anstaett Rd (T358)	7	63	290	**Supported**
1.0	13-04	US 50, near Batavia	10	337	8000	Not Supported
***Tributary to Stonelick Creek (RM 10.61)** – undesignated PCR Class B apply*						
0.89	13-03	Cedarville Rd	8	301	4900	Not Supported
***Shayler Run** – PCR Class B*						
1.71	13-05	Baldwin Rd, SE Of Perintown	10	206	5000	Not Supported

* *Samples were collected from May 21 - October 10, 2012. Condition status is based on the seasonal (May 1- October 31) geometric mean. The status cannot be determined at locations where fewer than two samples were collected during the recreation season (Ohio Administrative Code 3745-1-07).*

Recreation Use	*Seasonal geometric mean*	*Single Sample Maximum*
Bathing Water	*126*	*235*
Class A primary contact recreation	*126*	*298*
Class B primary contact recreation	*161*	*523*
Class C primary contact recreation	*206*	*940*
Secondary contact recreation	*1030*	*1030*

a *AU – Assessment Unit*
LRAU – Large River Assessment Unit
See Table 4 for 12-digit watershed assessment units.

Physical Habitat Quality for Aquatic Life

East Fork Little Miami River

Physical stream habitat in the East Fork Little Miami River is of sufficient quality to support typical warmwater aquatic assemblages along the entire run of the river, save for the uppermost location (RM 84.1; M04S17) where direct and indirect anthropogenic modifications are of sufficient magnitude to be potentially limiting - the river is essentially a network of drainage ditches upstream from New Vienna. Gradient in the reach through and downstream from New Vienna, however, is steep enough to provide the power necessary to passively recover functional attributes.

That said, historic channel modifications of the mainstem between New Vienna and Williamsburg were evident at several locations. These modifications included straightening and relocation of the stream channel (i.e., classic channelization) and dredging the existing channel to expand conveyance. These types of modifications were most evident in the reach between ~RMs 63 and 40, and are responsible, in part, for the observed sag in biological performance along said reach (see *Biological Quality - Fish Assemblages*). Downstream from Harsha Lake, physical habitat quality was excellent and capable of supporting the full potential for aquatic life.

Tributaries - Overview

Recent or intransigent anthropogenic habitat modifications were rarely observed within the sampling frame comprising the tributary network. The few exceptions included Hall Run at Roundbottom Road (RM 0.23, M04P13), the West Fork at Frazier Road (RM 7.45, 301891), Dodson Creek at Gibler Road (RM 5.83, 301887), and the South Fork Dodson Creek at Tedrick Road (RM 0.9, 301888). For the latter three cases, where channelization appeared to be related exclusively to drainage, the stream gradient in each is sufficient (>10 ft/mi) to provide the erosive power necessary to recover functional attributes. The modifications to Hall Run are, apparently, a legacy of sewer line construction.

Because direct modifications were rare in the sampling frame, the majority of sites (~64%) superficially possessed the physical attributes necessary to provide support for WWH assemblages in typical circumstances (Figure 21). The remaining sites, despite being largely physically intact, fell into the range where site-specific physical conditions (e.g., uniform bedrock substrates, low flow), tend to govern the potential to support WWH assemblages. However, across all sites, lack of swift flow (96% of sites), no riffle present (70%), and low sinuosity (54%) were frequently observed limiting factors (Table 12). No cover, a highly influential negative attribute, was noted at 20 of the sites (39% of sites), and corresponded to no riffle in 18 of the 20 cases – a characteristic of bedrock-dominated streams. Collectively, these are not atypical conditions for streams in the Interior Plateau ecoregion (at least as defined by former boundaries), and does not necessarily reflect watershed-scale anthropogenic modifications; however, it does represent a natural limit to the potential for small streams in the watershed to support WWH assemblages. For streams with intermittent or interstitial flows, pool depth and the water quality of the pools become especially important determinants of biological quality (Figure 22).

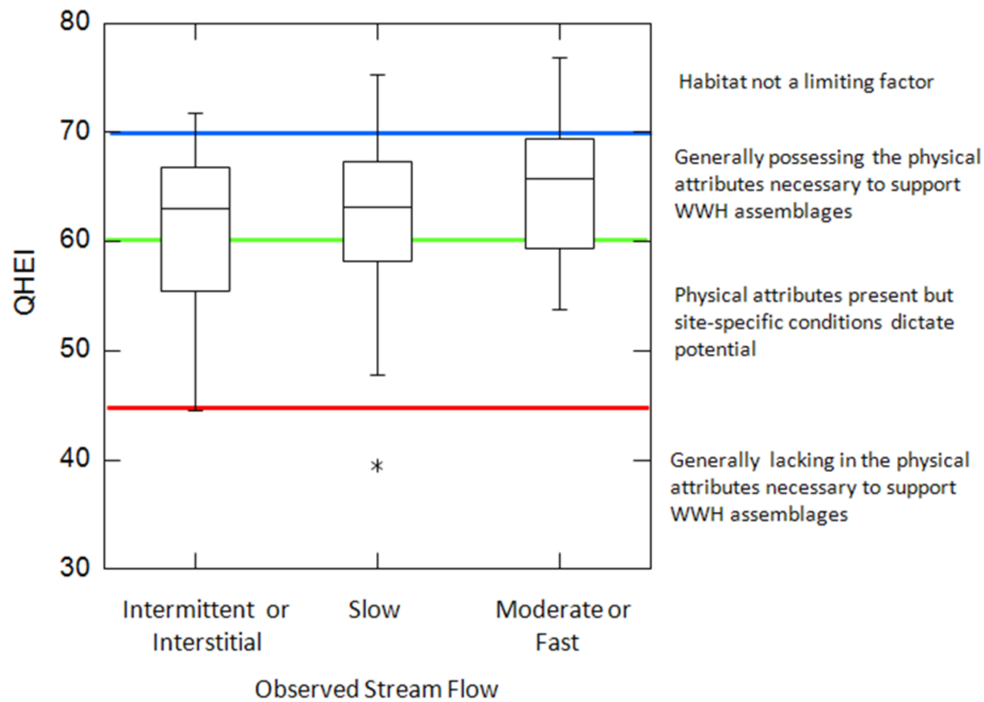


Figure 21. Distributions of QHEI scores for East Fork LMR tributaries sampled in the 2012 survey plotted by observed stream flow, and in relation to broadly functional narrative ranges.

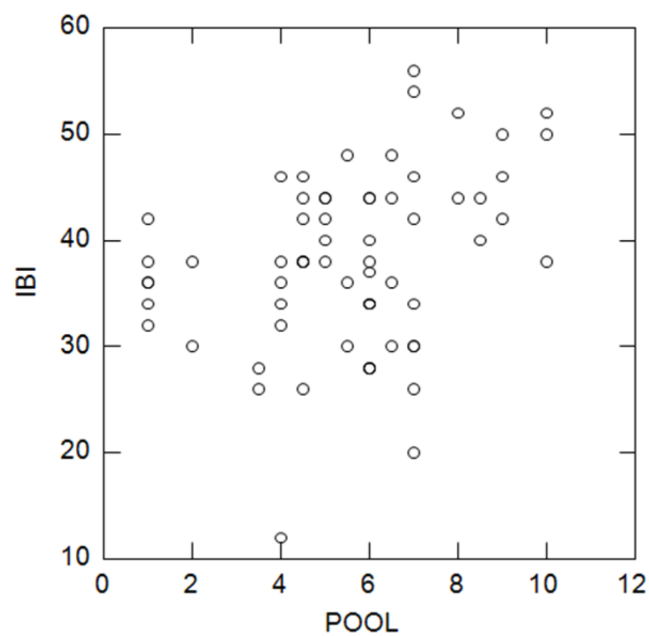


Figure 22. Fish Index of Biotic Integrity (IBI) scores plotted by pool metric scores. East Fork LMR tributaries, 2012.

Table 12. Matrix of habitat attributes and QHEI scores for sites sampled in the East Fork Little Miami River survey, 2012.

Key: QHEI Components

River Mile	QHEI	Gradient (ft/mi)	WWH Attributes: Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth>40cm	Low/Normal Riffle Embeddedness	WWH Attributes	MWH Attributes, High Influence: Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	Hi-influence Modified Attributes	MWH Attributes, Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	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	M.I.Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-100-000 East Fork Little Miami River																																		
Year	**2012**																																	
84.1	58.5	15.38	■	■				■			■	■	5						0		◆		◆	◆	◆		◆	◆	◆	◆		8	0.17	1.50
82.4	76.8	16.13	■	■		■	■	■		■	■	■	8						0					◆				◆				2	0.11	0.33
80.4	67.5	7.09		■				■		■	■	■	5						0	◆	◆			◆	◆			◆	◆			6	0.17	1.17
75.3	70.3	4.67	■	■		■	■	■		■	■	■	8						0		◆			◆				◆	◆	◆		5	0.11	0.67
72.8	77.5	8.62	■	■		■	■	■	■		■		7						0		◆				◆				◆	◆		4	0.13	0.63
70.9	71.0	3.76	■	■		■	■	■		■	■	■	8						0		◆				◆			◆				3	0.11	0.44
70.2	73.3	3.76	■			■	■	■			■		5						0						◆			◆	◆	◆		4	0.17	0.83
63.4	80.5	5.38	■	■		■	■	■	■	■	■	■	9						0		◆									◆		2	0.10	0.30
56.3	78.3	3.52	■	■		■	■	■	■	■	■	■	9						0													0	0.10	0.10
54.4	69.3	3.52	■	■		■	■	■		■	■	■	8						0					◆	◆			◆				3	0.11	0.44
48.7	68.8	3.91	■	■				■		■	■	■	6						0					◆	◆			◆				3	0.14	0.57
41.1	77.8	5.56	■	■		■	■	■		■	■	■	8						0									◆				1	0.11	0.22
35.9	81.3	6.13	■	■		■	■	■		■	■	■	8						0									◆				1	0.11	0.22
34.9	70.5	12.50	■			■	■	■			■	■	6						0									◆	◆			2	0.14	0.43
15.6	82.8	10.99	■	■		■	■	■	■	■	■	■	9						0													0	0.10	0.10
13.8	80.0	8.20	■	■		■	■	■	■	■	■	■	9						0						◆							1	0.10	0.20
13.2	81.0	8.20	■	■		■	■	■	■	■	■	■	9						0													0	0.10	0.10
11.5	85.0	5.76	■	■		■	■	■	■	■	■	■	9						0											◆		1	0.10	0.20
9.1	87.0	5.76	■	■	■	■	■	■	■	■	■	■	10						0													0	0.09	0.09
5.6	83.3	4.55	■	■		■	■	■	■	■	■	■	9						0											◆		1	0.10	0.20
4.3	83.0	4.55	■	■		■	■	■	■	■	■	■	9						0													0	0.10	0.10
2.2	82.5	3.23	■	■		■	■	■	■	■	■		8						0											◆		1	0.11	0.22
1.4	72.3	3.23	■	■		■	■	■		■	■		7						0					◆				◆			◆	3	0.13	0.50
11-100-003 Trib. to E. Fk. L. Miami R. (RM 78.45)																																		
Year	**2012**																																	
0.5	52.3	14.28	■	■			■			■			4				●	●	2					◆			◆	◆			◆	4	0.60	1.00
11-100-007 Glady Creek																																		
Year	**2012**																																	
0.7	66.5	11.63	■	■				■	■		■		5						0		◆			◆	◆				◆	◆		5	0.17	1.00

Table 12. Matrix of habitat attributes and QHEI scores for sites sampled in the East Fork Little Miami River survey, 2012.

Key QHEI Components

			WWH Attributes											MWH Attributes: High Influence						MWH Attributes: Moderate Influence														
River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	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	Hi-influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	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	M.I.Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-100-008 Trib. to E. Fk. L. Miami R. (RM 2.40)																																		
Year	**2012**																																	
0.4	56.0	20.62	■	■				■		■	■		5				●		1	◆				◆	◆			◆	◆		◆	6	0.33	1.17
11-101-000 Hall Run																																		
Year	**2012**																																	
2.3	58.0	90.91	■	■				■		■	■		5				●		1					◆	◆			◆			◆	4	0.33	0.83
0.2	47.8	40.00		■						■	■		3	●			●		2	◆				◆	◆	◆	◆	◆			◆	7	0.75	2.00
11-103-000 Salt Run																																		
Year	**2012**																																	
0.4	65.8	9.43	■	■		■		■		■	■	■	7						0					◆	◆			◆	◆	◆		5	0.13	0.75
11-104-000 Sugarcamp Run																																		
Year	**2012**																																	
0.2	59.3	66.67	■	■		■		■		■	■	■	7				●		1					◆	◆		◆	◆				4	0.25	0.63
11-105-000 Shayler Run																																		
Year	**2012**																																	
5.2	71.5	17.54	■			■	■	■		■	■	■	7						0									◆				1	0.13	0.25
1.7	67.5	29.85	■	■		■	■	■		■	■		7						0									◆			◆	2	0.13	0.38
11-105-001 Trib. to Shayler Run (RM 4.40)																																		
Year	**2012**																																	
0.4	63.8	37.04	■			■	■	■		■	■	■	7				●		1						◆		◆	◆				3	0.25	0.50
11-107-000 Stonelick Creek																																		
Year	**2012**																																	
20.0	57.3	18.18	■	■		■	■	■		■	■		7				●		1								◆	◆			◆	3	0.25	0.50
17.7	64.0	7.09	■	■				■			■		4				●		1					◆	◆			◆	◆		◆	5	0.40	1.20
13.4	73.0	6.85	■	■	■	■	■	■		■	■	■	9						0								◆	◆				2	0.10	0.30
9.8	69.0	18.87	■	■		■	■	■		■	■		7						0									◆			◆	2	0.13	0.38
6.2	66.8	29.41	■	■		■	■	■		■	■		7						0								◆	◆			◆	3	0.13	0.50
5.2	67.3	26.67	■	■		■	■	■		■	■	■	8						0		◆				◆			◆				3	0.11	0.44
1.0	67.0	7.58	■	■		■	■	■			■		6						0									◆	◆	◆		3	0.14	0.57

Table 12. Matrix of habitat attributes and QHEI scores for sites sampled in the East Fork Little Miami River survey, 2012.

Key: QHEI Components

			WWH Attributes											MWH Attributes – High Influence						MWH Attributes – Moderate Influence														
River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	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	Hi-influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	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	M.I.Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-107-002 Trib. to Stonelick Creek (RM 10.61)																																		
Year 2012																																		
0.9	61.8	33.33	■	■	■	■	■	■		■	■		8						0								◆	◆			◆	3	0.11	0.44
11-108-000 Lick Fork																																		
Year 2012																																		
0.6	72.0	40.00	■	■	■	■	■	■		■	■		8						0								◆	◆			◆	3	0.11	0.44
11-109-000 Brushy Fork																																		
Year 2012																																		
2.2	49.0	52.63	■			■					■		3				●		1					◆	◆		◆	◆	◆		◆	6	0.50	1.75
0.3	55.8	41.67	■	■	■	■	■	■		■	■		8						0					◆		◆	◆	◆			◆	5	0.11	0.67
11-111-000 Patterson Run																																		
Year 2012																																		
0.1	57.3		■		■	■	■			■	■		6				●		1						◆		◆	◆			◆	4	0.29	0.71
11-112-000 Moores Fork																																		
Year 2012																																		
2.9	63.0	19.61	■	■	■	■	■	■		■	■		8						0				◆				◆	◆			◆	4	0.11	0.56
0.7	66.5	5.32	■	■	■	■	■	■		■	■		8						0									◆			◆	2	0.11	0.33
11-115-000 Backbone Creek																																		
Year 2012																																		
0.6	65.5		■	■		■	■	■		■	■		7						0									◆			◆	2	0.13	0.38
11-115-001 Trib. to Backbone Creek (RM 1.36)																																		
Year 2012																																		
0.9	62.8	21.74	■	■	■	■	■	■		■	■		8				●		1						◆		◆	◆			◆	4	0.22	0.56
11-116-000 Lucy Run																																		
Year 2012																																		
1.9	63.5	55.56	■	■		■	■	■		■	■		7				●		1									◆			◆	2	0.25	0.38
0.1	58.8	60.61	■	■		■	■	■		■	■		7						0								◆	◆			◆	3	0.13	0.50
11-117-000 Fourmile Run																																		
Year 2012																																		
0.2	76.8	33.33	■	■		■	■	■		■	■	■	8						0									◆				1	0.11	0.22

Table 12. Matrix of habitat attributes and QHEI scores for sites sampled in the East Fork Little Miami River survey, 2012.

River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	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	Hi-influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	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	M.I.Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-118-000 Back Run																																		
Year 2012																																		
1.2	73.0	25.00	■	■		■	■	■		■	■		7						0									◆	◆		◆	3	0.13	0.50
11-119-000 Ulrey Run																																		
Year 2012																																		
1.3	61.5	80.00	■	■		■	■	■		■	■		7						0								◆	◆			◆	3	0.13	0.50
11-120-000 Slabcamp Run																																		
Year 2012																																		
2.6	65.8	38.46	■	■		■	■	■		■	■		7				●		1								◆	◆			◆	3	0.25	0.50
11-121-000 Cloverlick Creek																																		
Year 2012																																		
8.5	64.3	8.33	■			■	■	■		■	■		6				●		1		◆							◆			◆	3	0.29	0.57
4.6	62.0	10.75	■		■					■	■		4				●		1					◆	◆			◆			◆	4	0.40	1.00
11-121-002 Trib. to Cloverlick Creek (RM 7.48)																																		
Year 2012																																		
0.5	64.5	16.39	■			■	■	■		■	■		6						0						◆			◆			◆	3	0.14	0.57
11-122-000 Barnes Run																																		
Year 2012																																		
1.9	64.3	10.99	■	■		■	■	■		■	■		7						0					◆	◆			◆	◆		◆	5	0.13	0.75
11-123-000 Poplar Creek																																		
Year 2012																																		
8.4	70.5	20.83	■	■		■	■	■		■	■		7						0									◆	◆		◆	3	0.13	0.50
3.8	66.0	13.70	■	■		■	■	■		■	■	■	8						0						◆		◆	◆	◆	◆		5	0.11	0.67
11-124-000 Sugartree Creek																																		
Year 2012																																		
0.9	58.8	38.46	■	■		■	■	■		■	■		7				●		1						◆		◆	◆			◆	4	0.25	0.63
11-132-000 Kain Run																																		
Year 2012																																		
0.3	64.0		■			■	■	■		■	■	■	7						0						◆		◆	◆				3	0.13	0.50

Table 12. Matrix of habitat attributes and QHEI scores for sites sampled in the East Fork Little Miami River survey, 2012.

Key: QHEI Components

			WWH Attributes											MWH Attributes – High Influence						MWH Attributes – Moderate Influence														
River Mile	QHEI	Gradient (ft/mi)	Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	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	Hi-influence Modified Attributes	Recovering Channel	Heavy/Moderate Silt Cover	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	M.I.Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-133-000 Todd Run																																		
Year	**2012**																																	
1.0	58.3	47.62	■	■		■	■	■		■	■		7						0		◆						◆	◆	◆		◆	5	0.13	0.75
11-135-000 Crane Run																																		
Year	**2012**																																	
0.2	72.8	14.29	■	■		■	■	■		■	■		7						0									◆			◆	2	0.13	0.38
11-136-000 Fourmile Creek																																		
Year	**2012**																																	
0.3	60.0	20.83	■	■		■	■	■		■	■		7				●		1		◆					◆	◆	◆	◆		◆	6	0.25	0.88
11-137-000 Pleasant Run																																		
Year	**2012**																																	
1.3	67.5	14.71	■	■		■	■	■		■	■		7						0								◆	◆			◆	3	0.13	0.50
0.4	62.5	25.00	■	■		■	■	■		■	■		7				●		1						◆		◆	◆			◆	4	0.25	0.63
11-138-000 Fivemile Creek																																		
Year	**2012**																																	
2.3	54.3	10.10	■	■		■	■	■		■			6				●	●	2								◆	◆			◆	3	0.43	0.57
0.5	51.5	4.92	■	■		■		■		■	■		6				●		1		◆			◆	◆		◆	◆			◆	6	0.29	1.00
11-141-000 Howard Run																																		
Year	**2012**																																	
0.3	75.3	21.74	■	■		■	■	■		■	■		7						0									◆			◆	2	0.13	0.38
11-142-000 Grassy Fork																																		
Year	**2012**																																	
0.2	67.3	23.33	■	■		■	■	■		■	■		7						0		◆							◆	◆		◆	4	0.13	0.63
11-143-000 Glady Run																																		
Year	**2012**																																	
0.7	61.0	17.86	■	■			■	■		■	■		6						0					◆			◆	◆			◆	4	0.14	0.71
11-144-000 Saltlick Creek																																		
Year	**2012**																																	
0.1	51.5	41.67	■			■	■				■		4				●		1		◆		◆	◆	◆			◆	◆		◆	7	0.40	1.60

Table 12. Matrix of habitat attributes and QHEI scores for sites sampled in the East Fork Little Miami River survey, 2012.

Key QHEI Components

River Mile	QHEI	Gradient (ft/mi)	WWH Attributes: Not Channelized or Recovered	Boulder/Cobble/Gravel Substrates	Silt Free Substrates	Good/Excellent Development	Moderate/High Sinuosity	Extensive/Moderate Cover	Fast Current/Eddies	Low/Normal Embeddedness	Max Depth>40cm	Low/Normal Riffle Embeddedness	WWH Attributes	MWH Attributes, High Influence: Channelized/No Recovery	Silt/Muck Substrates	No Sinuosity	Sparse/No Cover	Max Depth < 40cm	Hi-influence Modified Attributes	MWH Attributes, Moderate Influence: Recovering Channel	Heavy/Moderate Silt Cover	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	M.I.Modified Attributes	MWH H.I.+1/WWH+1 Ratio	MWH M.I.+1/WWH+1 Ratio
11-147-000 Solomon Run																																		
Year	**2012**																																	
1.9	55.5	33.33	■	■				■		■	■		5				●		1					◆	◆		◆	◆			◆	5	0.33	1.00
11-149-000 Sycamore Creek																																		
Year	**2012**																																	
0.8	56.8	7.14	■	■						■	■	■	5				●		1		◆			◆	◆		◆	◆	◆	◆	◆	8	0.33	1.50
11-150-000 West Fork East Fork Little Miami River																																		
Year	**2012**																																	
7.5	39.5	14.71						■			■		2	●	●		●		3		◆		◆	◆	◆			◆	◆	◆	◆	8	1.33	3.00
0.2	71.8	8.67	■	■		■	■	■		■	■	■	8						0					◆	◆		◆	◆			◆	5	0.11	0.67
11-151-000 Dodson Creek																																		
Year	**2012**																																	
7.5	53.8	10.99	■	■				■					3					●	1		◆		◆	◆	◆			◆	◆	◆		7	0.50	2.00
5.8	54.0	14.08						■			■		2						0	◆	◆		◆	◆	◆			◆	◆	◆	◆	9	0.33	3.33
0.1	63.5	5.68	■	■			■	■		■	■	■	7						0		◆			◆				◆	◆			4	0.13	0.63
11-151-001 Trib. to Dodson Creek (RM 4.52)																																		
Year	**2012**																																	
0.6	72.3	12.82	■	■			■	■		■	■	■	7						0					◆				◆	◆			3	0.13	0.50
11-153-000 South Fork Dodson Creek																																		
Year	**2012**																																	
0.9	44.5	14.64						■			■	■	3	●					1		◆		◆	◆	◆		◆	◆	◆		◆	8	0.50	2.25
11-153-001 Trib. to S. Fk. Dodson Creek (RM 0.37)																																		
Year	**2012**																																	
0.9	72.3	10.87	■	■		■	■	■			■		6						0		◆							◆	◆	◆		4	0.14	0.71
11-154-000 Turtle Creek																																		
Year	**2012**																																	
5.9	59.5	10.10	■				■	■		■	■		5						0		◆			◆	◆			◆	◆	◆		6	0.17	1.17
4.4	44.8	26.32	■					■					2				●	●	2		◆			◆	◆		◆	◆	◆		◆	7	1.00	2.67
1.2	65.8	18.52	■			■		■	■	■	■	■	7						0					◆	◆		◆		◆	◆		5	0.13	0.75

Biological Quality – Fish Assemblages

Overview

Fish assemblages in the East Fork Little Miami River watershed differ in complexion according to stream size and in relation to Harsha Lake (Figure 23). Larger streams, especially the East Fork mainstem, are partitioned by Harsha Lake, and are represented in the ordination plot (Figure 23) as blue and green points. Freshwater drum, and deep-bodied suckers (buffalo and carpsuckers) occur almost exclusively[9] downstream from Harsha Lake (blue points in Figure 23). Also, downstream from the dam, spotfin, steelcolor, and emerald shiners dominate the *Notropis* genera, whereas silver, striped and sand shiners are relatively more abundant upstream from the reservoir (green points in Figure 23). The restriction of obligate large-river species to downstream from the dam is axiomatic, but the differing relative abundance of *Notropis* species is less obvious, given that a more gradual cline with drainage area is typical. Clearly, connectivity to the Ohio River favors steelcolor and emerald shiners in the downstream reach, but the lower relative abundance of silver shiner and sand shiners may reflect either the

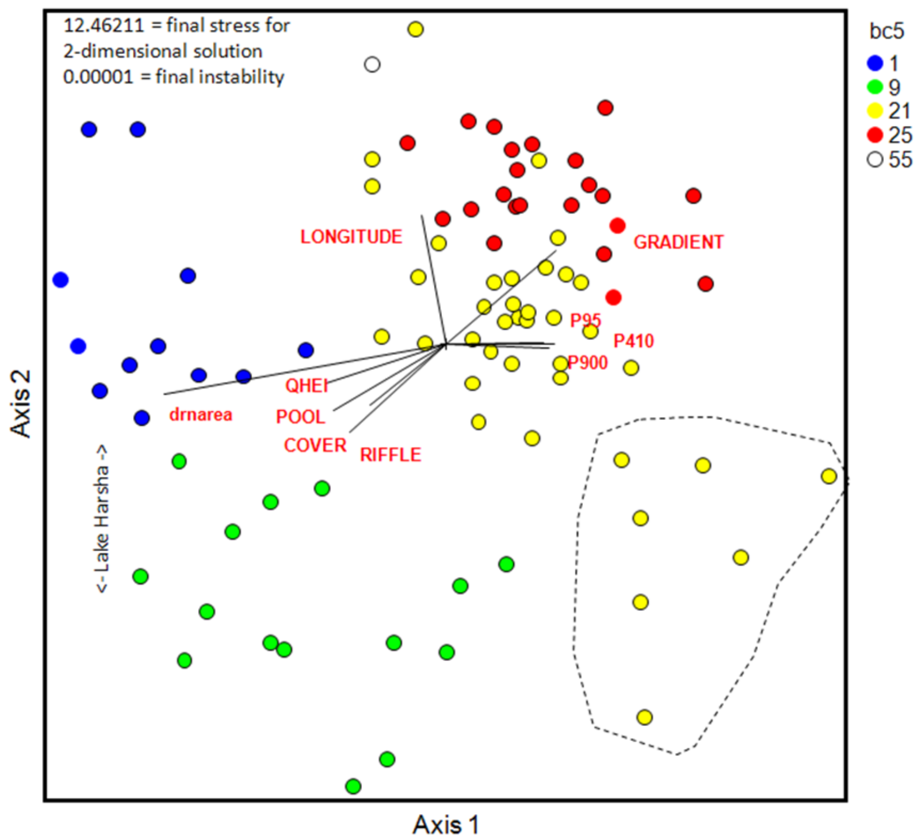


Figure 23. An ordination of fish assemblages sampled from the East Fork Little Miami River basin, 2012. Axis scores were generated by Nonmetric Multidimensional Scaling based on Bray-Curtis distances. Points are color coded to groups suggested by hierarchical clustering using Bray-Curtis distances and linking via the flexible beta method (McCune and Grace 2002). Environmental variables correlating with axes scores are shown as an overlay, with the relative strength of association (minimum R^2=0.3) being represented by the length of the respective overlay lines.

---

[9] Quillback carpsuckers occur upstream from Harsha Lake, but not river carpsuckers.

flow regime maintained downstream from the dam (Rahel 2007), loss of upstream-downstream connectivity (Perkin and Gido 2012), or export of suspended matter from the reservoir. Evidence to support the latter, however, was not observed in longitudinal concentrations of total suspended solids.

For smaller streams, hierarchical clustering suggested that the fish assemblages fell into two camps (Figures 23 and 24). These two camps tended to separate along an environmental gradient of stream size, stream gradient, and hardness (Figure 23), with smaller, higher gradient, more ion-rich waters (Cluster 25) being dominated by creek chubs and blacknose dace, whereas the larger streams tended to have a more diverse assemblage (Cluster 21). Although the basis for these differences seem obvious, an objective stratification of the data based on assemblages is important for identifying limiting environmental stressors.

For example, the negative correlation between the IBI and TKN observed for the unstratified sample nearly doubled in strength of association when stratified, and was consistent in terms of slope across groups (Figure 25). So although IBI scores in Cluster 25 were generally lower than those in Cluster 21, the IBI response to increasing levels of TKN was similar between groups. Also, the relative importance of habitat quality and total phosphorus as explanatory variables changed depending on whether the sample was stratified or unstratified.

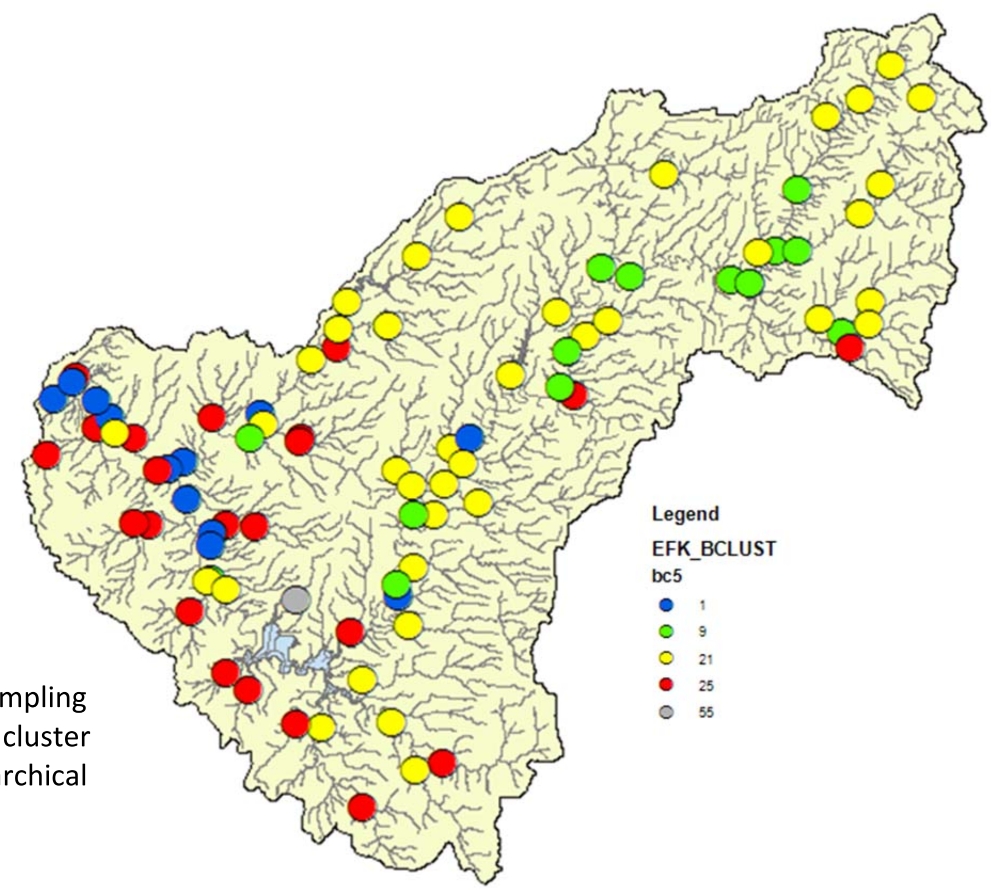


Figure 24. Locations of sampling points color-coded by the cluster groups suggested by hierarchical clustering.

Unstratified	
	IBI
Alkalinity	0.28681
TKN	-0.2281
TP	-0.2841
QHEI	0.34221
Cluster 21	
	IBI
Alkalinity	0.44052
TKN	-0.42002
TP	-0.19905
QHEI	0.26032
Cluster 25	
	IBI
Alkalinity	0.40001
TKN	-0.57242
TP	-0.40741
QHEI	0.40968

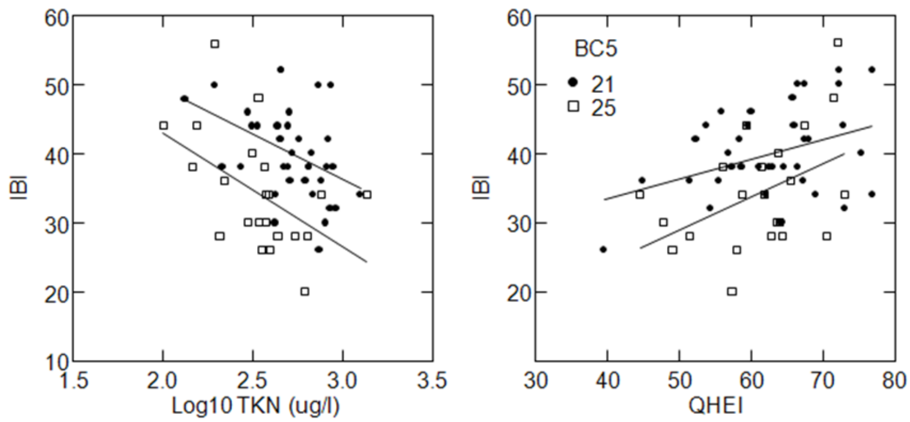


Figure 25. Scatter plots of IBI scores over TKN concentrations and QHEI scores stratified by cluster group. Pearson correlation between the IBI and several selected environmental variables are shown in the left panel.

For Cluster 21, a parsimonious set of stressors was suggested by an analysis of covariance model where flow was a categorical variable[10] (i.e., none, slow, swift), and chemical stressors and physical explanatory variables were subject to stepwise selection (backwards elimination, tolerance<0.2, p=0.05). The model was initially considered based on inspection of scatter plots and a correlation matrix. The model accounts for 64 percent of the variation in IBI scores, and suggests that organic enrichment (as represented by TKN) is likely the most proximate limiting stressor. Because many of the environmental variables are collinear, the resulting model (Figure 26, Table 13) is not taken at face value as deterministic, rather as more generally mechanistic. Evidence for the general nature of the model is given by all-subsets regression where only continuous variables are included; the results of which show TKN figures prominently in nearly all models, and is included in the most parsimonious one (Figure 27).

For Cluster 25, flow was categorized mostly as slow, therefore, all-subsets regression was used to explore the relationships between IBI scores and the various environmental variables. Here, no single best model was readily apparent, as many of the models were roughly similar in terms

[10] Categorical levels of flow are noted on the QHEI sheet.

of information content (Figure 28). And extra caution is urged to not over-interpret any individual model given that only 22 locations were in the data frame, and given the aforementioned problem of multicollinearity. However, habitat quality, as given by the QHEI, and indicators of organic or nutrient enrichment (e.g., TP, TKN, NOx) were consistently represented.

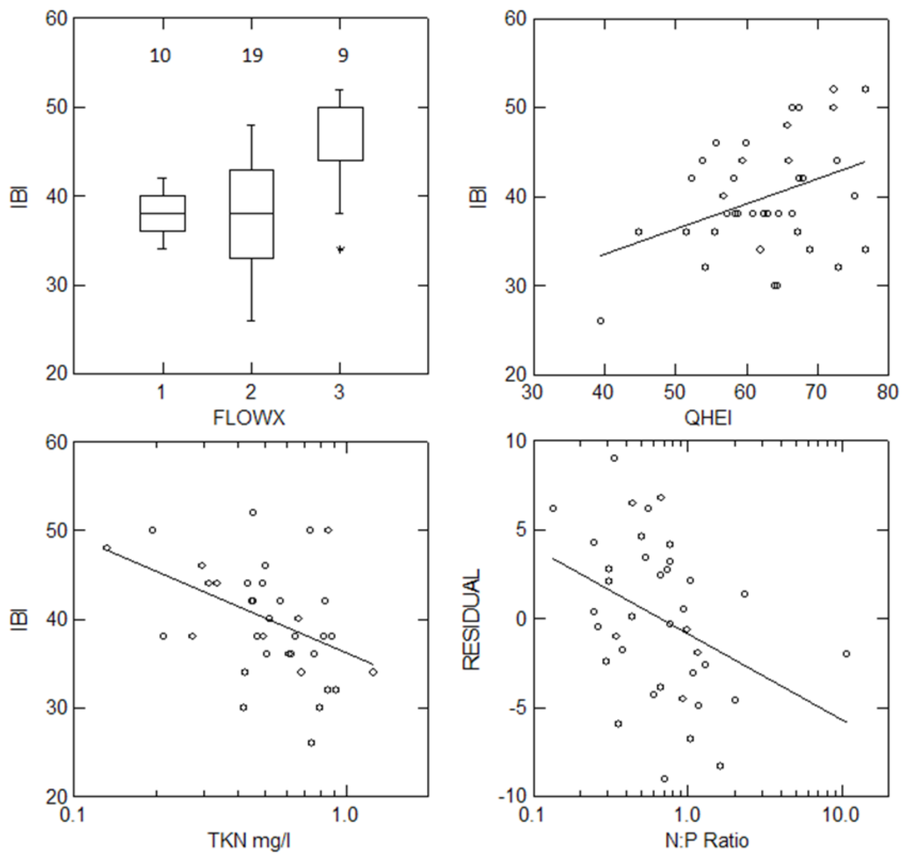


Figure 26. Graphical representation of relationships given by the ANCOVA model relating IBI scores to environmental variables for Cluster 21.

Table 13. Analysis of variance table for the model IBI~Flow+TKN+QHEI+N:P ratio. Flow was categorized to three levels (none, slow, swift).

Analysis of Variance Model R^2=0.64					
Source	Sum-of-Squares	df	Mean-Square	F-ratio	P
FLOWcat	490.73422	2	245.36711	14.24040	0.00004
TKN	470.73373	1	470.73373	27.32004	0.00001
QHEI	79.97205	1	79.97205	4.64135	0.03884
LOGN:P	172.21648	1	172.21648	9.99495	0.00342
Error	551.37112	32	17.23035		

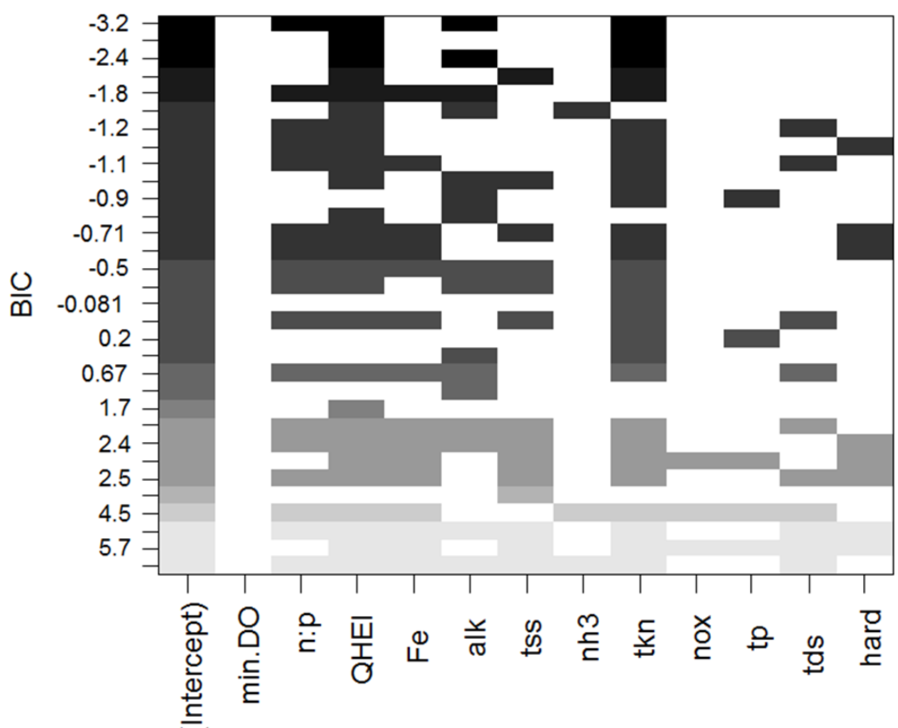


Figure 27. Graphical representation of all-subsets regression between IBI scores and the parameters listed on the x-axis for sites included in Cluster 21. The y-axis shows the Baysian Information Criterion (BIC). The most parsimonious models are those that include the fewest explanatory variables (x-axis) and have the lowest BIC value (e.g., TKN as a single explanatory variable is the most parsimonious, though that model may not necessarily have the highest explanatory power). Visual inspection of the overall pattern of sequences, along with inspecting the differences in explanatory power of suggested models (e.g., the TKN only model compared to the TKN+QHEI+ALK+N:P model) helps to gauge the influence of colinearity, and whether additional explanatory variables are making a significant or marginal contribution.

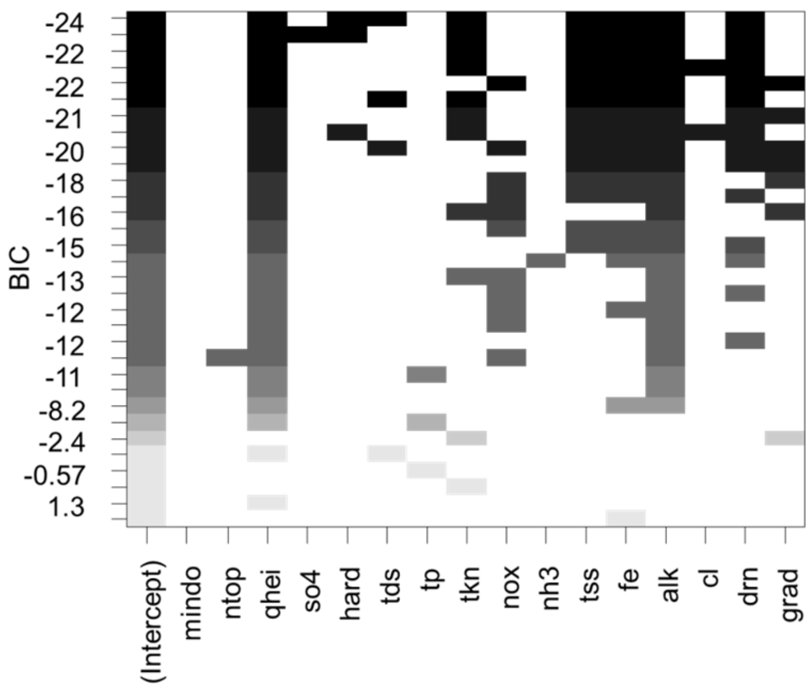


Figure 28. Graphical representation of all-subsets regression between IBI scores and the parameters listed on the x-axis for sites included in Cluster 25. The y-axis shows the Baysian Information Criterion (BIC).

Because neither statistical model is strictly deterministic, the general causal mechanism suggested by the models (i.e., organic enrichment and habitat quality) is best applied conditionally to impaired sites. Quite simply, where several or more of the indicators align at the site level, the general mechanism can be applied with greater confidence. Enrichment indicators are juxtaposed with IBI scores in Figure 29 for sites falling into cluster groups 21 and 25, and in doing so, several sites and reaches are readily identified as impaired by organic enrichment (Table 14). The headwater reach of the East Fork mainstem in the vicinity of New Vienna is clearly impacted by organic enrichment associated with the New Vienna WWTP (1PA00005), as is the South Fork Dodson Creek. The source of enrichment in the South Fork Dodson Creek appears to be from a highly eutrophic, pond-sized, impoundment upstream from Roush Road. Most of the sites sampled in the Stonelick Creek subwatershed appeared to be burdened by organic enrichment and low dissolved oxygen, as was Fivemile Creek.

For those cases where no readily defined source of enrichment was identified (e.g., unsewered communities, package plants, animal feeding operations [AFOs], etc.), the mechanism appears less direct, and may involve a feedback between low stream flows, dissolved oxygen and remineralization of nitrogen. The circumstantial evidence for this is found in the associations between stream flow and dissolved oxygen, dissolved oxygen and NH3-N and TKN, and between TKN and NH3-N (Figure 30). Although ammonia is a subset of TKN, increasing TKN concentrations do not necessarily equate to increasingly detectable concentrations of ammonia, but in the presence of low dissolved oxygen concentrations, the frequency increases dramatically. For example, the probability of observing an ammonia concentration >0.031[11] mg/l when TKN concentrations exceed 0.45[9] mg/l, and dissolved oxygen is maintained above 4 mg/l is 0.42. When dissolved oxygen concentrations are less than 4 mg/l, the probability increases to 0.89. Whether the apparent remineralization of nitrogen fuels further enrichment (i.e. as a feedback), is a matter of speculation, and is untested, but the mechanism is at least plausible, given that ammonia nitrogen is a more preferred uptake form for algae and heterotrophic bacteria compared to more complex forms of organic nitrogen (exclusive of amino acids; Middleburg and Nieuwenhuize 2000). Nevertheless, given that many of the small streams in the East Fork basin routinely experience low or intermittent stream flow during the summer, and are therefore naturally prone to oxygen depletion, reducing nitrogen inputs from diffuse sources would likely help maintain dissolved[12] oxygen during critical periods.

As ever, habitat quality was an important explanatory variable for IBI scores. Several locations were noted as being either primarily or co-limited by poor habitat. The West Fork the East Fork LMR and Dodson Creek experienced recent channelization and Hall Run still bore marks from historic channel modifications. Brushy Fork, though not directly channelized, appeared to carry an excessive bedload of sand and gravel.

---

[11] The median concentrations in the data frame.

[12] Although dissolved oxygen was not selected as an explanatory variable in either of the all subsets regressions, the relationship between the IBI and dissolved oxygen is more threshold in nature, and therefore not well captured by models adapted for continuous relationships. The probability of an IBI score ∃40 in Cluster 25 is zero when minimum dissolved oxygen is less than 4 mg/l, and 0.32 in Cluster 21.

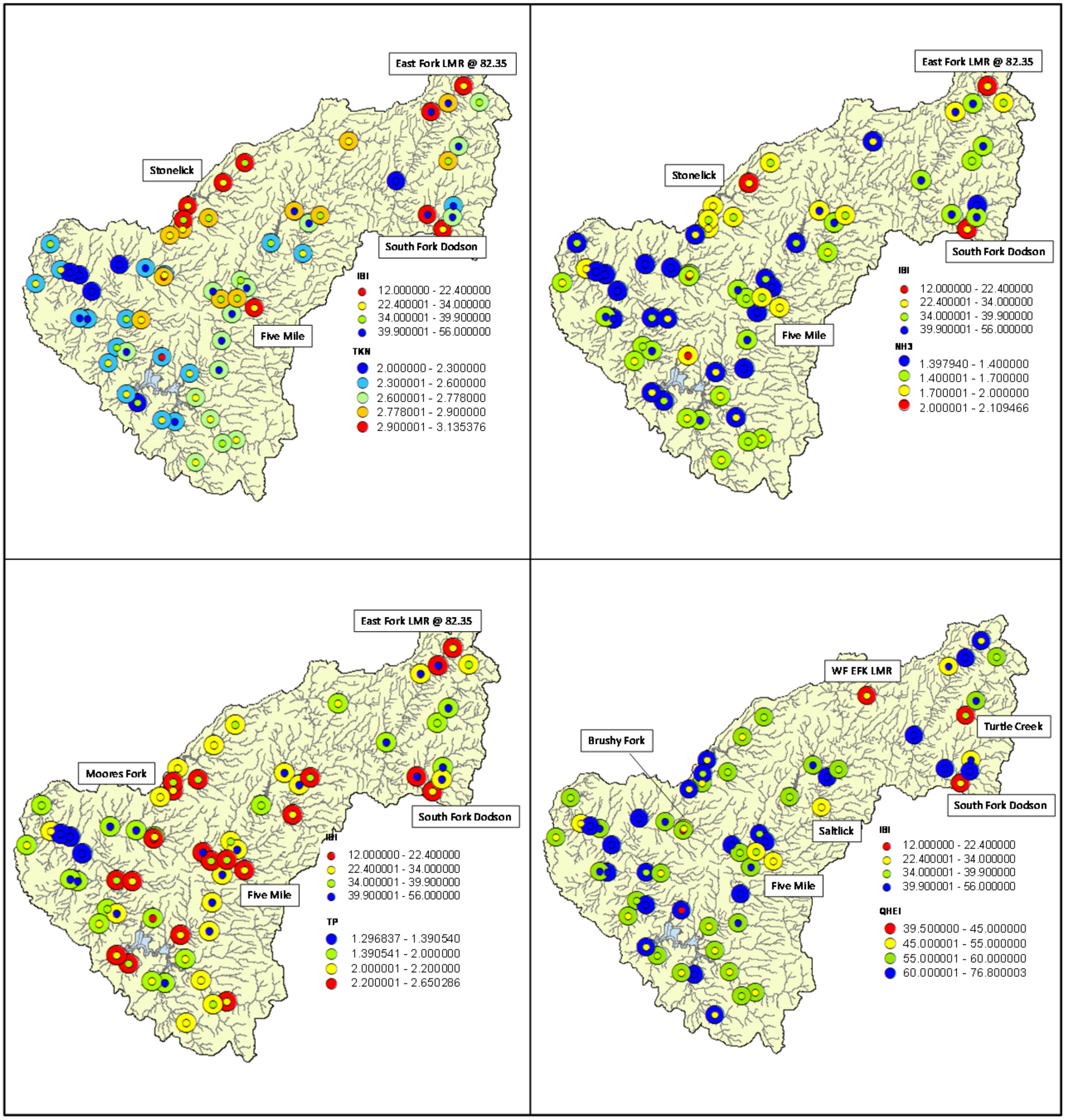


Figure 29. Overlays of IBI scores on (from left to right) total Kjeldahl nitrogen, ammonia nitrogen, total phosphorus and QHEI scores. Selected sites with one or more elevated indicators are labeled.

Table 14. Sites failing the IBI biocriterion, and probable causes based on available indicators, East Fork Little Miami River basin, 2012.			
STORET	SITE	Indicators	Probable Cause
Highest confidence in organic and/or nutrient enrichment as the probable cause of impairment based on indicator set			
301888	S. Fk. Dodson Creek @ Tedrick Rd.	NH3, TKN, TP, D.O., QHEI	1^{o} organic enrichment exacerbated by poor habitat & no flow
M04S35	E. Fk. L. Miami R. Dst New Vienna @ Thornbird Rd.	NH3, TKN, TP, D.O.	1^{o} organic and 2^{o} nutrient enrichment
301913	Patterson Run @ Brushy Fork Rd.	TKN, TP, QHEI	2^{o} organic enrichment exacerbated by marginal habitat (bedrock) & low flow
301902	Back Run @ Foozer Rd.	NOx, TP	Nutrient enrichment
M04S49	Fivemile Creek @ Blue Sky Park Rd. (Lower Crossing)	NH3, TKN, TP, D.O., QHEI	2^{o} organic enrichment exacerbated by marginal habitat & no flow
301895	Fivemile Creek @ Blue Sky Park Rd. (Upper Crossing)	NH3, TKN, TP, QHEI	2^{o} organic enrichment exacerbated by marginal habitat
M04W05	Solomon Run @ Anderson State Rd.	NH3, TKN, TP, QHEI	2^{o} organic enrichment exacerbated by marginal habitat & no flow
Other primary or contributing causes.			
M04P13	Hall Run near Milford @ Roundbottom Rd.	QHEI, D.O., TSS	Poor habitat, low flow, urban runoff
200481	Hall Run at Summerside Estates, Dst. Summerside Rd.	D.O., Zn	Urban runoff
M04S41	Stonelick Creek W of Newtonsville @ St. Rt. 131	TKN, TP, D.O.	Low flow, 2^{o} organic enrichment
301905	Stonelick Creek Dst. Stonelick Lake @ St. Rt. 727	TKN, NH3, TP	Low flow, 2^{o} organic enrichment
M04S42	Stonelick Creek Upst. Stonelick Lake, Adj St. Rt. 133	NH3, TKN, D.O.	No flow, 2^{o} organic enrichment
301148	Trib. To Stonelick Creek (10.61) @ Cedarville Rd.	TKN, NH3, TP	No flow, 2^{o} organic enrichment
301911	Brushy Fork @ Brushy Fork Rd.	QHEI, D.O.	Poor habitat
301904	Trib. To Backbone Creek (1.36) @ Elmwood Rd.	TKN, TP	Low flow, modest nutrient enrichment
M04S44	Lucy Run S of Batavia, Dst. Lucy Run Cemetery	QHEI	Unknown, low flow
200468	Cloverlick Creek Ne of Bethel @ St. Rt. 133	QHEI	Low flow, marginal habitat (bedrock)
301898	Cloverlick Creek @ Bethel New Hope Rd.	D.O., TKN, TP	Low flow, 2^{o} organic enrichment
200469	Barnes Run S of Concord @ Concord-bethel Rd.	D.O., QHEI	Low flow, sediment
301900	Poplar Creek @ Bethel Maple Rd.	D.O.	Low flow

Table 14. Sites failing the IBI biocriterion, and probable causes based on available indicators, East Fork Little Miami River basin, 2012.			
STORET	SITE	Indicators	Probable Cause
301901	Sugartree Creek Adj. South Campbell Rd.	D.O., QHEI	Low flow, marginal habitat (bedrock)
200471	Kain Run Sw of Williamsburg @ Williamsburg-bantam Rd.	D.O. (saturation)	Low flow, natural (bedrock), modest nutrient enrichment
301893	Saltlick Creek @ U.s. Rt. 68	QHEI	Marginal habitat
301891	W. Fk E. Fk. L. Miami R. @ Frazier Rd.	QHEI, TKN	Poor habitat

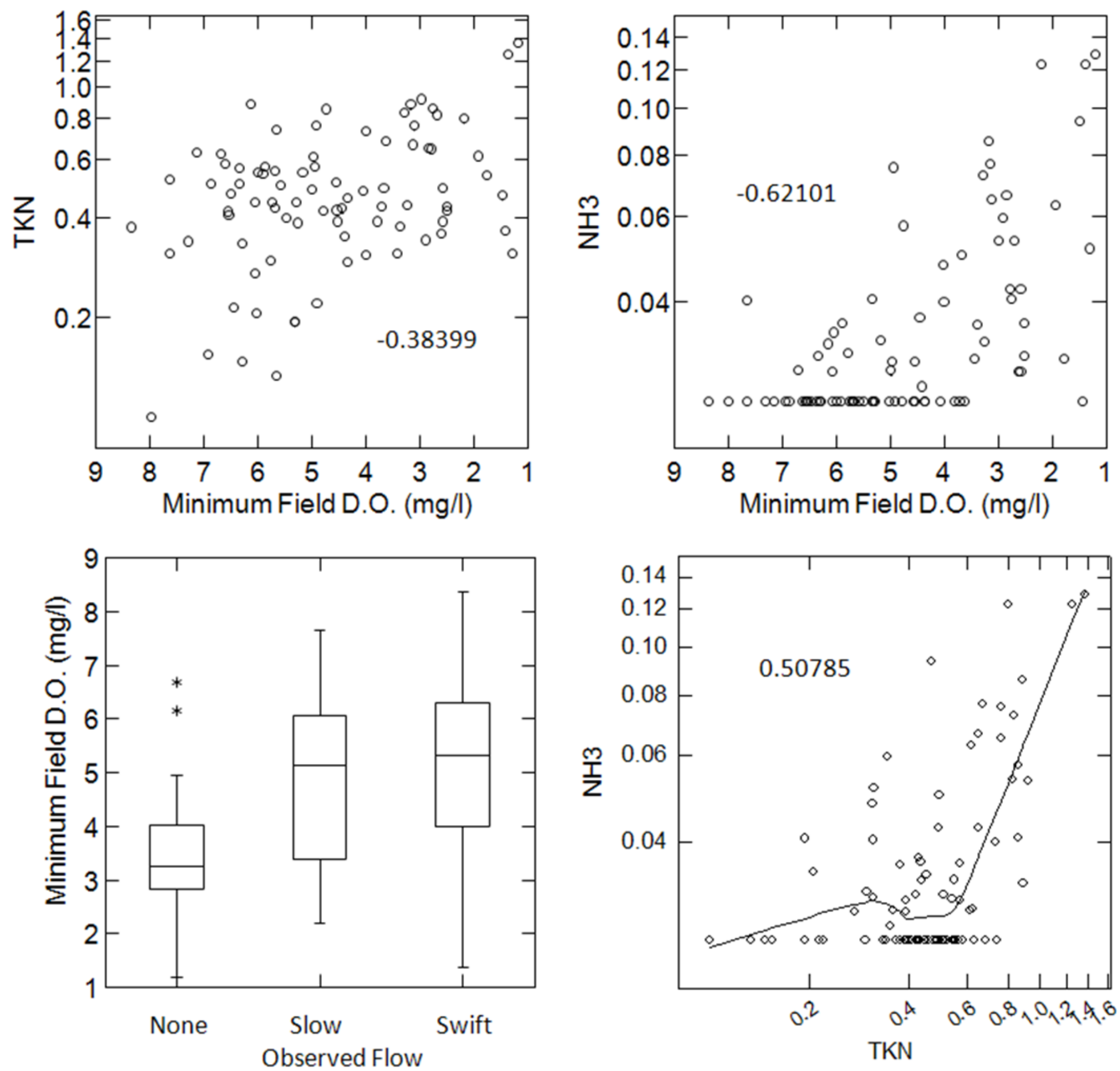


Figure 30. Top row: relationships between minimum dissolved oxygen concentrations measured during the field survey and TKN and NH3-N. Bottom row: distributions of minimum dissolved oxygen concentrations binned by categorical levels of observed flow, and the relationship between TKN and NH3-N. Data are from Cluster Groups 21 and 25.

East Fork Little Miami River Mainstem
Despite measurable differences in the composition of assemblages upstream and downstream from Harsha Lake, distributions and means of IBI scores did not differ significantly between reaches. The mean IBI score for the mainstem upstream from the reservoir was 46.7 ±5.8 SD, compared to 46.0±2.3 SD downstream. Longitudinal profiles of IBI and MIwb scores revealed a localized impact associated with the New Vienna WWTP (1PA00005), the Williamsburg WWTP (1PB00034) and in the reach containing historic channel modifications centered around RM 50. The impact associated with the New Vienna WWTP was primarily from organic enrichment as evidenced by elevated concentrations of ammonia and total Kjeldahl nitrogen measured immediately downstream from the plant compared to concentrations measured upstream. The impact downstream from the Williamsburg WWTP appears related to elevated 3rd quarter ammonia concentrations during 2010 and 2011 as observed in MOR data (see *Pollutant Loadings*).

The overall mean IBI score recorded in 2012 upstream from Harsha Lake (46.7 ± 1.9 SE) was marginally higher compared to 1998 (43.1 ± 2.0 SE), and significantly higher compared to 1982 (37.6 ± 1.8). Overall mean MIwb scores were higher in 2012 compared to 1982, though the difference was not statistically significant. The improvement in IBI and MIwb scores is due to increased species richness and a shift away from larger, pollution tolerant species (i.e., carp) being disproportionately abundant in the electrofishing samples. The decreased abundance of carp is clearly a reflection of decreased organic enrichment owing to improved sewage treatment. Higher species richness likely reflects a combination of decreased organic enrichment and improved management of nonpoint sources of pollution, especially the management of soil erosion. Darters are generally sensitive to sedimentation, and averaged 5.56 (± 1.71 SD) species per sample in 2012, compared to 2.86 (± 2.52 SD) in 1982. A similar trend was observed for the tributaries, where IBI scores and the mean number of sensitive fish per site were higher in 2012 relative to 1982 and 1998.

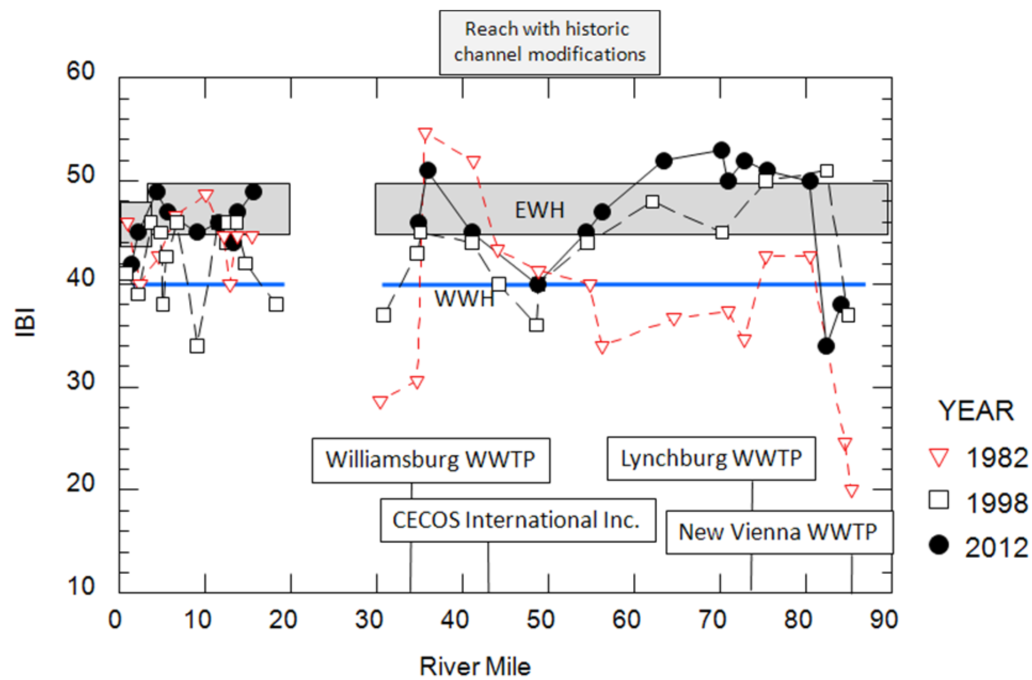
Downstream from Harsha Lake, no significant longitudinal trend was apparent in either the IBI or MIwb (Figure 32). The apparent decrease in the IBI and MIwb downstream from the Milford WWTP relative to the scores obtained immediately upstream was an artifact of local habitat, not plant performance. The riffle included in the sampling zone downstream from the plant was anemic compared to the strong riffle-run complex in the zone upstream from the plant. No significant differences in overall mean IBI scores were detected between 1982, 1998 and 2012 (Table 15). MIwb scores were nearly similar between years, but the MIwb was higher in 2012 compared to 1998 (P = 0.02, Bonferonni-adjusted pairwise comparison).

Table 15. Mean (±SE) IBI and MIwb[13] scores by year for the East Fork LMR downstream from Harsha Lake.

Year	IBI	MIwb
1982	44.2 ± 0.8	9.01 ± 0.13
1998	43.0 ± 0.9	8.87 ± 0.11
2012	46.0 ± 1.0	9.37 ± 0.15

[13] Means for the MIwb are adjusted for sampler type(ANOVA YEAR, TYPE, YEAR*TYPE).

a)



b)

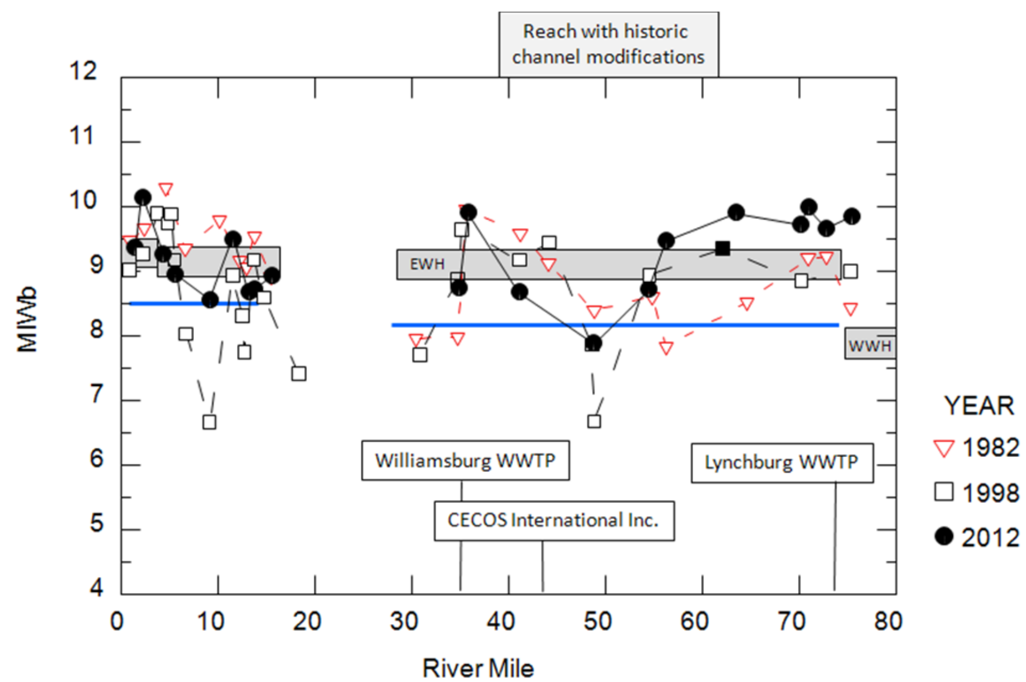


Figure 31. Longitudinal plots of (a) IBI and MIwb (b) scores by river mile for the East Fork Little Miami River mainstem, 1982, 1998 and 2012. Existing biocriteria are noted by the gray-shaded horizontal bars. The WWH biocriteria are shown by blue lines for perspective. Locations of permitted dischargers for the reach upstream from Harsha Lake are annotated along the x-axis (see Figure 32 for detail of the reach downstream from Harsha Lake).

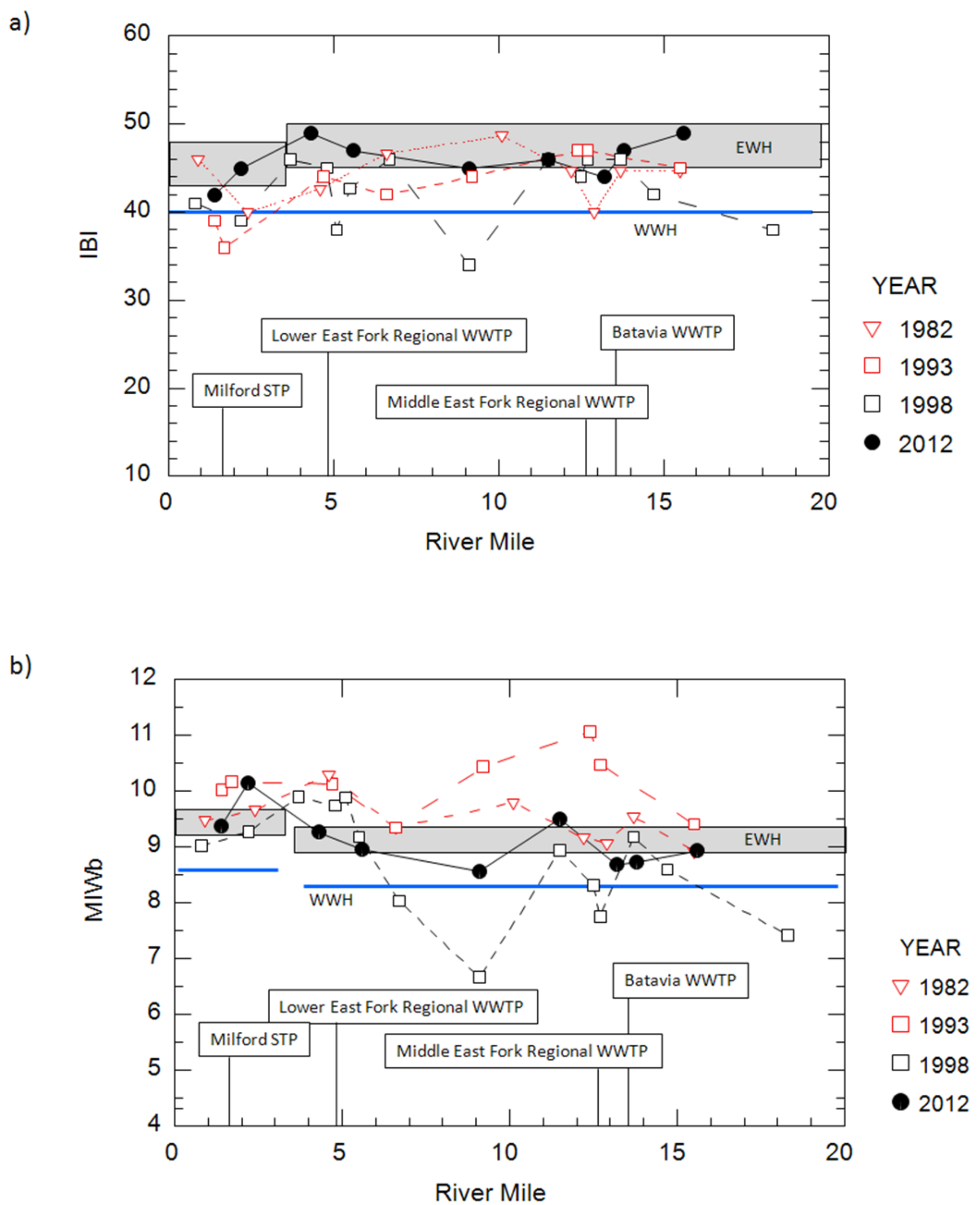


Figure 32. Longitudinal plots of (a) IBI and (b) MIwb scores plotted by river mile for the East Fork Little Miami River downstream from Harsha Lake. Existing biocriteria are noted by the gray-shaded horizontal bars. The WWH biocriteria are shown by blue lines for perspective. Locations of permitted dischargers are annotated along the x-axis.

Table 17. Attributes of fish samples collected from the East Fork LMR basin, 2012. Attribute values are averages except in cases where sampling method differed between passes.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives	Drain Area
11-100-000		**East Fork Little Miami River**							
Warmwater									
84.1 [E]	15.0		571.5	3,087.0	58.5	38		Marginal : NA	3.0
82.4 [E]	12.0		605.5	1,674.6	76.8	34		Fair : NA	5.4
80.4 [E]	22.0		2,628.0	4,016.0	67.5	50		Exceptional : NA	12.8
75.3 [D]	30.5	83.4	1,359.8	1,848.8	70.3	51	9.9	Exceptional : Exceptional	26.2
Exceptional Warmwater									
72.8 [D]	25.0	13.2	1,275.0	1,477.5	77.5	52	9.8	Exceptional : Exceptional	48.0
72.8 [E]	26.0	18.6	889.5	1,128.0	77.5	52	9.6	Exceptional : Exceptional	48.0
70.9 [D]	32.5	90.4	1,654.5	2,173.5	71.0	50	10.0	Exceptional : Exceptional	54.0
70.1 [D]	30.0	37.0	944.7	1,105.3	73.3	53	9.8	Exceptional : Exceptional	88.0
63.4 [D]	29.5	66.8	1,096.3	1,255.6	80.5	52	9.9	Exceptional : Exceptional	100.0
56.3 [D]	27.5	31.9	544.5	733.5	78.3	47	9.5	Very Good : Exceptional	151.0
54.4 [D]	26.5	30.3	390.8	564.8	69.3	45	8.7	Good : Good	165.0
46.9 [D]	18.5	27.0	332.3	426.0	68.8	40	7.9	Good : Marginal	178.0
41.1 [D]	26.0	12.3	747.0	948.8	77.8	45	8.7	Good : Good	221.0
35.9 [D]	31.0	35.9	798.8	873.0	81.3	51	9.9	Exceptional : Exceptional	235.0
34.9 [D]	23.5	13.7	252.8	319.5	70.5	46	8.8	Very Good : Good	237.0
15.6 [D]	24.0	14.6	846.8	916.5	82.8	49	8.9	Very Good : Very Good	352.0
13.8 [D]	26.5	15.0	484.5	538.5	80.0	47	8.7	Very Good : Good	363.0
13.2 [D]	23.0	12.8	415.5	430.5	81.0	44	8.7	Good : Good	364.0
11.5 [D]	29.0	33.7	683.3	754.5	85.0	46	9.5	Very Good : Exceptional	375.0
9.1 [D]	20.5	15.9	601.5	633.0	87.0	45	8.6	Good : Good	380.0
5.6 [D]	25.0	10.4	437.3	461.3	83.3	47	9.0	Very Good : Very Good	484.0
4.3 [D]	30.0	19.6	471.0	491.3	83.0	49	9.3	Very Good : Very Good	491.0
2.2 [A]	27.0	179.1	335.0	340.0	82.5	45	10.2	Very Good : Exceptional	494.0
0.8 [A]	24.5	135.8	279.0	305.0	72.3	42	9.4	Good : Very Good	498.0
11-100-003		**Trib. to E. Fk. L. Miami R. (RM 78.45)**							
None									
0.5 [E]	18.0		228.0	582.0	52.3	42		Good : NA	4.0
11-100-007		**Glady Creek**							
Warmwater									
0.7 [E]	19.0		1,380.0	2,810.0	66.5	50		Exceptional : NA	4.2

Table 17. Attributes of fish samples collected from the East Fork LMR basin, 2012. Attribute values are averages except in cases where sampling method differed between passes.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives	Drain Area
11-100-008		**Trib. to E. Fk. L. Miami R. (RM 2.40)**							
None									
0.4 E	8.0		66.0	388.0	56.0	38		Marginal : NA	2.6
11-101-000		**Hall Run**							
Warmwater									
2.3 E	4.0		229.1	1,101.8	58.0	26		Poor : NA	3.1
0.2 E	9.0		50.0	212.0	47.8	30		Fair : NA	5.5
11-103-000		**Salt Run**							
Warmwater									
0.4 E	15.0		498.0	740.0	65.8	48		Very Good : NA	6.4
11-104-000		**Sugarcamp Run**							
Warmwater									
0.2 E	8.0		992.0	1,734.0	59.3	44		Good : NA	3.6
11-105-000		**Shayler Run**							
Warmwater									
5.2 E	12.0		1,244.0	1,634.0	71.5	48		Very Good : NA	4.9
1.7 E	12.0		526.0	752.0	67.5	44		Good : NA	12.1
11-105-001		**Trib. to Shayler Run (RM 4.40)**							
Warmwater									
0.4 E	10.0		380.0	706.0	63.8	40		Good : NA	4.4
11-107-000		**Stonelick Creek**							
Warmwater									
20.0 E	16.0		201.0	741.0	57.3	38		Marginal : NA	4.9
17.7 E	11.0		155.4	289.2	64.0	30		Fair : NA	11.6
13.4 E	10.0	4.5	220.0	663.0	73.0	32	5.6	Fair : Poor	23.0
9.8 D	14.0	4.0	120.8	348.0	69.0	34	6.3	Fair : Fair	38.0
6.2 E	20.5	9.4	293.0	454.0	66.8	37	7.9	Marginal : Marginal	43.3
5.2 D	25.0	5.3	513.8	741.8	67.3	44	8.4	Good : Good	62.0
1.0 D	24.5	25.3	540.0	609.0	67.0	42	8.9	Good : Very Good	75.0
11-107-002		**Trib. to Stonelick Creek (RM 10.61)**							
None									
0.9 E	8.0		294.0	788.0	61.8	34		Fair : NA	2.0

Table 17. Attributes of fish samples collected from the East Fork LMR basin, 2012. Attribute values are averages except in cases where sampling method differed between passes.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives	Drain Area
11-108-000		**Lick Fork**							
Warmwater									
0.6 E	16.0		432.0	592.5	72.0	56		Exceptional : NA	6.3
11-109-000		**Brushy Fork**							
Warmwater									
2.2 E	8.0		92.0	658.0	49.0	26		Poor : NA	5.7
0.3 E	16.0		930.0	1,640.0	55.8	46		Very Good : NA	14.8
11-111-000		**Patterson Run**							
Warmwater									
0.1 E	4.0		14.0	348.0	57.3	20		Poor : NA	4.2
11-112-000		**Moores Fork**							
Warmwater									
2.9 E	12.0		372.0	782.0	63.0	38		Marginal : NA	4.6
0.7 E	12.0		276.0	482.0	66.5	38		Marginal : NA	10.6
11-115-000		**Backbone Creek**							
Warmwater									
0.6 E	9.0		592.0	1,164.0	65.5	36		Marginal : NA	7.4
11-115-001		**Trib. to Backbone Creek (RM 1.36)**							
None									
0.9 E	6.0		370.0	962.0	62.8	28		Fair : NA	3.8
11-116-000		**Lucy Run**							
Warmwater									
1.9 E	8.0		164.0	768.0	63.5	30		Fair : NA	3.7
0.1 E	10.0		568.8	1,008.0	58.8	38		Marginal : NA	7.2
11-117-000		**Fourmile Run**							
Warmwater									
0.2 E	17.0		312.0	394.0	76.8	52		Exceptional : NA	3.5
11-118-000		**Back Run**							
Warmwater									
1.2 E	5.0		392.0	788.0	73.0	34		Fair : NA	2.4

Table 17. Attributes of fish samples collected from the East Fork LMR basin, 2012. Attribute values are averages except in cases where sampling method differed between passes.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives	Drain Area
11-119-000		**Ulrey Run**							
Warmwater									
1.3 E	10.0		292.2	769.6	61.5	38		Marginal : NA	3.5
11-120-000		**Slabcamp Run**							
Warmwater									
2.6 E	2.0		3.0	6.0	65.8	12		Poor : NA	0.7
11-121-000		**Cloverlick Creek**							
Warmwater									
8.5 E	9.0		78.0	224.0	64.3	28		Fair : NA	12.4
5.2 E	14.0	1.9	377.0	646.0	62.0	34	7.1	Fair : Fair	23.0
11-121-002		**Trib. to Cloverlick Creek (RM 7.48)**							
None									
0.5 E	11.0		432.0	708.0	64.5	38		Marginal : NA	6.9
11-122-000		**Barnes Run**							
Warmwater									
1.9 E	11.0		212.0	476.0	64.3	30		Fair : NA	7.9
11-123-000		**Poplar Creek**							
Warmwater									
8.4 E	9.0		240.0	534.0	70.5	28		Fair : NA	5.8
2.1 E	14.0		1,430.0	1,734.0	66.0	44		Good : NA	17.5
11-124-000		**Sugartree Creek**							
Warmwater									
1.0 E	8.0		252.0	666.0	58.8	34		Fair : NA	3.6
11-132-000		**Kain Run**							
Warmwater									
0.3 E	10.0		114.0	378.0	64.0	30		Fair : NA	5.9
11-133-000		**Todd Run**							
Warmwater									
1.0 E	15.0		649.6	1,173.9	58.3	42		Good : NA	9.4

Table 17. Attributes of fish samples collected from the East Fork LMR basin, 2012. Attribute values are averages except in cases where sampling method differed between passes.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives	Drain Area
11-135-000		**Crane Run**							
Warmwater									
0.2 E	18.0		214.0	552.0	72.8	44		Good : NA	8.9
11-136-000		**Fourmile Creek**							
Warmwater									
0.3 E	15.0		198.0	422.0	60.0	46		Very Good : NA	5.5
11-137-000		**Pleasant Run**							
Warmwater									
1.4 E	15.0		220.0	630.9	67.5	42		Good : NA	5.3
0.4 E	13.0		152.0	558.0	62.5	38		Marginal : NA	7.8
11-138-000		**Fivemile Creek**							
Warmwater									
2.3 E	13.0		128.0	418.0	54.3	32		Fair : NA	8.3
0.5 E	9.5		102.0	160.0	51.5	36		Marginal : NA	10.6
11-141-000		**Howard Run**							
Warmwater									
0.4 E	15.0		284.0	566.0	75.3	40		Good : NA	5.6
11-142-000		**Grassy Fork**							
Warmwater									
0.2 E	13.0		194.0	602.0	67.3	36		Marginal : NA	6.3
11-143-000		**Glady Run**							
Warmwater									
0.8 E	16.0		285.6	804.0	61.0	38		Marginal : NA	5.3
11-144-000		**Saltlick Creek**							
Warmwater									
0.6 E	12.0		57.0	342.0	51.5	28		Fair : NA	5.7
11-147-000		**Solomon Run**							
Warmwater									
1.9 E	15.0		194.0	650.0	55.5	36		Marginal : NA	6.1

Table 17. Attributes of fish samples collected from the East Fork LMR basin, 2012. Attribute values are averages except in cases where sampling method differed between passes.

River Mile	Mean No. of Species	Relative Weight	Rel. No. minus Tol.	(all) Relative Number	QHEI	IBI	MIWb	Narratives	Drain Area
11-149-000	**Sycamore Creek**								
Warmwater									
0.8 ^{E}	20.0		636.8	1,627.7	56.8	42		Good : NA	6.6
11-150-000	**West Fork East Fork Little Miami River**								
Warmwater									
7.5 ^{E}	13.0		236.0	958.0	39.5	26		Poor : NA	8.2
0.1 ^{E}	24.5	7.3	1,203.0	1,606.5	71.8	45	7.8	Good : Marginal	28.3
11-151-000	**Dodson Creek**								
Exceptional Warmwater									
7.5 ^{E}	22.0		604.0	1,522.0	53.8	44		Good : NA	5.1
5.8 ^{E}	32.0		834.0	1,336.0	54.0	46		Very Good : NA	16.1
0.1 ^{E}	27.5	8.5	898.5	1,422.8	63.5	46	9.1	Very Good : Very Good	32.5
11-151-001	**Trib. to Dodson Creek (RM 4.52)**								
None									
0.6 ^{E}	20.0		438.0	799.5	72.3	50		Exceptional : NA	4.9
11-153-000	**South Fork Dodson Creek**								
Warmwater									
0.9 ^{E}	8.0		84.0	132.0	44.5	34		Fair : NA	2.3
11-153-001	**Trib. to S. Fk. Dodson Creek (RM 0.37)**								
None									
0.9 ^{E}	22.0		1,462.0	2,470.0	72.3	52		Exceptional : NA	6.5
11-154-000	**Turtle Creek**								
Warmwater									
5.9 ^{E}	20.0		584.3	1,376.5	59.5	44		Good : NA	5.6
4.4 ^{E}	19.0		284.6	653.1	44.8	36		Marginal : NA	13.7
1.2 ^{E}	27.0		1,122.0	1,576.0	65.8	54		Exceptional : NA	17.2

Biological Quality – Macroinvertebrate Assemblages

Overview

Macroinvertebrate assemblages sampled in the East Fork Little Miami catchment clustered into three general groups based on drainage area, and a gradient of organic enrichment and observed stream flow (Figure 33). One group (*i.e.*, Group 11 in Figure 33) was essentially the mainstem of the East Fork Little Miami River demarcated by a drainage area greater than 150 mi^2, and characterized by uniformly high quality assemblages (as defined by biological standards) and relatively low inter-site variability in water quality parameters (Figure 34). This group was unfailingly classified by a linear combination of drainage area, flow and TKN in discriminant analysis (Table 18). The other two groups also separated along a gradient of drainage area, albeit less distinctly, but arrayed strongly along the gradient of organic enrichment. The upshot being that one of these groups (Group 6) can be described as small headwater streams characterized by comparatively high average concentrations of ammonia and TKN, low flow, low dissolved oxygen concentrations, and uniformly stressed macroinvertebrate assemblages. The other (Group 1) can be described as intermediately-sized streams wherein the quality of macroinvertebrate assemblages is arrayed along a gradient of drainage area and organic enrichment.

Clearly, the condition status of macroinvertebrate assemblages in the East Fork LMR basin follows the same general model as that identified for fish assemblages, and on a site-specific basis, this was most apparent for sites in Stonelick Creek, Fivemile Creek, Dodson Creek, and the upper East Fork catchment in the vicinity of New Vienna (Figure 35). However, the condition status of macroinvertebrate assemblages tended to follow water quality gradients more closely than the fish assemblages, in that low dissolved oxygen concentrations were nearly synonymous with macroinvertebrate impairment (Table 19), and only five of the impaired macroinvertebrate sites had ill-defined causes[14].

[14] This is not to be construed as meaning macroinvertebrates are better indicators of disturbance. Rather, it shows the value of the dual indicator approach. Here, macroinvertebrates are reading the signal from shorter-duration, more proximate and episodic water quality disturbances, and the fish are signaling comparatively more distal (*i.e.*, both temporal and reach-scale) disturbances.

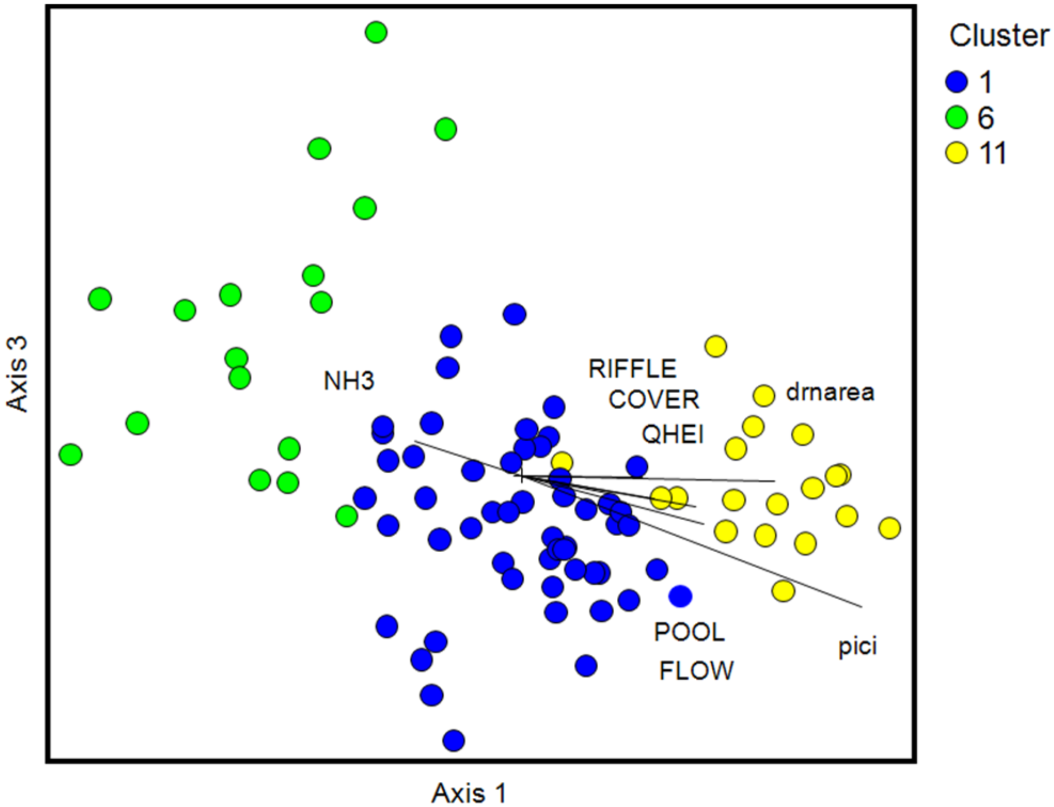


Figure 33. Sites sampled in the East Fork Little Miami River arrayed by two axes derived from an ordination[15] of assemblage attributes. The color-coded groupings were defined by hierarchical cluster analysis. Environmental measures correlating with Axis 1 ($r2>0.3$) are superimposed on the plot (the length of the superimposed lines show relative degree of correlation). The variable "PICI" is an indicator of macroinvertebrate assemblage quality based on assemblage attributes from qualitative samples that lack ICI scores. The "PICI" correlates well with the ICI[16] (also, *n.b.*, the correlation between "PICI" and Axis 1 is 0.89).

[15] i.e., from nonmetric multidimensional scaling

[16] The relationship is formed by a linear combination of total taxa, EPT taxa, percent of taxa classified as tolerant, and percent of taxa classified as predators, and was derived from statewide reference sites.

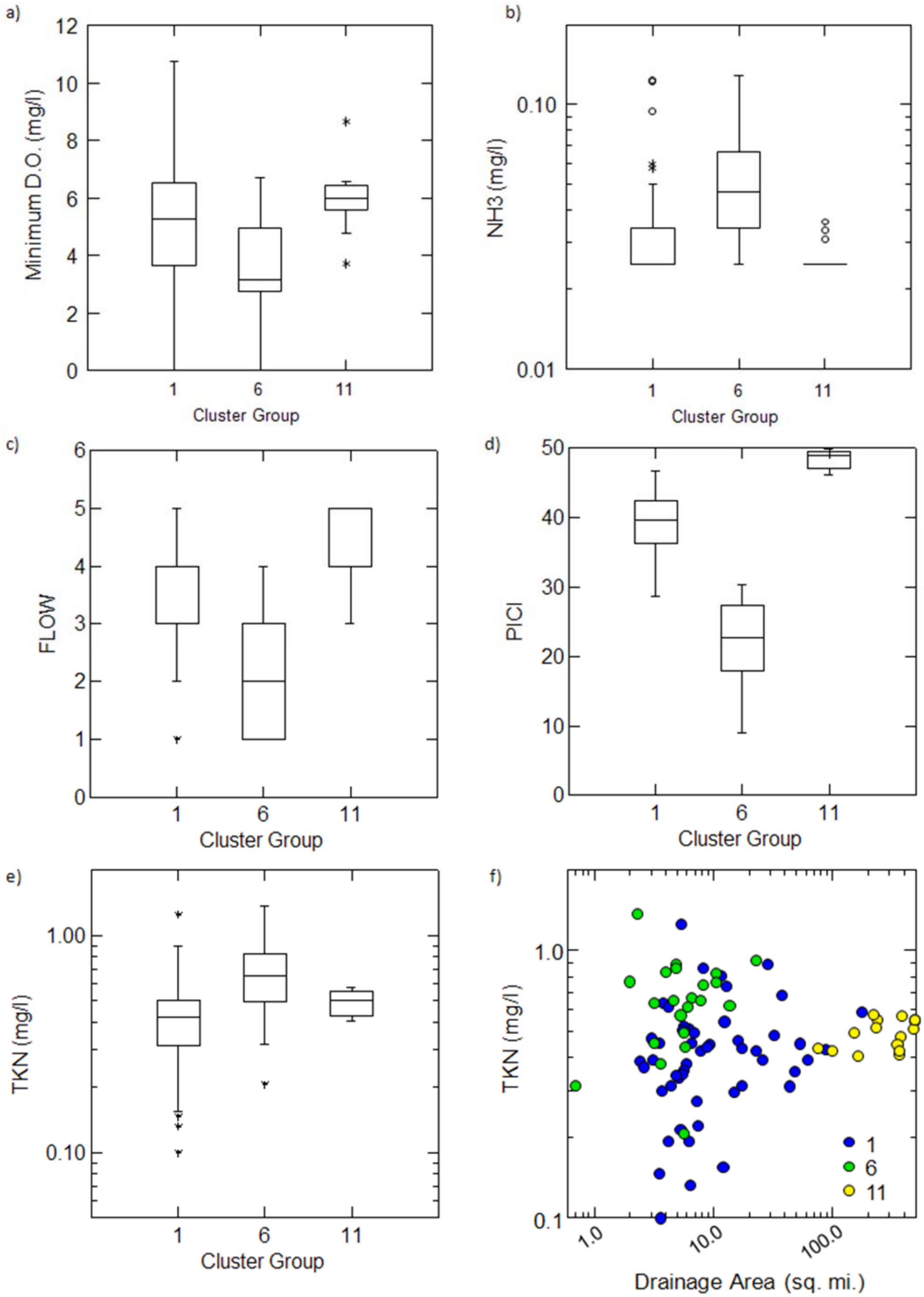


Figure 34. Distributions of a) minimum D.O. concentrations, b) mean ammonia concentrations, c) categorical levels of flow (1- no flow to 5 fast flow), d) an index of macroinvertebrate assemblage condition based on qualitative metrics (PICI), and e) average TKN concentrations within groups identified by hierarchical cluster analysis. Plot f) shows the relationship between mean TKN concentrations and drainage area for sites sampled in the East Fork LMR basin. Sites are color-coded by hierarchical cluster groups.

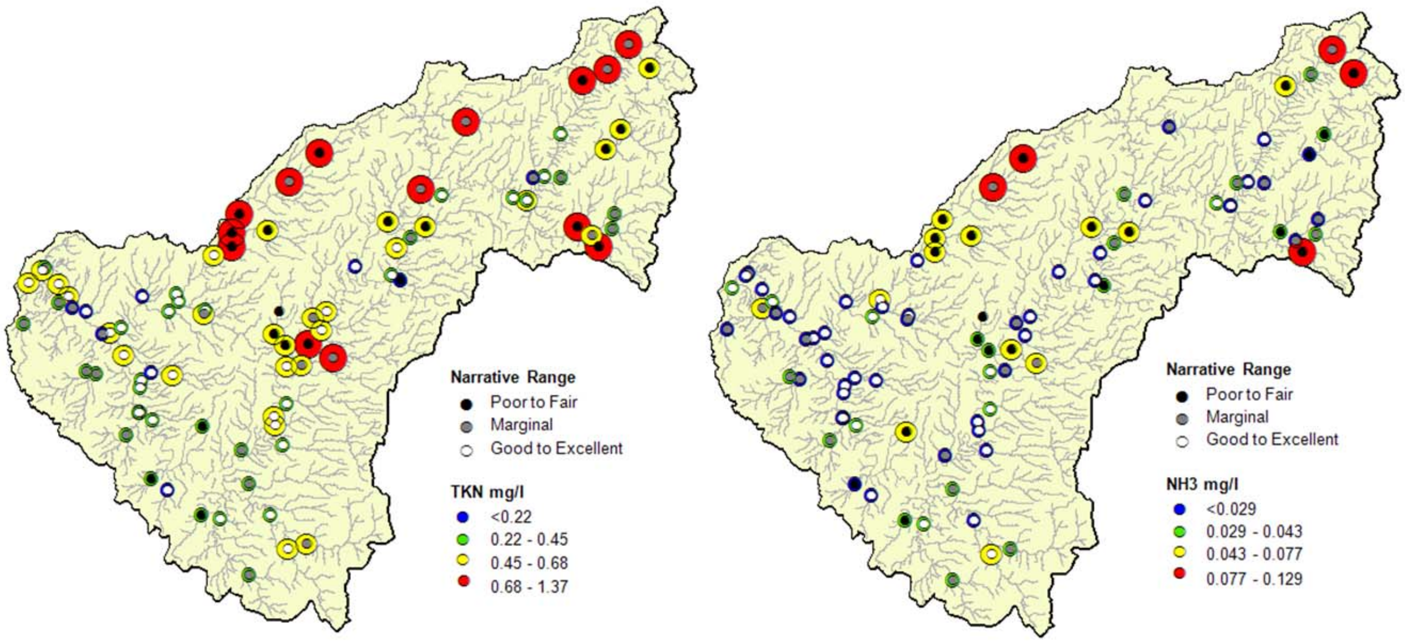


Figure 35. Overlays of macroinvertebrate assemblage ratings on total Kjeldahl nitrogen and ammonia nitrogen concentrations for sites sampled in the East Fork LMR basin, 2012. Compare these plots with those in Figure 29.

Group	1	6	11	% Correct
1	36	11	4	71
6	4	18	0	82
11	0	0	16	100

Table 18. Percentage 2012 East Fork LMR basin macroinvertebrate of sites properly classified by a linear discriminant function predicting group membership (*i.e.*, the groups identified by hierarchical clustering) applied to a jackknifed sample of the data.

Table 19. Sites failing the ICI biocriterion or narrative status, and probable causes for failure based on available environmental indicators, East Fork LMR basin, 2012.

STORET	SITE	Indicators	Probable Cause
301888	S Fk Dodson Creek @ Tedrick Rd	D.O., TKN, NH3, QHEI	low flow, organic enrichment, condition exacerbated by marginal habitat
M04S45	Slabcamp Run W of Williamsburg @ Zagar Rd	D.O.	low do, condition exacerbated by low flow
M04S35	E Fk L Miami R Dst New Vienna @ Thornbird Rd	D.O., TKN, NH3	low do, organic enrichment (municipal)
M04S17	E Fk L Miami R at New Vienna @ SR 28 (East)	D.O., NH3	low flow, organic enrichment, condition exacerbated by marginal habitat
301898	Cloverlick Creek @ Bethel New Hope Rd	D.O.	low do, condition exacerbated by low flow
301884	Turtle Creek @ Panhandle Rd	D.O.	low flow, organic enrichment, condition exacerbated by marginal habitat
301910	Moores Fork @ Spring Hill Drive	D.O., TKN	low do, organic enrichment
301890	Trib To Dodson Creek (Rm 4.52) @ US 50	D.O., TKN	low do, organic enrichment
M04S46	Pleasant Run at Glancy Corner @ Marathon Rd	D.O.	low do, organic enrichment
301909	Moores Fork @ Meek Rd	D.O., NH3	low do, organic enrichment, condition exacerbated by low flow
301905	Stonelick Creek Dst Stonelick Lake @ SR 727	D.O., TKN	low do, organic enrichment, condition exacerbated by low flow
M04S49	Fivemile Creek @ Blue Sky Park Rd (Lower Crossing)	D.O., TKN, NH3, QHEI	low flow, organic enrichment, condition exacerbated by marginal habitat
200474	Sycamore Creek Nw of Fayetteville @ Glady Rd	D.O., NH3	low do, organic enrichment, condition exacerbated by low flow
200492	Stonelick Creek Sw of Blanchester @ Woodville Rd	D.O., TKN, NH3	low do, organic enrichment, condition exacerbated by low flow
301900	Poplar Creek @ Bethel Maple Rd	D.O.	low do, condition exacerbated by low flow
M04P04	Trib To E Fk L Miami R (78.45) @ Rapid Forge Rd	D.O., TKN, QHEI	low do, organic enrichment, condition exacerbated by low flow
M04S47	Pleasant Run W of Marathon @ US 50	D.O.	low do, condition exacerbated by low flow

STORET	SITE	Indicators	Probable Cause
301901	Sugartree Creek Adj South Campbell Rd	D.O.	low do, condition exacerbated by low flow
301148	Trib To Stonelick Creek (10.61) @ Cedarville Rd	TKN, NH3	organic enrichment
301893	Saltlick Creek @ US 68	QHEI	marginal habitat
M04W05	Solomon Run @ Anderson State Rd	QHEI	marginal habitat, low flow
200508	Turtle Creek E of Lynchburg @ Bald Knob Rd	QHEI	marginal habitat
M04S14	E Fk L Miami R Dst Lynchburg @ Wise Rd		no well-defined cause
M04S22	Pleasant Run N of Williamsburg @ Blue Sky Park Rd		no well-defined cause
301902	Back Run @ Foozer Rd		no well-defined cause
M04S34	E Fk L Miami R SW of Lynchburg, Upst Dodson Creek		no well-defined cause
200506	E Fk L Miami R Ust Lynchburg WWTP		no well-defined cause

East Fork Little Miami River Mainstem

Macroinvertebrate assemblages measured along the run of the East Fork mainstem generally met expectations based on the respective biocriterion. The exception, as previously discus, was in the vicinity of New Vienna, and in the reach that is transitional between WWH and EWH near Lynchburg (Figure 36). Within the transitional reach (river miles 65-75), indicators of environmental stress (e.g., elevated TKN or ammonia, low D.O., poor habitat) were not evident except for a marginally low dissolved oxygen concentration (4.45 mg/l) sampled on one date at RM 70.12. Note, however, that of the 4 stations in the reach, only one water chemistry sample was collected from each of the upstream most two stations (M04S15 [75.33] & 200506 [72.80]). Downstream from river mile 65, macroinvertebrate assemblages met expectations for EWH, and showed no variation in relationship to point sources. Similarly, downstream from Harsha Lake all ICI scores (or narrative equivalents) met expectations for EWH, and showed no longitudinal variation in relation to point sources (Figure 37).

Consistent with broader statewide trends, the quality of macroinvertebrate assemblages measured in 2012 was similar to that measured in 1998, and better than that measured in 1982 (Figure 38) owing to improved wastewater infrastructure and treatment facilitated by the Construction Grants program[17].

[17] The Construction Grants program was implemented under the US EPA National Municipal Policy as contained within the Federal Water Pollution Control Act (Clean Water Act), as amended in 1977 and 1981.

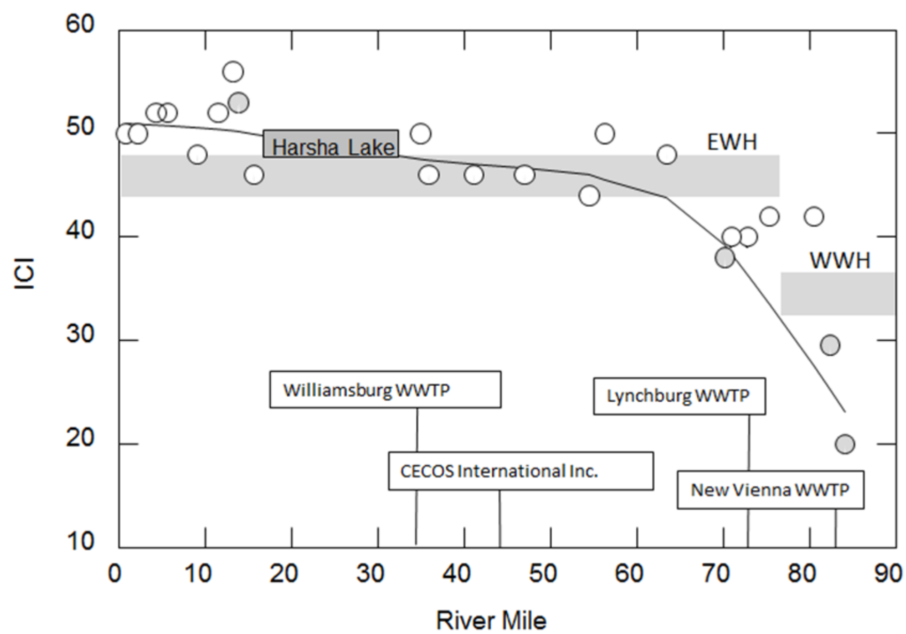


Figure 36. ICI scores plotted by river mile for the East Fork Little Miami River, 2012, in relation to publicly owned treatment works and Harsha Lake. Gray-shaded regions of the plot denote the range of non-significant departure from the given biocriterion. Shaded points were given numeric scores based on narrative assessments.

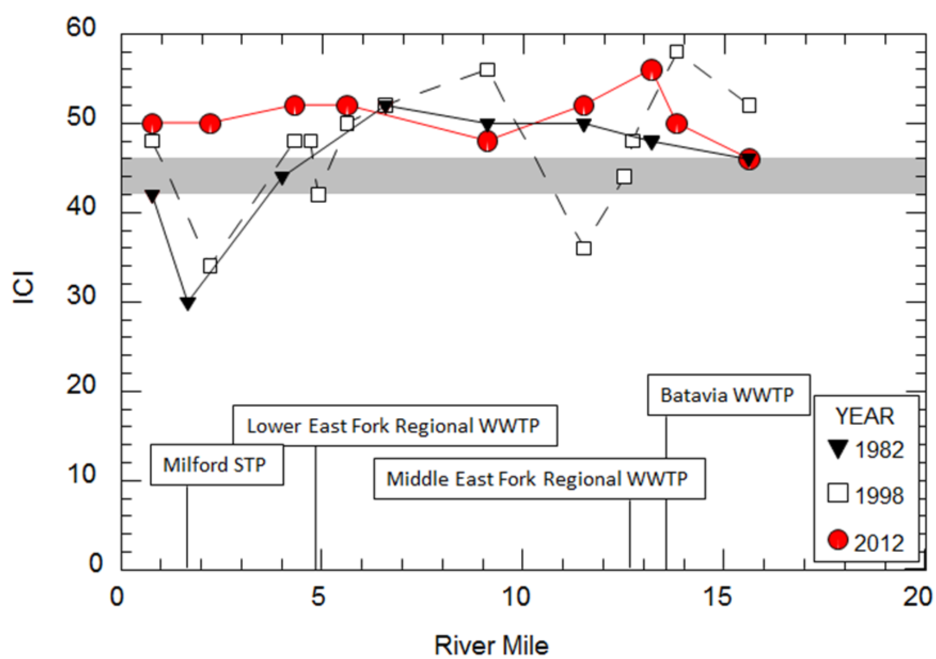


Figure 37. Invertebrate Community Index (ICI) scores stratified by year and plotted by river mile for the East Fork Little Miami River downstream from Lake Harsh. The approximate discharge locations of publicly owned treatment works are shown along the x-axis.

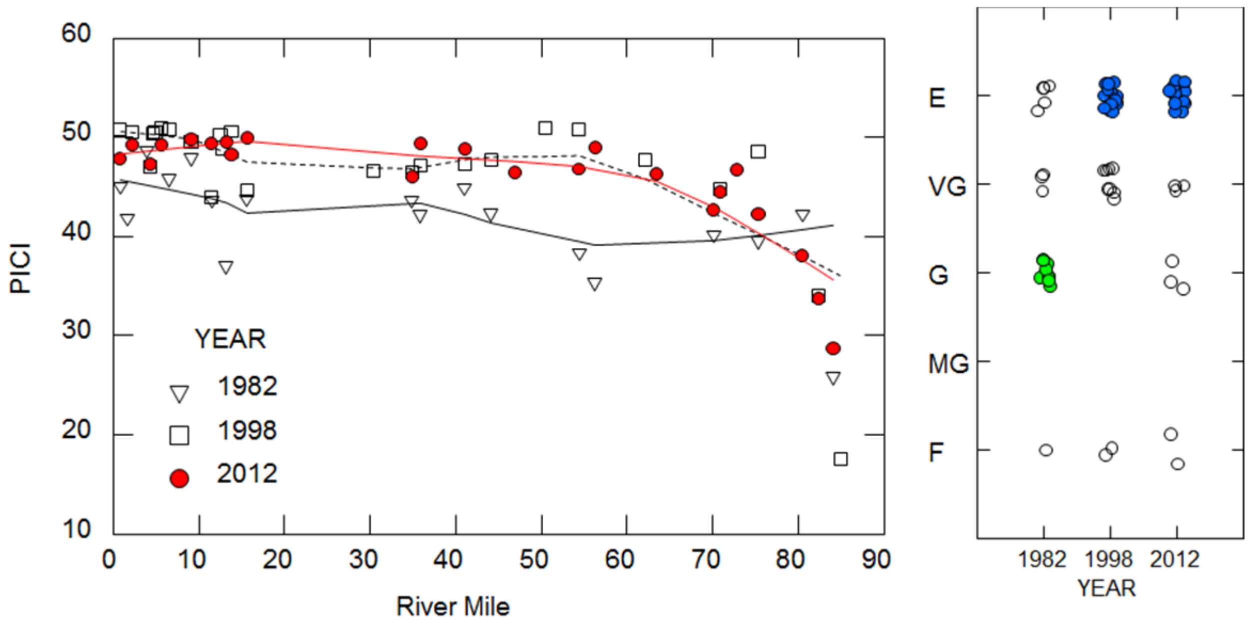


Figure 38. Trends in macroinvertebrate assemblage quality for the East Fork Little Miami River. The left panel shows numeric scores generated from qualitative measures, and plotted by river mile and year. Lines are from LOWESS (α=0.5). The right panel shows narrative rankings plotted by year, with the within-year, median rank highlighted. Years 1998 and 2012 were similar, and both differed from 1982 (Kruskal-Wallis non-parametric ANOVA, Bonferroni pairwise comparison).

Tributaries - Trends

For matching locations, macroinvertebrates assemblages measured in 2012 were marginally better than those measured in 1998 (two-sample t-test using the PICI [as a normally distributed continuous variable], p=0.06). When all tributary sampling locations are considered, macroinvertebrate assemblages were rated higher in 2012 compared to 1998 (Mann-Whitney U-test). In Stonelick Creek, longitudinal performance and scores were similar between 1998 and 2012 at three common locations.

Table 20. Macroinvertebrate community attributes, East Fork Little Miami River Basin 2012 TMDL

River Mile	Drainage Area	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens.	Qual Sens.	Total Cold	Qual Tolerant	Density	ICI	Flow	Current	Dominant Taxa
11-100-000		***East Fork Little Miami River***													
84.10	3.0	51		51	4	4	2	2	0	17	Low	F	LOW		Midges (F,MI,MT,T)
82.35	5.4	41		41	6	6	1	1	0	9	Mod-High	F	LOW		Blackflies, hydropsychids, midges(F,MT,T)
80.44	12.8	59	42	42	11	9	7	5	0	6	645/sqft	42	LOW	0.00	Hydropsychids, tanytarsini & red midges(MI,F,MT,T)
75.33	26.2	76	54	51	14	13	14	9	0	10	763/sqft	42	LOW	0.33	Baetids,hydropsychids,flatworms,midges (F,MI,MT,T)
72.80	48.0	69	41	57	17	15	17	15	0	8	1228/sqft	40	LOW	0.32	Baetids,hydropsychids,flatworms,midges (F,MI,MT,T)
70.90	54.0	76	52	54	16	13	20	14	0	9	593/sqft	40	LOW	0.15	Baetids,hydropsychids,red & tanytarsini midges(F-T)
70.12	88.0	48		48	12	12	11	11	0	10	Moderate	G	LOW		Baetids,hydropsychids,Chimarra sp.,midges (MI,F,MT,T)
63.40	100.0	70	45	48	24	22	19	16	0	9	1147/sqft	48	LOW	0.90	Chimarra sp.,baetids,hydropsychids,midges (MI,F,MT,T)
56.25	151.0	79	48	58	21	19	27	24	0	8	520/sqft	50	LOW	0.13	Baetids,Chimarra sp.,hydropsychids,flatworms,midges
54.42	165.0	77	45	56	19	15	24	21	0	9	438/sqft	44	LOW	0.15	Baetids,Hydropsychids,Tanytarsus&Polypedilum midges
46.92	178.0	86	51	61	21	14	23	18	0	9	839/sqft	46	LOW	0.21	Baetis,Acerpenna,Chimarra sp.,hydropsychids,midges
41.07	221.0	76	51	52	25	20	34	28	0	5	1235/sqft	46	LOW	0.50	Baetis,Acerpenna,Chimarra,Polypedilum/Tanytarsus sp
35.87	235.0	80	49	58	29	24	28	22	0	6	572/sqft	46	LOW	0.10	Baetis,Acerpenna,Chimarra,Elimia sp., riffle beetles(MI,F)
34.91	237.0	61	39	44	21	16	22	20	0	6	979/sqft	50	LOW	0.40	Baetids,Chimarra,Elimia,hydropsychids,clams,flatworms
15.60	352.0	92	45	78	29	28	34	30	0	8	389/sqft	46	LOW	0.80	Baetids, Protoptila, Elimia,Helicopsyche,Macaff. sp(F,MI)
13.80	363.0	73		73	29	29	34	34	0	9	Moderate	E	LOW		Baetids, Protoptila sp., hydropsychids, riffle beetles(F,MI)
13.18	364.0	87	52	66	30	25	35	29	0	8	719/sqft	56	LOW	0.90	Elimia,Tanytarsus,Baetis,flathead mayflies,Hydroptila sp.
11.50	375.0	73	39	61	27	20	33	28	0	8	1719/sqft	52	LOW	1.00	Protoptila,Rheotanytarsus, hydropsychids, Baetis, Elimia
9.10	380.0	86	36	72	29	20	31	22	0	13	1926/sqft	48	NORMAL	2.00	Protoptila,Rheotanytarsus, Baetis, hydropsychids (MI,F)
5.60	484.0	70	47	60	24	20	27	24	0	7	1181/sqft	52	LOW	0.80	Protoptila,Petrophila, hydropsychids, baetids (MI,F)
4.30	491.0	73	36	57	23	18	26	19	0	17	1106/sqft	52	LOW	1.90	Hydropsychids, Protoptila, baetids (F,MI)
2.20	494.0	78	50	56	26	19	29	19	0	11	878/sqft	50	LOW	0.55	Protoptila,hydropsychids, midges, Elimia (F,MI)
0.77	498.0	73	38	55	32	24	32	21	0	9	1514/sqft	50	LOW	1.20	Hydropsychids, baetids, midges, Petrophila sp. (F,MI)
11-100-003		***Trib. to E. Fk. L. Miami R. (RM 78.45)***													
0.46	4.0	38		38	2	2	1	1	0	25	Mod-Low	F	INTERSTITIAL		Stenonema femoratum,Sphaerium clams(F), midges(F-VT)
11-100-007		***GLADY CREEK***													
0.70	4.2	55		55	10	10	7	7	2	11	High-Mod	G	LOW		Hydropsychids,Elimia(F,MI), tanytarsini & P. illinoense(F,T)
11-100-008		***TRIB. TO E. FK. L. MIAMI R. (2.40)***													
0.40	2.6	20		20	9	9	5	5	0	3	Mod-Low	G	LOW		H20 pennies(MI),Chimarra(MI),hydropsychids,baetids(F,MI)

* WBT waterbody type <> river or stream

Table 20. Macroinvertebrate community attributes, East Fork Little Miami River Basin 2012 TMDL

River Mile	Drainage Area	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens.	Qual Sens.	Total Cold	Qual Tolerant	Density	ICI	Flow	Current	Dominant Taxa
11-101-000		***Hall Run***													
2.30	3.1	30		30	8	8	4	4	2	5	Low	G	NORMAL		Hydropsychids,Stenelmis(F),baetids,isopods(F),midges(F,T)
0.23	5.5	29		29	7	7	3	3	0	9	Low	MG	NORMAL		Hydropsychids,baetids,isopods,Stenelmis(F),Psephenus(MI)
11-103-000		***Salt Run***													
0.40	6.4	37		37	9	9	5	5	1	9	Mod-Low	G	NORMAL		Chimarra(MI),hydropsychids,baetids,midges(F),H20 pennies
11-104-000		***Sugarcamp Run***													
0.17	3.6	42		42	12	12	7	7	1	5	Mod-Low	G	NORMAL		Chimarra(MI),hydropsychids,baetids,midges,heptageneids(F)
11-105-000		***Shayler Run***													
5.15	4.9	35		35	7	7	5	5	1	8	Mod-Low	MG	NORMAL		Caddisflies(MI,F),flatworms,baetids(F),Elimia(MI),midges(F)
1.71	12.1	38		38	9	9	5	5	1	11	Low	G	NORMAL		Caddisflies(MI,F),flatworms,baetids(F),midges(F), Elimia(MI)
11-105-001		***Trib. to Shayler Run (RM 4.40)***													
0.40	4.4	38		38	7	7	5	5	0	10	Mod-Low	MG	NORMAL		Hydropsychids(F),Chimarra,Elimia(MI),flatworms & baetids(F)
11-107-000		***Stonelick Creek***													
20.00	4.9	19		19	2	2	0	0	0	8	Low	F	INTERSTITIAL		Midges (F,MT), Stenonema femoratum (F), baetids (MT)
17.72	11.6	36		36	10	10	4	4	0	11	Mod-Low	MG	INTERSTITIAL		Midges (F,MT,T), hydropsychids (F), Chimarra spp. (MI)
13.40	23.0	35		35	6	6	2	2	0	14	Low	F	LOW		Midges (F,MT,T), flatworms (F)
9.84	38.0	52		52	13	13	15	15	0	9	Moderate	VG	INTERSTITIAL		Chimarra(MI),hydropsychids(F), Elimia(MI),midges(F,MI,MT)
6.20	43.3	71	44	49	18	13	13	9	0	14	848/sqft	46	LOW	0.25	Chimarra(MI),Elimia(MI),baetids(MI,F),tanytarsini midges(F)
5.20	62.0	73	34	61	18	16	14	12	0	12	666/sqft	42	LOW	1.00	Rheotanytarsus& Polypedilummidges(F), Chimarra, Elimia
1.00	75.0	67	43	55	22	19	21	19	0	10	1059/sqft	E38	LOW	0.15	Chimarra(MI), riffle beeltes (F), baetids (MI,F), midges (F)
11-107-002		***Trib. to Stonelick Creek (RM 10.61)***													
0.89	2.0	23		23	0	0	0	0	0	12	Low	P	LOW		Flatworms (F), snails (MT.T), riffle beetles (F)
11-108-000		***Lick Fork***													
0.60	6.3	46		46	14	14	10	10	0	9	Mod-Low	G	NORMAL		Hydropsychids(F),Stenelmis(F),midges(MI-MT),Chimarra(MI)
11-109-000		***Brushy Fork***													
2.20	5.7	43		43	13	13	5	5	0	11	Low	G	NORMAL		Hydropsychids(F),Psephenus,Helicopsyche(MI),midges(F,T)
0.30	14.8	52		52	18	18	12	12	0	9	Mod-Low	E	LOW		Psephenus(MI),midges,Stenelmis(F),caddisflies,baetids(F,MI)
11-111-000		***Patterson Run***													
0.10	4.2	47		47	8	8	5	5	0	13	Mod-Low	G	NORMAL		Midges(F,MT,T),baetids,hydropsychids(F),Helicopsyche(MI)

* WBT waterbody type <> river or stream

Table 20. Macroinvertebrate community attributes, East Fork Little Miami River Basin 2012 TMDL

River Mile	Drainage Area	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens.	Qual Sens.	Total Cold	Qual Tolerant	Density	ICI	Flow	Current	Dominant Taxa
11-112-000		***Moores Fork***													
2.90	4.6	12		12	3	3	0	0	0	5	Low	F	INTERSTITIAL		Planorbid snails (F,MT), Physella snails (T)
0.70	10.6	30		30	5	5	1	1	0	13	Mod-High	F	INTERSTITIAL		Elimiariver snails(MI),planorbid snails(MT,F),heptageneids(F)
11-115-000		***Backbone Creek***													
0.60	7.4	40		40	13	13	7	7	0	8	Low	G	NORMAL		Baetids (F,MI), Hydropsychids (F,MI), midges (F,MT)
11-115-001		***Trib to Backbone (1.36)***													
0.90	3.8	45		45	12	12	7	7	2	9	Mod-Low	G	NORMAL		Hydropsychids (F),Chimarra(MI),baetiids(F,MI),midges(F-T)
11-116-000		***Lucy Run***													
1.90	3.7	33		33	8	8	4	4	1	6	Mod-Low	MG	INTERSTITIAL		Stenelmis,hydropsychids,flatworms,heptageneids,isopods
0.10	7.2	38		38	12	12	10	10	1	5	Moderate	G	LOW		Hydropsychids (F,MI), Chimarra (MI), heptageneids (F,MI)
11-117-000		***Fourmile Run***													
0.20	3.5	42		42	12	12	9	9	0	7	Low	G	NORMAL		Hydropsychids(F),Chimarra(MI),baetids,Stenelmis,midges(F)
11-118-000		***Back Run***													
1.20	2.4	33		33	5	5	3	3	1	10	Mod-Low	F	LOW		Hydropsychids, Stenelmis, Stenonema femoratum (F)
11-119-000		***Ulrey Run***													
1.30	3.5	44		44	13	13	11	11	3	7	Mod-Low	G	NORMAL		Caddisflies(F,MI), baetids (F,MI), midges (F,MI,T)
11-120-000		***Slabcamp Run***													
2.60	0.7	34		34	5	5	2	2	1	17	Mod-Low	F	NORMAL		Scuds (MT), isopods (F), riffle beetles(F)
11-121-000		***Cloverlick Creek***													
8.50	12.4	32		32	5	5	3	3	0	9	Low	F	NORMAL		Midges(F,MT),aquatic worms(T),riffle beetles(F),isopods(F)
5.20	23.0	42		42	12	12	11	11	0	4	Moderate	G	LOW		Mayflies (F,MI),Caddisflies (MI,F),midges(F,MI),Elimia(MI)
11-121-002		***TRIB TO CLOVERLICK CR (7.48)***													
0.50	6.9	40		40	14	14	11	11	0	9	Low	VG	NORMAL		Water pennies(MI), heptageneids(F), Elimia(MI), midges(F)
11-122-000		***Barnes Run***													
1.90	7.9	37		37	8	8	4	4	0	11	Mod-Low	G	LOW		Hydropsychids,Helicopsyche(MI),Stenelmis,heptageneids(F)
11-123-000		***Poplar Creek***													
8.40	5.8	33		33	5	5	5	5	2	10	Mod-Low	F	LOW		Hydropsychids,Stenelmis,heptageneids(F),H2O pennies(MI)
2.10	17.5	50		50	15	15	12	12	0	8	Moderate	VG	NORMAL		Caddisflies(F,MI),H2O pennies (MI),midges(F-T),Caenis, Elimia

* WBT waterbody type <> river or stream

Table 20. Macroinvertebrate community attributes, East Fork Little Miami River Basin 2012 TMDL

River Mile	Drainage Area	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens.	Qual Sens.	Total Cold	Qual Tolerant	Density	ICI	Flow	Current	Dominant Taxa
11-124-000		***Sugartree Creek***													
0.95	3.6	13		13	2	2	1	1	0	5	Fair	F	LOW		Hydropsychids (F), riffle beetles (F), Physella snails (T)
11-132-000		***Kain Run***													
0.30	5.9	40		40	8	8	6	6	0	9	Moderate	G	NORMAL		Hydropsychids,baetids,midges(MT,F,MI,T),Helicopsyche(MI)
11-133-000		***Todd Run***													
1.00	9.4	40		40	13	13	8	8	0	8	Mod-Low	G	LOW		Hydropsychids,Stenelmis,heptageneids(F),Helicopsyche(MI)
11-135-000		***Crane Run***													
0.20	8.9	42		42	12	12	5	5	0	12	Low	G	INTERSTITIAL		Chimarra (MI), hydropsychids (F), midges (F,T)
11-136-000		***Fourmile Creek***													
0.30	5.5	25		25	8	8	5	5	0	5	Moderate	G	INTERSTITIAL		Hydropsychids(F),riffle beetles(F),Chimarra(MI),midges(F)
11-137-000		***Pleasant Run***													
2.70	3.2	17		17	0	0	0	0	0	10	Low	P	INTERSTITIAL		Flatworms (F), midges (F,MT,T)
1.35	5.3	21		21	2	2	1	1	0	8	Mod-Low	LF	LOW		Fingernail clams (F), flatworms (F,MT)
0.42	7.8	29		29	3	3	2	2	0	8	Mod-Low	F	LOW		Hydropsychids,riffle beetles,heptageneids(F),H2O penny(MI)
11-138-000		***Fivemile Creek***													
2.30	8.3	34		34	7	7	5	5	0	13	Low	MG	LOW		Helicopsyche&Acerpenna(MI),hydropsychids,Elimia sp.(MI)
0.50	10.6	20		20	4	4	3	3	0	6	Moderate	F	INTERSTITIAL		Crayfish & heptageneids (F), Elimia sp.& Polycentropus(MI)
11-141-000		***Howard Run***													
0.35	5.6	45		45	15	15	5	5	0	16	Low-Mod	G	LOW		Helicopsyche,baetds,hydropsychids,snails,midges(MI,F-T)
11-142-000		***Grassy Fork***													
0.18	6.3	45		45	8	8	5	5	0	11	Low	MG	LOW		Midges (F,MT,T),Physella(T),flatworms & hydropsychids(F)
11-143-000		***Glady Run***													
0.75	5.3	55		55	11	11	5	5	0	16	Mod-High	G	LOW		Tanytarsini,tanypode midges(F,MT),Hydroptila,Stenelmis(F)
11-144-000		***Saltlick Creek***													
0.60	5.7	40		40	5	5	3	3	0	24	Mod-Low	F	LOW		Midges(T,MT,F),Elimia(MI),hydropsychids & riffle beetles(F)
11-147-000		***Solomon Run***													
1.86	6.1	20		20	4	4	3	3	0	6	High-Mod	F	INTERSTITIAL		Elimia(MI),crayfish (F),Polycentropus(MI),heptageneids(F)

* WBT waterbody type <> river or stream

Table 20. Macroinvertebrate community attributes, East Fork Little Miami River Basin 2012 TMDL

River Mile	Drainage Area	Total Taxa	Quant Taxa	Qual Taxa	Total EPT	Qual EPT	Total Sens.	Qual Sens.	Total Cold	Qual Tolerant	Density	ICI	Flow	Current	Dominant Taxa
11-147-001		***Murray Run***													
0.05	3.2	31		31	6	6	2	2	0	10	Mod-Low	MG	INTERSTITIAL		Elimia sp. river snails (MI), heptageneid mayflies (F)
11-149-000		***Sycamore Creek***													
0.80	6.6	34		34	4	4	3	3	0	19	Low	F	INTERSTITIAL		Physella snails, water boatmen, beetles, midges (T,MT,F,MI)
11-150-000		***West Fork East Fork Little Miami River***													
7.45	8.2	43		43	8	8	2	2	0	20	Mod-High	MG	LOW		Plumatella sp. & flatworms(F), Chimarra (MI), baetids,beetles
0.12	28.3	50		50	9	9	6	6	0	15	Moderate	G	LOW		Rheotanytarsus & P. flavum(F),hydropsychids,Elimia (F,M)
11-151-000		***Dodson Creek***													
7.50	5.1	42		42	9	9	7	7	1	8	Mod-Low	G	LOW		Midges (F,MT,MI), hydropsychids (F), Chimarra(MI)
5.83	16.1	64	43	48	10	9	10	8	0	8	516/sqft	40	LOW	0.70	Corbicula,Helicopsyche,Chimarra,baetids,midges(F,MI,MT)
0.05	32.5	70	42	49	15	12	14	7	0	12	887/sqft	44	LOW	0.60	Chimarra,hydropsychids,Helicopsyche,Elimia,midges(F,MI)
11-151-001		***TRIB TO DODSON CREEK (4.52)***													
0.60	4.9	22		22	0	0	1	1	2	11	Low	P	INTERMITTENT		Midges (MT,T,F),Elimia river snails (MI),Physella snails (T)
11-153-000		***S. FK. DODSON CREEK***													
0.90	2.3	22		22	0	0	0	0	0	14	Low	VP	INTERSTITIAL		Midges (MT,T,F,VT), oligochaete worms (T), Physella (T)
11-153-001		***TRIB TO S. FK DODSON CR (0.37)***													
0.90	6.5	52		52	10	10	7	7	2	9	Low	G	LOW		Midges (F,MT,T), flatworms, baetids, riffle beetles (F)
11-154-000		***Turtle Creek***													
5.90	5.6	32		32	3	3	1	1	0	10	Mod-Low	F	INTERSTITIAL		Midges (MT,F,T,MI), odonates (T,F,MT), Caenis mayflies (F)
4.40	13.7	25		25	3	3	2	2	0	14	Moderate	LF	INTERSTITIAL		Sphaerium clams(F), Elimia river snails(MI), damselflies(T)
1.20	17.2	39		39	10	10	7	7	0	7	Moderate	G	LOW		Midges (F,MT,T), hydropsychids, Chimarra, baetids (F,MI)

* WBT waterbody type <> river or stream

References

Cabelli V.J., A. P. Dufour, L. J. McCabe, and M. A. Levin. 1982. Swimming associated gastroenteritis and water quality. American Journal of Epidemiology 115:606–616.

Coughlin, S.S. 1990. Recall bias in epidemiologic studies. Journal of Clinical Epidemiology 43: 87-91.

Dufour, A. P. 1977. Escherichia coli: The fecal coliform. pp48-58 in A. W. Hoadley and B. J. Dutka (eds.) Bacterial Indicators/Health Hazards Associated with Water, ASTM STP 635. American Society for Testing Materials.

Dufour, A.P. (1977). Escherichia coli: The fecal coliform. Am. Soc. Test. Mater. Spec.Publ. 635: 45-58.
Fujioka, R., C. Sian-Denton, M. Borja, J. Castro, and K. Morphew. 1999. Soil: the environmental source of Escherichia coli and Enterococci in Guam's streams. Journal of Applied Microbiology 85(Supplement 1): 83S-89S.

Fry, J., Xian, G., Jin, S., Dewitz, J., Homer, C., Yang, L., Barnes, C., Herold, N., and Wickham, J., 2011. Completion of the 2006 National Land Cover Database for the Conterminous United States, PE&RS, Vol. 77(9):858-864.

Karr, J. R. 1991. Biological integrity: A long-neglected aspect of water resource management. Ecological Applications 1(1): 66-84.

Karr, J. R., K. D. Fausch, P. L. Angermier, P. R. Yant, and I. J. Schlosser. 1986. Assessing biological integrity in running waters: a method and its rationale. Illinois Natural History Survey Special Publication 5: 28 pp.

MacDonald, D., C. Ingersoll, T. Berger. 2000. Development and evaluation of consensus-based sediment quality guidelines for freshwater ecosystems. Arch. Environ. Contam. Toxical.: Vol.39, 20-31.

McCune, B., and J. B. Grace. 2002. Analysis of Ecological Communities. MjM Software Design, Gleneden Beach, Oregon.

Miner R. and D. Borton. 1991. Considerations in the development and implementation of biocriteria, Water Quality Standards for the 21st Century, U.S. EPA, Offc. Science and Technology, Washington, D.C., 115 pp.

Ohio Department of Natural Resources (ODNR). 2001. Gazetter of Ohio Streams. Ohio Water Inventory Report No. 29. Ohio DNR Div. of Water, Columbus, Ohio.

Ohio Environmental Protection Agency (OEPA). 2009. Ohio EPA manual of surveillance methods and quality assurance practices, updated edition. Division of Environmental Services, Columbus, Ohio.

Ohio Environmental Protection Agency (OEPA). 2010. Biological and Water Quality Study of the Captina Creek Watershed, 2009. Belmont County, Ohio. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency (OEPA). 2013a. Surface water field sampling manual for water column chemistry, bacteria and flows. Version 4.0, January 31, 2013. Div. of Surface Water, Columbus, Ohio.

Ohio Environmental Protection Agency (OEPA). 2013b. 2013 Updates to Biological criteria for the protection of aquatic life: Volume II and Volume II Addendum. Users manual for biological field assessment of Ohio surface waters. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency (OEPA). 2013c. 2013 Updates to Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1987a. Biological criteria for the protection of aquatic life: Volume I. The role of biological data in water quality assessment. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio.

Ohio Environmental Protection Agency. 1987b. Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Monit. & Assess., Surface Water Section, Columbus, Ohio. Rankin, E.T. 1989. The qualitative habitat evaluation index (QHEI): rationale, methods, and application. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1989a. Addendum to Biological criteria for the protection of aquatic life: Volume II. Users manual for biological field assessment of Ohio surface waters. Div. Water Qual. Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 1989b. Biological criteria for the protection of aquatic life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. Water Quality Plan. & Assess., Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2006. Methods for assessing habitat in flowing waters: Using the Qualitative Habitat Evaluation Index (QHEI). Ohio EPA Tech. Bull. EAS/2006-06-1. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2008a. 2008 updates to Biological Criteria for the Protection of Aquatic Life: Volume II and Volume II Addendum. Users manual for biological field assessment of Ohio surface waters. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2008b. 2008 updates to Biological Criteria for the Protection of Aquatic Life: Volume III. Standardized biological field sampling and laboratory methods for assessing fish and macroinvertebrate communities. Div. of Surface Water, Ecol. Assess. Sect., Columbus, Ohio.

Ohio Environmental Protection Agency. 2008c. Ecological risk assessment guidance manual. Feb 2003; revised April 2008. Division of Emergency and Remedial Response, Columbus, Ohio. http://epa.ohio.gov/portals/30/rules/RR-031.pdf

Omernik, J.M. and A.L. Gallant. 1988. Ecoregions of the upper midwest states. EPA/600/3-88/037. U. S. Environmental Protection Agency, Environmental Research Laboratory, Corvallis, Oregon. 56 pp.
Perkin, J. S., and K. B. Gido. 2012. Fragmentation alters stream fish community structure in dendritic ecological networks. Ecological Applications 22:2176–2187.

Rahel, F. J. 2007. Biogegraphic barriers, connectivity and homogenization of freshwater faunas: it's a small world after all. Freshwater Biology 52: 696-710.

Solo-Gabriele, H. M., M. A. Wolfert, T. R. Desmarais, and C. J. Palmer. 2000. Sources of Escherichia coli in a coastal subtropical environment. Applied and Environmental Microbiology 66: 230-237.
Suter, G.W., II. 1993. A critique of ecosystem health concepts and indexes. Environmental Toxicology and Chemistry, 12: 1533-1539.

United States Environmental Protection Agency (USEPA 2000). Ambient water quality criteria recommendations information supporting the development of state and tribal nutrient criteria rivers and streams in nutrient ecoregion VI. EPA 822-B-00-017.

Wade, T. J. and eleven co-authors. 2010. Rapidly measured indicators of recreational water quality and swimming-associated ilness at marine beaches: a prospective cohort study. Environmental Health 9:66.

Wade, T. J. and seven co-authors. 2006. Rapidly measured indicators of recreational water quality are predictive of swimming-associated gastrointestinal illness. Environmental Health Perspectives 114: 24-28.

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

Yoder, C.O. 1989. The development and use of biological criteria for Ohio surface waters. U.S. EPA, Criteria and Standards Div., Water Quality Stds. 21st Century, 1989: 139-146.

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