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Assessment of the Fish and Macroinvertebrate Assemblages and Habitat Quality in the Lower Black River, 2010-2012

Lacustuary Portion: Lorain, OH

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Lower Black River above turning basin

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Assessment of the Fish Assemblages and Habitat Quality in the Lower Black River 2010-2012

Lacustuary Portion in Lorain, OH

A report submitted to:

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Acknowledgements

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Executive Summary

A biological assessment of the fish and macroinvertebrate assemblages and habitat quality in the Black River lacustuary was conducted during 2010-12. The primary purpose was to provide pre- and post-construction assessment for the ARRA and NOAA Phase I grant projects and to establish the pre-construction baseline for NOAA Phase III. The Black River was designated as an Area of Concern (AOC) by the International Joint Commission (IJC) in 1985 and in response to remaining degradation and pollutional effects resulting from past industrial uses of the river and resulting legacy impacts. A total of nine Beneficial Use Impairments (BUIs) have been identified for this AOC and targets established for delisting. As such restoration projects that address one or more BUIs are given a high priority for funding. Three BUIs that are directly addressed by the ARRA and NOAA restoration projects include:

1. BUI 3: Degradation of Fish Populations – Delisting targets focus on the Ohio biological criteria and impairment thresholds that are applicable to Lake Erie lacustuaries. Interim NOAA targets below these BUI thresholds were also evaluated. In addition, increases in native species richness and top carnivores are additional targets for this set of projects.
2. BUI 6: Degradation of Benthos – Delisting targets focus on the Ohio biological criteria and impairment thresholds that are applicable to Lake Erie lacustuaries. Interim NOAA targets below these BUI thresholds were also assessed.
3. BUI 14: Loss of Fish & Wildlife Habitat – The Lacustuary Qualitative Habitat Evaluation Index (LQHEI) with project specific LQHEI thresholds was used as delisting targets.

Pre- and post-construction biological monitoring was conducted following Ohio EPA protocols for Lake Erie lacustuaries. This included the Lacustuary Index of Biotic Integrity (LIBI) and Modified Index of Well-Being (MIwb), which are based on fish sampling data, and the Lacustuary Invertebrate Community Index (LICI), which is based on macroinvertebrates. The Lacustuary version of the Qualitative Habitat Evaluation Index (LQHEI) was used to assess habitat quality. A total of 19 sites were sampled in 2010-12 within a study area that begins at the 31st Street Bridge in Lorain extending downstream to the end of the break wall at the river mouth. The project area extends landward from the river bank to encompass those properties that abut the Lower Black River.

Project evaluation criteria were developed to serve as restoration targets and to evaluate progress towards meeting project restoration goals and objectives. The biological and habitat assessment was designed to provide site- and project-specific data to evaluate pre- and post-construction changes. This was accomplished by this study at four restoration project locations. The study design also permitted an assessment of the 5.2 miles of Black River lacustuary in order to determine the overall quality of the river relative to past and ongoing efforts to address all sources and agents that could limit or preclude a positive biological response to habitat restoration. The Black River has been historically and severely polluted by diverse sources both within and upstream from the lacustuary and despite efforts to limit those sources and remove contaminated sediments over the past 30 years significant biological

impairments remain as demonstrated by the 2010-12 results. This aspect of the study provides important context not only for evaluating the present-day responses to the restoration projects, but also for tracking incremental changes as the river responds as a whole to the sum total of natural resource and water quality management efforts.

The results at each restoration location were evaluated against a historical baseline (based on 1997 Ohio EPA results), a current baseline (based on 2010 MBI results), revised NOAA targets, and Ohio BUI delisting criteria which are the same as the Ohio EPA biological criteria for Lake Erie lacustuaries. Table E-1 summarizes attainment of this hierarchy of targets and criteria for the five key biological indicators and the habitat indicator. The assessment itself is hierarchical, i.e., if the highest target or criterion is met all "lesser" targets and criteria are also met.

Assessing BUI 3 (Degradation of Fish Populations) involved using the Ohio fish assemblage indices (LIBI and MIwb) and the NOAA targets for species richness and the proportion of top carnivores. All of the assemblage index results met the BUI delisting or the NOAA targets at all four sites and at least for the latest year of assessment, which also represents post-construction conditions. The species richness results met the NOAA target at all four sites at least in 2012. For the top carnivore indicator, the NOAA target was met at only one site (Lily Pad Fish Shelf). The historical baseline was met at the other three sites, but was below the NOAA target of a 30% increase over the current baseline. These results are not unexpected given that the structural measures usually respond more quickly than functional measures like the top carnivore metric. Future monitoring should verify this premise.

Assessing BUI 6 (Degradation of Benthos) involved using the Ohio LICI which failed to meet any target or criteria except the current baseline (Table E-1). This is the result of the widespread poor and very poor condition of the macroinvertebrate assemblage in the upper reaches of the Black River lacustuary than any deficiencies in the habitat restoration projects. The analysis of the assemblage response at the restoration sites revealed conditions to be only marginally better than the historical baseline that was derived from the 1997 Ohio EPA results. A more quantitative analysis of the severity and extent of departures in the LICI from the Ohio biocriteria for the overall Black River lacustuary suggest slightly poorer conditions in 2012. The lack of a general positive response over the long term suggests a lingering or undiagnosed impact to the Black River lacustuary. The results from the mouth of French Creek were much better and the LICI values of 30, 38, and 30 in 2010, 2011, and 2012, respectively, all exceeded the NOAA target of 25. The 2011 value of 38 was within the non-significant departure of the BUI delisting criterion. The macroinvertebrate results also seem to correspond to the elevated conductivity values in the upper lacustuary. Conductivity values exceeded regional reference concentrations with a pattern of steadily declining values downstream through the lacustuary and independent of sources that discharge to or otherwise affect water quality in the lacustuary. The results strongly suggest a dry weather source or sources upstream from the lacustuary. Determining the extent and source(s) of this impact is critical to assuring the sustained success of the restoration measures that are presently being undertaken.

Table E-1. Summary of how the 2010-12 biological and habitat assessment results demonstrated attainment of historical baseline, current baseline, revised NOAA targets, and Ohio BUI delisting criteria for the primary biological and habitat indicators used for the ARRA and NOAA Phase I Projects.

Indicator (BUI measure)	Targets and Criteria				Attainment of Targets and Criteria			
	Historical Baseline	Current Baseline	Revised NOAA	Ohio BUI Delisting	Lily Pad Fish Shelf (RM 4.3)	High Banks Bluff (4.0)	Back Channel Monkey Is. (RM 3.9)	Heron Rookery (RM 3.6)
LIBI (BUI 3)	31.9 – C[1] 34.5 - B	34.5 – C 32.0 - B	38	42	**BUI met all years**	**BUI met in 2012**	**NOAA met in 2012**; ns[4] for BUI	**BUI met in 2012**
MIwb (BUI 3)	6.8 – C 7.4 - B	7.6 – C 8.2 - B	8.1	8.6	**BUI met all years**	**BUI met in 2012**	**NOAA met in 2012**; ns[4] for BUI	**BUI met in 2011**; ns[4] for BUI in 2012
LICI (BUI 6)	16 – C 18 - B	6.8 – C 9.5 - B	25	42	Current baseline only; fails all others	Current baseline only; fails all others	Current baseline only; fails all others	Current baseline only; fails all others
LQHEI (BUI 14)	43.3 – C 38.6 - B	43.8 – C 48.0 - B	55	NA[2]	Historical & current baselines; fails NOAA	**NOAA met in 2012**	Historical & Current Baselines; fails NOAA	**NOAA met in 2011 and 2012**
Species Richness (BUI 3)	14.3 – C 15.3 - B	14.4 – C 14.8 - B	10% increase	NA[3]	**NOAA met all years**	**NOAA met in 2012**	**NOAA met in 2012**	**NOAA met in 2012**
%Top Carnivore (BUI 3)	7.7 – C 9.0 - B	15.4 – C 17.2 - B	30% increase	NA[3]	**NOAA met in 2012**	Historical baseline only; fails NOAA	Historical baseline only; fails NOAA	Historical baseline only; fails NOAA

[1] – C is the upper segment RM 5.21-4.0; B is the middle segment RM 4.0-2.6.
[2] – There is no criterion for the LQHEI (Ohio uses a guideline of 60 for habitat to support biocriteria attainment).
[3] – There are no delisting criteria for these attributes.
[4] – ns is non-significant departure from Ohio lacustuary biocriterion (same as BUI delisting target).

Assessing BUI 14 (Loss of Fish & Wildlife Habitat) involved using the Ohio LQHEI to assess against the historical baseline (2008 results), current baseline, and the NOAA target of 55. The NOAA target was met at two sites, High Banks Bluff (RM 4.0) and Heron Rookery (RM 3.6). The historical and current baselines only were met at the Lily Pad Fish Shelf (RM 4.3) and Back Channel Monkey Island (RM 3.9; Table E-1). However, the LQHEI results in both cases were generally with 5 or fewer points of the NOAA target.

Overall, the 2010-12 biological and habitat assessment results demonstrated the positive effects of the ARRA and NOAA Phase I restoration projects on the fish assemblage and habitat in the Black River lacustuary. With the exception of the LICI, results that failed to meet either the BUI delisting or NOAA targets were close to those targets and additional monitoring through time may well reveal full recovery as the newly restored habitat matures. The macroinvertebrate assemblage results stand in stark contrast, but we believe this is due to factors other than habitat to which the macroinvertebrates are being particularly sensitive. Additional analysis of the macroinvertebrate data beyond the assessment of the LICI, its component metrics, and the ordination analyses that were conducted are recommended.

Assessment of the Fish and Macroinvertebrate Assemblages and Habitat Quality in the Lower Black River 2010-2012: Lacustuary Portion

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INTRODUCTION

The Midwest Biodiversity Institute (MBI) conducted a biological assessment of the fish and macroinvertebrate assemblages and habitat quality in the Lower Black River during 2010-12. This report provides the pre- and post-construction assessment for the ARRA and NOAA Phase I grant projects and also establishes the pre-construction baseline for NOAA Phase III. There will be a second report completed in 2014 for the NOAA Phase II Project.

The Black River was designated as a Great Lakes Area of Concern (AOC) by the Water Quality Board of the International Joint Commission (IJC) in 1985. Remedial action plans (RAP) were then developed to focus on the cleanup and restoration of beneficial uses to these areas and to address beneficial use impairments (BUIs) that remained after the initial implementation of Clean Water Act based programs in the 1970s and 1980s. Ohio EPA is the lead agency for RAPs on the Ohio portion of Lake Erie and out of 14 possible BUIs they have identified nine (9) for the Black River and one BUI that is in recovery (Ohio EPA 2008). Of the nine (9) BUIs, three are directly addressed by our assessment of the Black River lacustuary:

4. BUI 3: Degradation of Fish Populations – Ohio EPA recognizes degraded fish populations primarily via the Ohio biological criteria and impairment thresholds that are applicable to Lake Erie lacustuaries. Criteria for the Lacustuary Index of Biotic Integrity (LIBI), Modified Index of Well-Being (MIwb), and specific fish assemblage composition thresholds are used as delisting targets.
5. BUI 6: Degradation of Benthos – Ohio EPA recognizes degraded macroinvertebrate (benthos) via the Ohio biological criteria and impairment thresholds that are applicable to Lake Erie lacustuaries. The criterion for the Lacustuary Invertebrate Community Index (LICI) is used as a delisting target.
6. BUI 14: Loss of Fish & Wildlife Habitat – Ohio EPA recognizes degraded fish and wildlife habitat by using the Lacustuary Qualitative Habitat Evaluation Index (LQHEI) with project specific LQHEI thresholds used as delisting targets.

Other BUIs including BUI 4: Fish Tumors and Other Deformities, BUI 7: Restrictions on Dredging Activities, and BUI 8: Eutrophication and Undesirable Algae are relevant to the assessment as

either representing a legacy impact or a potentially confounding impact on meeting the principal BUI delisting targets.

Restoration Project Area

The project area is located within the City of Lorain, within the lacustrine portion of the Lower Black River which is a Great Lakes Area of Concern (AOC). Land use in the area is highly urbanized and industrial, and riparian habitat has been significantly impacted. Degradation of riparian buffers has contributed to habitat fragmentation, bank erosion, loss of instream cover, and increased sedimentation, which in turn has resulted in impairments to water quality, instream habitat, and aquatic assemblages. Habitat related Beneficial Use Impairments (BUIs) in the Black River AOC include the loss of fish and wildlife populations, degradation of fish and wildlife habitat, and degradation of benthos. The objective of the restoration projects described herein is to reduce or eliminate the BUIs in the Black River Lacustuary portion of the AOC. Sampling was conducted to monitor the effectiveness of the following projects, which involved significant construction of both riparian and aquatic habitat:

1. The Black River Restoration Project funded by the American Recovery & Reinvestment Act (ARRA) and administered by the Ohio EPA via the Ohio Water Pollution Control Loan Fund.
2. The Lower Black River Fish Habitat Restoration Project (Phase I), funded by the Great Lakes Restoration Initiative (GLRI) and administered by the National Oceanic and Atmospheric Administration (NOAA).
3. The Lower Black River Habitat Restoration Project (Phase III) funded by the GLRI and administered by the NOAA.

The first two projects (ARRA and Phase I) were implemented between 2010 and 2011. Pre-construction and post-construction biological and habitat data were collected at and adjacent to the project sites in order to gage their effectiveness. Sampling was also conducted at and adjacent to the Phase II and III Projects in order to document pre-construction conditions. Two additional projects, funded by a GLRI grant from the U.S. Fish and Wildlife Service and an Ohio EPA Supplemental Environmental Project, achieved additional restoration within the riparian areas. As they were located in the upland riparian, these two projects were not specifically monitored as part of this effort.

Pre- and post-construction biological monitoring was conducted following Ohio EPA protocols for Lake Erie lacustuaries. This included the Lacustuary Index of Biotic Integrity (LIBI) and Modified Index of Well-Being (MIwb), which are based on fish sampling data, and the Lacustuary Invertebrate Community Index (LICI), which is based on macroinvertebrates. The Lacustuary version of the Qualitative Habitat Evaluation Index (LQHEI) was used to assess habitat quality. The field sampling and assessment methods are detailed in Biological Criteria for the Protection of Aquatic Life: Volumes II and III (Ohio EPA 1987, 1989) and for Lake Erie lacustuaries in Thoma (1999) and Ohio EPA (1993, 2010).

STUDY AREA

The Black River is located in north-central Ohio and drains 467 square miles (1,210 km2) of land in Lorain, Medina, Ashland, Huron and Cuyahoga Counties. Fifty-one (51) percent of the land area is used for agriculture, while only 1% is industrial. The remaining land uses are rural (38%), urban residential (7%) and commercial (3%). Over the past few decades, water and sediment quality have improved in the Black River in response to remediation efforts. Contaminated sediments were removed by dredging and pollutant loadings from point sources (steel mills, waste water treatment plants, etc.) have been significantly reduced via NPDES permit limitations. Nonpoint source impacts throughout the basin are seen as the principal threat to water quality and use attainment at present, although impacts from both current and past activities still occur in the lacustuary. Based on previous Ohio EPA biological and water quality assessments, while improvements in both water quality and biological condition have been observed following the implementation of water quality based permitting at major point sources and in response to the remediation of contaminated sediments, significant impairments remain. The sheer complexity of these impacts that likely includes both present day and legacy pollution impacts necessitated an intensive pollution survey design in the ≈6 mile long lacustuary portion of the Black River AOC. The study area included a total of 18 sampling locations on the Black River between river miles (RM) 5.21 and RM 0.60 plus one site at the mouth of French Creek (RM 0.10; Figure 1) for a total of 19 sites.

Study Area Description

The 2010-12 study area begins at the 31st Street Bridge in Lorain extending downstream to the end of the break wall at the river mouth. The project area extends landward from the river bank to encompass those properties that abut the Lower Black River. Historically, Lorain was a major industrial center whose landscape was dominated by steel mills, rail hubs, and a major Great Lakes port. The historical impacts of steel production along the Black River lacustuary was a major factor in the AOC listing. The earliest effort to reduce environmental pollution by the steel industry occurred in 1971 when open hearth and Bessemer furnaces were removed and replaced by more efficient and less polluting processes. Since the 1960s the steel industry has reduced water and air emissions by 90%. Two major mill complexes remain, U.S. Steel Tubular and Republic Engineered Products, each with multiple and permitted discharges of wastewater within a 2.75 mile span of the Black River lacustuary. These discharges occur in close proximity to the aquatic habitat and riparian restoration projects that are the focus of the ARRA and NOAA Phase I-III restoration Projects.

Point sources occur as NPDES permitted facilities and include wastewater treatment plants (WWTPs) that serve the metropolitan areas of Elyria, North Ridgeville, and Lorain. Major and minor industrial discharges also occur in, or in close proximity to, the study area and include both industrial process and stormwater discharges. Each of these sources are listed in Table1.

Table 1. Facilities within or near the Lower Black River study area regulated by an individual NPDES permit.

Facility Name Permit Number	Outfall	Receiving Stream	River Mile	Description
Elyria WWTP 3PD00034	001	Black River	10.6	Municipal wastewater treatment
United States Steel Corporation-Lorain Tubular Operations 3ID00074	001 006	Black River	5.35 5.05	D2 Landfill Leachate (006); Seamless Mill Process and non-contact cooling water, Seamless Scrubber Blowdown, Quench and Temper blowdown and non-contact cooling water, Seamless Hydrotester Blowdown, Stormwater (001)
North Ridgeville WWTP 3PD0004	001	French Creek	5.10	Municipal wastewater treatment
Republic Engineered Products-Lorain Plant 3ID00028	005 002 003 004	Black River	3.95 3.50 2.65 2.60	Non-Contact Cooling Water; Non-Contact Cooling Water; Non-Contact Cooling Water, Boiler Blowdown, Stormwater Non-Contact Cooling Water, Groundwater, Stormwater; Boiler water treatment residuals
Lorain Black River WWTP 3PE00005	001	Black River	0.08	Municipal wastewater treatment

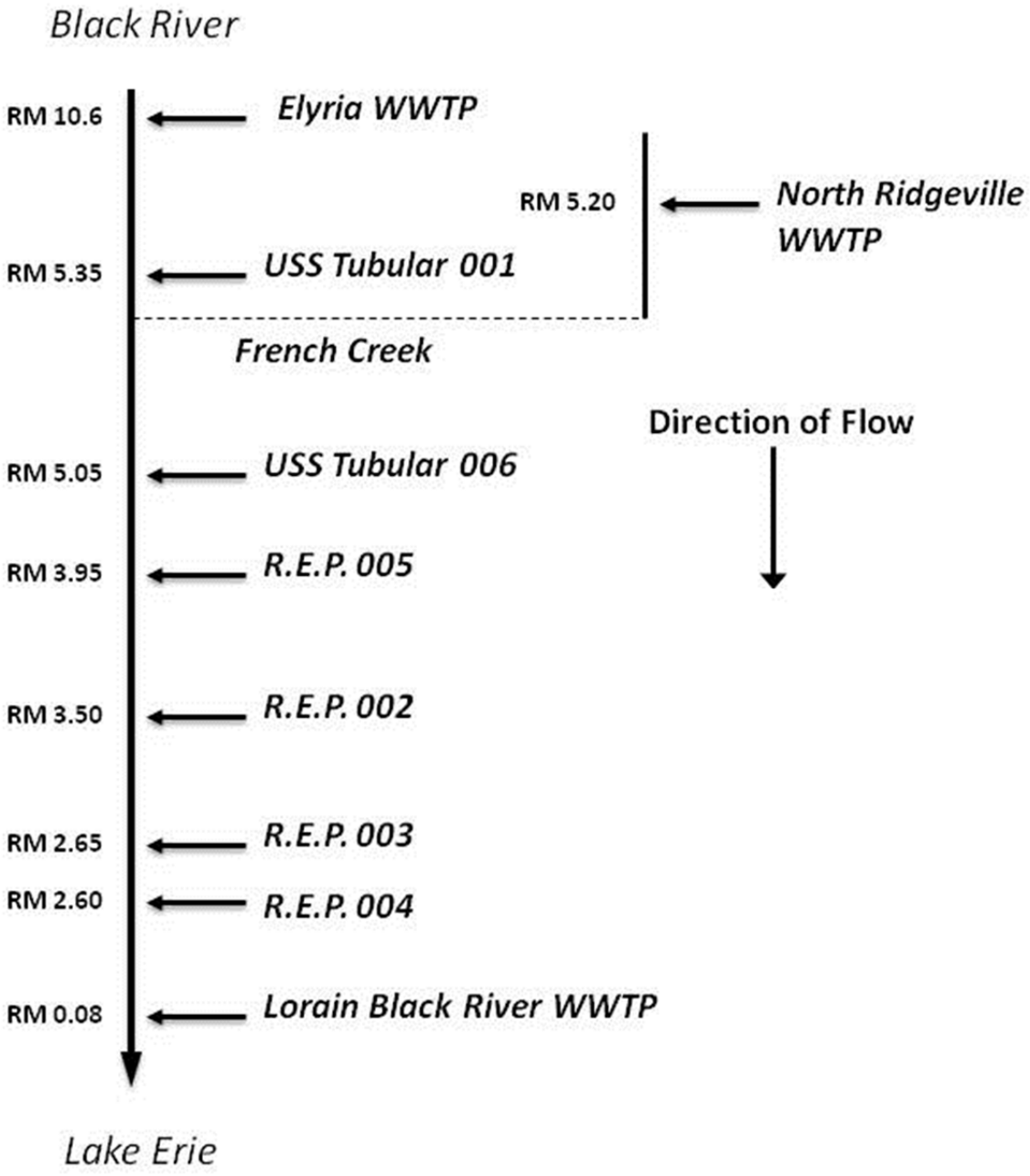


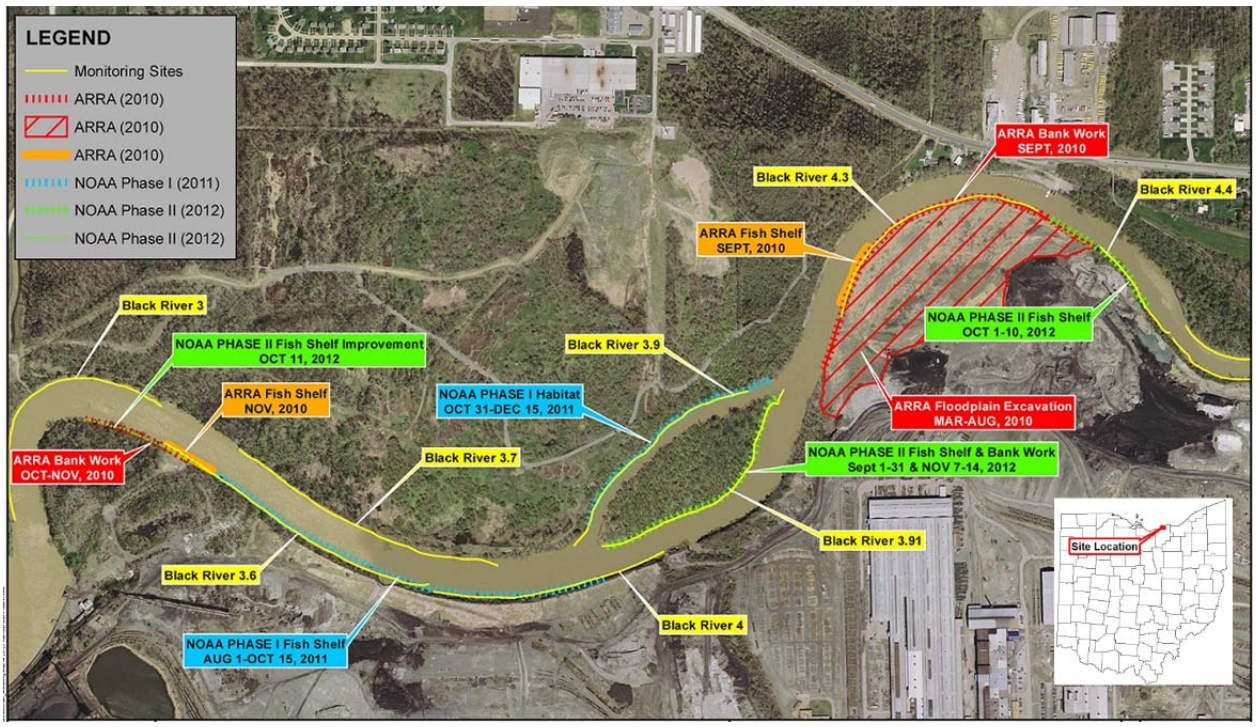
Figure 1. Schematic of the Black River lacustuary study area showing relative locations of point sources and tributaries.

The ARRA Project involved the following activities:

- Removal of more than 1,000,000 cubic yards of steel slag, restoration of the active floodplain, bank stabilization, and construction of a fish shelf along the south bank of the river between RM 4.8 and RM 4.6
- Riparian restoration along the south bank of the river between RM 3.3 and RM 3.8;
- Riparian and fish habitat restoration on the south bank of the river between RM 3.2 to RM 3.3; and,
- Fish habitat restoration and bank restoration along the south bank between RM 3.0 to RM 3.2.

The Phase I Project involved fish habitat restoration along the south bank of the river from approximately RM 3.2 to RM 3.7 and fish habitat restoration, bank stabilization, and invasive species removal along the north bank of the river between RM 3.7 to RM 4.1.

Fish habitat shelves are the principal instream restoration design and involve the construction of a shallow, underwater ledge with a variety of hard substrates. Boulder clusters, sand and gravel substrates, and submersed aquatic plants are included to provide better quality habitat for fish, macroinvertebrates, and other aquatic organisms. Stream bank stabilization involved the placement of a rock toe and topsoil, installation of brush layers and erosion control blankets, and native vegetation plantings. All of the project areas are depicted in Figure 2.



PROJECT MONITORING GOALS AND OBJECTIVES

Biological and habitat monitoring was included to provide the following data and information for determining restoration project effectiveness:

- Biological monitoring for fish. The LIBI and MIwb were used to assess overall fish assemblage condition; species richness, abundance, biomass, and proportion of carnivorous species were also assessed.
- Biological monitoring for macroinvertebrates. The LICI was used to assess the macroinvertebrate assemblage; taxa richness, abundance, and proportion of tolerant species were also assessed.
- Habitat monitoring. Assessment of aquatic habitat was accomplished by using the LQHEI, an accepted indicator for the evaluation of beneficial use impairments and AOC delisting in Ohio.
- Characterization of pre- and post-construction instream conditions, including vegetative cover, erosion/deposition, instream habitat, and value to key species.

Project evaluation criteria have been developed to serve as restoration targets and to evaluate progress towards meeting project restoration goals and objectives. Benefits to fish will be quantified by achieving LIBI scores of at least 38 and MIwb scores of at least 8.1, which categorize fish assemblage condition as "marginally good" and which minimally meet the Ohio EPA threshold for attainment of the interim Lake Erie lacustuary biocriteria. Additional targets include increases in the abundance of top carnivore fish species that are anticipated to improve by 30%. In addition to these species, the restoration projects are also expected to benefit other fish species such that overall species richness will increase by 10%. Benefits to macroinvertebrates will be quantified by calculating LICI scores, which are anticipated to increase to at least 25, thus elevating macroinvertebrate assemblage condition from "poor" to "fair" quality based on the narrative scale associated with the Ohio EPA interim Lake Erie lacustuary biocriteria. The restoration techniques are expected to enhance habitat complexity by incorporating sand, gravel, boulders, woody debris, and submerged and emergent native plants into the project design. By achieving an LQHEI score of at least 55, a project will meet the habitat quality objective set forth by the Lower Black River Ecological Master Plan. Historical and current baselines for all of these measures were also established by this study.

METHODS

Survey design and sampling methods generally followed those developed and used by Ohio EPA for conducting biological assessments in Lake Erie lacustuaries. The survey design is based on an intensive pollution survey where sites are allocated to assess multiple and overlapping objectives including overall status and detailed assessments of specific reaches and sites. For the Black River lacustuary we oriented the sampling design to include the goals and objectives of the habitat restoration projects in addition to establishing a current day baseline against the results of previous Ohio EPA surveys in 1982, 1994, and 1997.

Survey Design

Biological monitoring was conducted during a summer-fall seasonal index period (June 1-October 31). Ohio EPA has determined that biological sampling is preferably conducted during this time period as lake levels and river flows are generally low, pollution stresses are potentially the greatest, and the aquatic assemblages are the most stable and sedentary. Further, electrofishing and macroinvertebrate sampling methods are negatively affected by high lake level and/or river flow conditions due to the associated decrease in visibility (i.e. increased turbidity) and other difficulties encountered during these conditions. A longitudinal pollution survey design was employed in an attempt to delineate and quantify biological and habitat conditions in the Black River lacustuary.

Sampling Site Selection and Delineation

Individual electrofishing sites were located along the shoreline and within proximity to ongoing and planned instream habitat and riparian restoration projects and other sources of potential impact. Historical Ohio EPA sites that were previously assessed in 1982, 1992, and 1997 were also included. This resulted in a total of 19 sites of 0.5 km in length located within a 4.6 mile section of the lacustuary (Figure 3). Sampling distance was measured with a GPS unit and/or a laser range finder. When using the GPS unit each zone is measured by determining lineal distance using intermediate waypoints to account for non-linear features of the river channel and the sampling track. Exact sampling locations were determined in the field and included a representative proportion of reaches along the mainstem with respect to the restoration projects. Sampling site locations were delineated using the GPS mechanism and indexed to

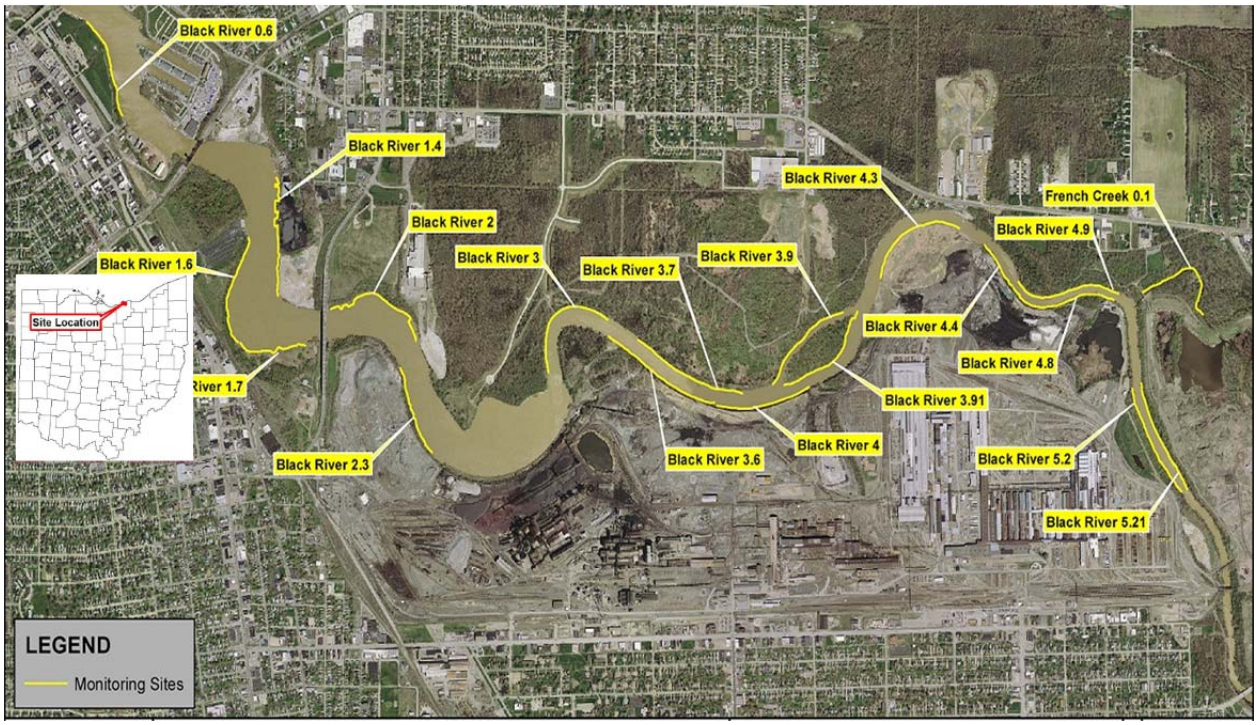


Figure 3. Lower Black River study area showing biological and habitat monitoring locations (courtesy of Coldwater Consulting, LLC).

latitude/longitude and UTM coordinates at the beginning, mid-point, and terminus of each zone and subzone if applicable. A detailed description of the river channel, habitat features, and sampling track was also recorded on the LQHEI data sheet. The description of each sampling location also included proximity to a fixed local landmark such as a bridge, road, discharge outfall, railroad crossing, park, tributary, etc. The field crew involved with the sampling were also noted on the field sheet with crew duties listed (boat driver, netters, primary I.D., etc.).

Field Sampling Procedures

Fish Sampling Procedures

A boat-rigged, pulsed D.C. electrofishing apparatus was the predominant gear type employed in this study. This consisted of an 18' john boat that was specifically constructed and modified for electrofishing. Electric current was converted, controlled, and regulated by a Smith-Root 5.0 GPP alternator-pulsator that produces up to 1000 volts DC at 2-20 amperes depending on the relative conductivity. The pulse configuration consists of a fast rise, slow decay wave that can be adjusted to 30, 60, or 120 Hz (pulses per second). Generally, electrofishing was conducted at 120 Hz depending on which selection produced the optimum combination of voltage and amperage output and most effectively stunned fish. This was initially determined on a trial and error basis at the beginning of each survey and the same setting held for all sites. The voltage range was also selected based on what percentage of the power range produced the highest amperage readings. The low range was used at the conductivities of 500-600 $\mu S/cm^2$ that were common to the Black River lacustuary. The electrode array consisted of two Smith Root umbrella style anodes (positive polarity) suspended from a swing arm that extends 2.75 meters in front of the bow. Each anode consisted of six 3/16" woven stainless steel cables array in a circular or "umbrella" array. The boat hull and multiple woven steel cable cathodes (3/16" diameter; negative polarity) of 6' length were suspended directly from the front and each side of the bow to complete the electrical field. Anodes and cathodes are replaced when they are lost, damaged, or become worn. The boat electrofishing crew consisted of a boat driver, a single bow netter, and one assist netter standing behind the primary netter. All 3 crew members have nets and each can capture all fish sighted. Reasonable attempts are made to capture all fish sighted including those that appear behind the boat. A 14' raft-mounted apparatus was used to sample sites that were too shallow for the 18' boat. This consisted of a 2.5 GPP unit and a two person crew, a netter and a raft driver. The electrode array consisted of anodes hung from an aluminum boom and cathodes hung over each side. The sampling procedure was similar to the 18' boat.

The accepted sampling procedure is to slowly and methodically maneuver the electrofishing boat in a down current direction along the shoreline maneuvering in and around submerged cover to advantageously position the netter(s) to pick up stunned and immobilized fish. This required frequent turning, backing, shifting between forward and reverse, changing speed, etc. depending on current velocity and cover density and variability. The boat driver's task was to maneuver the electrofishing boat (or raft) in a manner that positions the netter(s) advantageously to pick up stunned and immobilized fish. The driver also monitors and adjusts

the 5.0 GPP (or 2.5 GPP) pulsator to provide the maximum yet safe operational mode in terms of voltage range, pulse setting, and amperage. In areas with extensive woody debris and submergent aquatic macrophytes, it was necessary to maneuver the boat in and out of these "pockets" of habitat and wait for fish to appear within the netters field of view. In moderately swift to fast current the procedure is to electrofish with or slightly ahead of the current through the fast water sections and then return upstream to more thoroughly sample the eddies and side edges of the faster water. It is often necessary to pass over these swift water areas twice to ensure an adequate sample. Electrofishing efficiency is enhanced by keeping the boat and electric field moving with or at a slightly faster rate than the prevailing current velocity. Fish are usually oriented into the current and must turn sideways or swim into the approaching electric field to escape. As such they present an increased voltage gradient making the fish more susceptible to being immobilized by the electric current. Sampling in an upstream direction is prohibited as this compresses the electrical field against the current and towards the surface, which significantly diminishes sampling effectiveness. Although sampling effort is measured by distance, time fished is an important indicator of adequate effort. Time fished can legitimately vary over the same distance as dictated by cover, current velocities, and the number of fish encountered. In all cases, there is a minimum time that should be spent sampling each zone regardless of the catch. In our experience this is generally in the range of 2000-2500 seconds for a 0.5 km site, but could range upwards to 3500-4500 seconds where there is extensive instream cover and slack flows.

Safety features include easily accessible toggle switches on the pulsator unit located next to the driver and a foot pedal switch operated by the primary netter. The netters wore jacket style life preservers, rubber gloves, and all crew members wore chest waders. Netters were required to wear polarized sunglasses to facilitate seeing stunned fish in the water during each daytime boat electrofishing run. Boat nets with a 2.5m long handle and 7.62mm Atlas mesh knotless netting were used to capture stunned fish as they were attracted to the anode array and/or stunned within sight of the netters. A concerted effort was made to capture every fish sighted by both the netters and driver. Since the ability of the netters to see stunned and immobilized fish was partly dependent on water clarity, sampling was conducted only during periods of "normal" water clarity and flows. Periods of unusually high turbidity and high flows were avoided due to their negative influence on sampling efficiency.

Sample Processing Procedures

Captured fish were immediately placed in an on-board live well for processing. Water was aerated using a 12 volt pump and air stone, as well as being replaced regularly to maintain adequate dissolved oxygen levels and to minimize handling mortality. Special handling procedures were used for species of special concern. Fish not retained for voucher or other purposes were released back into the river after they were identified to species, examined for external anomalies, weighed and, if necessary, measured for total length. Every effort was made to minimize holding and handling times. The majority of captured fish were identified to species in the field; however, any uncertainty about the field identification of individual fish required their preservation for later laboratory identification. Individual fish that were too large to preserve were photographed in detail.

Fish voucher specimens were preserved in borax buffered 10% formalin and labeled by date, river, and geographic identifier (e.g., river mile). Large specimens (>100 mm) required visceral incision (lower right abdominal) to permit proper preservation of internal spaces and organs. After an initial fixation period of 3-4 weeks, specimens are washed in plain water and then transferred to increasing dilutions of non-denatured ethyl alcohol and water (35%, 50%) with a final solution of 70% ethyl alcohol. This process takes approximately 4-5 weeks to complete. Identification was performed to the species level at a minimum. Regional ichthyology keys were used. Photographs were also used to record species occurrences, particularly larger species that were not preserved and stored. Photographs are maintained by MBI in an archived electronic file.

The sample from each electrofishing zone was processed by enumerating and recording weights by species or by three species age classes when this was distinguished. Fish weighing less than 1000 grams were weighed to the nearest gram on a spring dial scale (1000 g x 1 g) or a 1000 g hand held spring scale. Fish weighing more than 1000 grams were weighed to the nearest 25 grams on a 12 kg spring dial scale (12 kg x 50 g) or 20-50 kg hand held spring scales. Species with a large number of individuals were batch weighed. Samples comprised of two or more distinct size classes of fish (e.g., young-of-year, juveniles, and adults) were processed separately. These were recorded on the field data sheet by designating an A (adult), B (1+ year), or Y (young-of-year) to the numeric family-species code. For example, if both adult and juvenile white suckers occurred in the same sample the adult numbers and weights were recorded as family-species code 40-016A with juvenile numbers and weights recorded as 40-016B. Although each was listed separately on the fish data sheet they can be treated in the aggregate as a single sample of the same species in any subsequent data analyses or as distinct size class entities. The data management programs used by MBI are designed to calculate relative numbers and biomass data based on the input of weighted subsamples. Larval and/or post-larval fish measuring less than 15-20 mm in length were generally not included in the data recording as a matter of practice following the recommendations of Angermeier and Karr (1986).

The incidence of external anomalies is recorded following procedures outlined by Ohio EPA (1989) and refinements made by Sanders et al. (1999). The frequency of DELT anomalies (deformities, eroded fins and body parts, lesions, and tumors) is a good indication of chronic stress caused by biological agents, intermittent stresses, and chemical contaminants. The percentage of DELT anomalies is a metric that is included in most of the large river fish assemblage IBIs that have been developed across the U.S. including the LIBI.

Macroinvertebrate Sampling and Sample Processing Procedure

Macroinvertebrates were sampled quantitatively using modified Hester-Dendy (HD) samplers in conjunction with a qualitative assessment of Ephemeroptera (mayfly), Plecoptera (stonefly) and Trichoptera (caddisfly), also referred to as EPT taxa, inhabiting available habitats at the time of HD retrieval. Sampling was conducted at 19 locations. Methods for sampling followed the Development of Biological Indices Using

Macroinvertebrates in Ohio Nearshore Waters, Harbors, and Lacustuaries of Lake Erie in Order to Evaluate Water Quality (Ohio EPA 1993). Artificial substrates were set and retrieved following a six week colonization period. The substrates were preserved in a solution of 10% formalin and returned to the MBI lab for processing. Samplers were disassembled and cleaned of organisms to produce a raw sample. The contents were transferred to 70% ethyl alcohol and then processed in accordance with Ohio EPA (1989). Identification was accomplished to the lowest practicable taxonomic levels using keys consistent with Ohio EPA protocols and updates.

Habitat Assessment

Habitat assessment monitoring was conducted using the Ohio EPA Lacustuary Qualitative Habitat Evaluation Index (LQHEI; Ohio EPA 2010). The LQHEI has been accepted as a means to assess habitat characteristics of Lake Erie lacustuaries for BUI delisting purposes. This sampling technique is designed to provide for assessment of river reaches that are representative of the overall conditions of the existing lacustuarine habitat. Use of the LQHEI has been found to be helpful in distinguishing habitat impacts from pollution impacts, especially to fish assemblages in Ohio's Lake Erie water, and illustrating those habitat components that enhance aquatic community structure (Thoma 1999). The LQHEI provides a rapid, reproducible measure of lacustuarine habitat generally corresponding to the physical factors that affect fish assemblages and other aquatic life and thereby can be used to provide insight into the biological potential of a site or lacustuary segment. The LQHEI is based upon the fish sampling reach of 500 meters and is conducted along with an electrofishing sample.

Data Management and Analysis

Data were analyzed using routines available in the Ohio ECOS data management system that was adapted for use by MBI in this and other projects. Ohio ECOS produces standardized data outputs and reports on fish species relative abundance and condition that includes assemblage attributes such as numbers, biomass, functional and tolerance guilds, condition metrics, and compositional expressions. These outputs can also be exported as Excel files. These reports were used to support the data analyses and produce the data summaries reported in Appendix A. Relative abundance data is reported as numbers and biomass per kilometer. While several types of data expressions and indices are possible, we focused our analyses on two principal assessment tools; the Lacustuary Index of Biotic Integrity (LIBI) and the modified Index of Well-Being (MIwb). Macroinvertebrate results are presented as taxa lists including relative abundance for artificial substrate samples (Appendix B). Results analysis focused primarily on the Lacustuary Invertebrate Community Index (LICI). Habitat assessment using the LQHEI consisted of evaluating scores and habitat attributes at each site. The LQHEI metric values and scores are summarized in Appendix C.

RESULTS AND DISCUSSION

The presentation of the results and the discussion of their meaning were accomplished following a stepwise process:

1. Establish the historical and current baseline for the Black River lacustuary in order to determine the effectiveness of recently initiated restoration projects. This includes assessing the BUI delisting targets and the attainment status for aquatic life and in accordance with the methods and practices of Ohio EPA.
2. Assessing long term changes in the aquatic assemblages and habitat of the Black River lacustuary in order to determine if any current or legacy impacts continue to influence the present-day conditions. This included relating the results of prior Ohio EPA surveys conducted between 1982 and 1997 to the results obtained during 2010-12 for the fish and macroinvertebrate assemblages and habitat.
3. Detailed analyses in support of determining the associated causes and sources of remaining impairments. This was necessary to determine how the biological assemblages have thus far responded to restoration projects.
4. Restoration project-specific analyses that include tracking changes in the key BUI indicators based on pre- and post-construction sampling.

The benchmarks for evaluating the biological and habitat results are summarized in Tables 2, 3, and 4. These include historical and current baselines for the abundance of top carnivores, species richness, the fish and macroinvertebrate assemblage indices, and habitat. We used the most recent Ohio EPA Lake Erie lacustuary biocriteria thresholds and revised NOAA targets for the LIBI, MIwb, LICI, and LQHEI (Ohio EPA 2010). For the historical and current baseline these were calculated from the 1997 Ohio EPA and the 2010 MBI results, respectively, with values for the proportion of top carnivores and species richness added in support of evaluating the revised NOAA targets. The 1997 Ohio EPA results were originally reported using the inland riverine fish and macroinvertebrate indices, but we were able to recalculate the LIBI and LICI scores that were developed subsequent to the 1997 survey. The historical MIwb scores were unaffected, but the 1997 QHEI was not converted to the newer LQHEI format so no historical baseline was established from those studies. However, LQHEI scores from 2008 were available in support of the development of the Lower Black River Ecological Master Plan and these were used to develop the historical LQHEI baseline.

Assessment of BUI Delisting Targets

Fish, macroinvertebrate, habitat, and limited water quality sampling were conducted at 19 sampling locations during 2010-2012 and are the primary focus of this report. The Black River lacustuary was previously sampled by Ohio EPA in 1982, 1992 and 1997 for fish, macroinvertebrates, and habitat. The Lake Erie modifications embodied in the LIBI, LICI, and LQHEI were not available at those times hence the results were assessed by Ohio EPA using the

Table 2. Compilation of historical and current baseline benchmarks, revised NOAA targets, and Lake Erie Lacustuary biocriteria for the key biological and habitat measures used to gage the effectiveness of Black River lacustuary restoration projects.

Attribute	Historical Baseline (1997)[1]			Current Baseline (2010)			Revised NOAA Targets	Lacustuary Biocriteria[2]
Segment →	A	B	C	A	B	C		
Top Carnivore (%)	9.3	9.0	7.7	22.7	17.2	15.4	30%	NA
Species Richness	13.5	15.3	14.3	14.0	14.8	14.4	10%	NA
LIBI	34.2	34.5	31.9	37.2	32.0	34.5	38	42
MIwb	7.3	7.4	6.8	8.1	8.2	7.6	8.1	8.6
LICI	16.0	18.0	16.0	15.7	9.5	6.8	25	42
LQHEI[3]	37.4	38.6	43.3	42.5	48	43.8	55	60[4]

[1] - Lower Reach (**A**): mouth to RM 2.3; Middle Reach (**B**): RM 2.4-4.0; Upper Reach (**C**): RM 4.0 to RM 5.21. These were used in lieu of not having matching site data for each restoration site in the historical database. Matching site data is available for 2010-12, but reach values were calculated to compare with the historical baseline. The derivation of the historical baseline for %top carnivore and species richness is described in Appendix A.
[2] – BUI delisting criteria are the same as the Ohio biocriteria; [3] – Historical baseline LQHEI values are from the Lower Black River Ecological Master Plan Table 1.4 since LQHEI was not used by Ohio EPA in 1997; [4] – accepted LQHEI consistent with attainment of biocriteria.

Table 3. Ohio EPA biological criteria applicable to streams and rivers (left) and Lacustuary Benchmarks that are used to assess aquatic life use attainment in Lake Erie lacustuaries (from Ohio EPA 2010). The boat method was used to sample fish in the Black River lacustuary in all years hence the corresponding boat benchmarks were used to assess the fish assemblage.

Index – Site Type	Biological Criteria (Huron Erie Lake Plain)			Lacustuary Benchmarks[1]				
	EWH	WWH	MWH (Channelized)	Exceptional	Good	Fair	Poor	Very Poor
IBI – Headwaters	50	28	20	N/A	N/A	N/A	N/A	N/A
IBI – Wading	50	32	22	N/A	N/A	N/A	N/A	N/A
IBI – Boat	48	34	20	50	42	31	17	<17
MIwb – Wading	9.4	7.3	5.6	N/A	N/A	N/A	N/A	N/A
MIwb – Boat	9.6	8.6	5.7	10	8.6	5.6	2.8	<2.8
ICI	46	34	22	52	42	25	12	<12

Table 4. Ohio EPA narrative ranges assigned to QHEI scores for rivers and streams and Lake Erie lacustuaries using the LQHEI (3rd column).

General narrative ranges assigned to QHEI scores.				
Narrative Rating		QHEI Range		
		Headwaters (≤20 sq mi)	Larger Streams	Lacustuary
Excellent		≥70	≥75	≥80
Good		55 to 69	60 to 74	60 to 80
Fair		43 to 54	45 to 59	45 to 59
Poor		30 to 42	30 to 44	30 to 44
Very Poor		<30	<30	<30

criteria applicable to inland rivers (Ohio EPA 1997). The QHEI that was used to assess habitat was not converted to the LQHEI for the lacustuary sites. However, it was possible to recalculate the LIBI and LICI given that the sampling methods have remained unchanged since that time. These results were used to construct a retrospective analysis in order to better understand the current conditions in the Black River lacustuary that are represented by the 2010-12 results. This is an essential step in the process of determining the effectiveness of recent restoration projects on both a site-specific and lacustuary-wide basis.

The status of the aquatic life use in Lake Erie lacustuaries is determined using the interim LIBI, MIwb, and LICI biocriteria in Table 3. Following the procedures of Ohio EPA, a use attainment table was developed for the Black River lacustuary to include all sites sampled in 2010-12 (Table 5). The 1997 results from Ohio EPA were included as a basis for comparison. This analysis was conducted to further define the current baseline in terms of aquatic life use attainment and to provide context for evaluating the additional benefits of the restoration projects to the overall conditions in the Black River lacustuary. It was also done to aid in the determination of the causes and sources of any remaining impairments.

The fish assemblage has shown a consistent improvement since the first Ohio EPA survey in 1982 and progressively since 1997 through the current study period (2010-12). It has progressed to the point where the BUI delisting targets were met in 2012 at 8 sites for either the LIBI and/or MIwb. NOAA targets were met in 2012 at 14 sites for either or both indices (Table 5). The scores at two of non-attaining sites are within reach of the delisting targets. The macroinvertebrate assemblage has not shown nearly as much improvement with LICI values well below the BUI target of 25 at all except the mouth of French Creek which exceeded that value in all three years. The cause of the comparative lack of improvement was initially unclear and it was an objective of our analyses to determine the reasons if at all possible. As a result of the consistently poor performance by the macroinvertebrate assemblage the attainment status of the Black River lacustuary is mostly in non-attainment based on the 2010-12 results. Eight (8) of the 19 sites are in partial attainment meaning that one or more of the indices meets the lacustuary biocriteria, but at least one does not meet the criteria or one of the assemblages

Table 5. Aquatic life use attainment status for the Warmwater Habitat (WWH) Aquatic life use designation in the Black River lacustuary based on data collected by MBI during August-October 2010 and June-October 2011 and June-July-August 2012. Green shaded scores meet the revised NOAA delisting targets whereas yellow shaded scores do not. The IBI and MIwb are expressed as the mean of two sampling passes except at the restoration sites where the two individual passes are shown. 1997 data was collected by Ohio EPA and is included to show changes in scores compared to the historical baseline. The RM for ARRA and NOAA Phase I restoration sites are gray shaded and in bold. LQHEI scores from 2008 are used as the historical baseline.

RIVER MILE	LIBI				MIwb				LICI				LQHEI				Attainment Status				Comments
	1997	2010	2011	2012	1997	2010	2011	2012	1997	2010	2011	2012	2008	2010	2011	2012	1997	2010	2011	2012	
5.21	-	34*	31*	40^{ns}	-	7.1*	7.3*	8.9	-	2*	14*	10*	-	50	51	53	-	NON	NON	PART.	Ust. French Creek (East Bank) - RBD
5.2	36*	32*	34*	41^{ns}	6.8*	7.4*	8.4^{ns}	9.0	10*	8*	14*	12*	43	41.3	43.7	46.5	NON	NON	PART.	PART.	Ust. French Creek (West Bank) LBD
FC 0.1	-	33*	35*	33*		8.4^{ns}	8.1^{ns}	7.5*	-	30*	38^{ns}	30*	-	46	55	52.3	-	PART.	PART.	NON	French Creek at mouth
4.9	-	29*	32*	33*	-	7.0*	7.9*	7.1*	-	6*	16*	6*	44.8	38	41.5	43.7	-	NON	NON	NON	Dst. French Creek - RBD
4.8	25*	35*	32*	36*	6.1*	7.5*	7.5*	8.6	24*	14*	22*	8*	40	46	44	42.7	NON	NON	NON	NON	Dst. French Creek –LBD; Proposed NOAA Phase III Restoration
4.4	-	-	27*	38^{ns}	-	-	6.4*	8.1^{ns}	-	-	16*	6*	38	-	43.5	45	-	NON	NON	NON	Ust. Lilly Pad Marina; NOAA Phase II Fish Habitat Shelf
4.3	-	46	40^{ns}	42	42	-	9.5	9.2	9.5	9.0	-	4*	-	10*	38	52	51	51.3	-	NON	PART.	NON	**Lily Pad Fish Shelf** located across from Lilly Pad Marina; ARRA Fish Habitat Shelf, AARA Stream Bank Restoration, ARRA Slag Removal & FP Restoration
4.0	-	-	-	44	-	-	-	8.5^{ns}	-	-	-	14*	47	-	-	62	-			PART.	**High Banks Bluff**; ARRA Slag Removal & Riparian Restoration, NOAA Phase I Fish Habitat Shelf
3.91	-	-	34*	41^{ns}	-	-	7.8*	9.0	-	-	10*	-	52	-	46.5	44	-	-	NON	PART.	Main Channel Monkey Island; NOAA Phase II Bank Restoration & Fish Habitat Shelf
3.9	-	34*	33*	39^{ns}		8.5^{ns}	7.8*	8.3^{ns}	8.5^{ns}	-	8*	6*	12*	48	54.5	50.5	53.8	-	NON	NON	NON	**Back Channel Monkey Island Fish Shelf**; NOAA Phase I Bank Restoration & Fish Habitat Shelf/Structure
3.7	32*	33*	35*	37*	7.4*	7.7*	8.3^{ns}	8.0*	12*	10*	8*	10*	47.5	49.5	40.5	40.5	NON	NON	NON	NON	Dst. Monkey Island RBD
3.6	-	32*	31*	34*	44	43		8.2^{ns}	7.6*	8.9	8.9	8.5^{ns}	-	12*	12*	14*	47	49	45.8	60.8	59	-	NON	NON	PART.	**Heron Rookery Fish Shelf** located dst. Monkey Island; AARA Bank Restoration, AARA Fish Habitat Shelf, NOAA Phase I Fish Shelf
3.0	37*	30*	36*	37*	7.3*	8.5^{ns}	8.1^{ns}	8.1^{ns}	-	8*	8*	10*	51	48	44	45.5	NON	NON	NON	NON	Ust. Turning basin; RBD Adj. Heron Rookery
2.3	34*	40^{ns}	38^{ns}	46	7.2*	8.2^{ns}	8.3^{ns}	8.3^{ns}	20*	10*	6*	16*	33	39	36	36	NON	NON	NON	PART.	Dst. Turning basin; LBD
2.0	-	38^{ns}	36*	36*	-	9.0	9.0	8.6	-	12*	8*	14*	42.5	46	47	47.5	-	NON	NON	NON	Ust. SR57 bridge LBD
1.7	-	38^{ns}	34*	35*	-	7.8*	8.4^{ns}	7.4*	-	16*	12*	20*	45	36	49	37.3	-	PART.	NON	NON	Dst. SR57 Bridge; LBD
1.6	-	36*	34*	36*	-	7.9*	7.4*	6.9*	-	20*	6*	16*	45	43	42	43.7	-	PART.	NON	NON	Dst. SR57 bridge- across from boat ramp
1.4	-	32*	31*	41^{ns}	-	7.7*	8.0*	8.0*	-	12*	-	16*	35	35	39	35.7	-	NON	PART.	PART.	Dst. SR57 bridge- across from boat ramp
0.6	45	40^{ns}	39^{ns}	42^{ns}	8.5*	7.9*	7.8*	8.2^{ns}	18*	24*	10*	18*	57	49	55	47.5	PART.	PART.	NON	PART.	**Historic Fish Shelf**

Lake Erie Lacustuary Interim Biocriteria

Index	NOAA Targets	WWH	EWH
LIBI	38	42	50
MIwb	8.1	8.6	10
LICI	25	42	52
LQHEI	55	--	--

* - significant departure from biocriterion; ^{ns} - nonsignificant departure from biocriterion; poor and very poor values are underlined. Boxes shaded with Green indicate values meeting NOAA Targets; Boxes shaded with Yellow indicate values failing to meet NOAA Targets.

reflects poor or very poor quality. The results for the macroinvertebrate assemblage was for very poor and poor sites in 2010-11 to change to fair quality below the turning basin in 2012, and it was the primary reason for the increase in partial attainment. However, 9 of 11 sites above the turning basin reflected poor or very poor quality and four of these were fair in 2011. These results reflect a general decline in the macroinvertebrate assemblage in the non-navigable portion of the Black River lacustuary. The highest LICI scores occurred at the mouth of French Creek with one value in non-significant departure of the lacustuary biocriterion in 2011. The partial attainment in this instance was due to the LIBI failing to meet the biocriterion. LICI scores at the 3 restoration sites all improved slightly during the 2010-12 period, but were well below the NOAA target of 24.

LQHEI scores were consistently lower than the revised NOAA target of 55 attaining that benchmark at only three sites in the Black River lacustuary during 2010-12 and in 2011 at the mouth of French Creek (Table 5). The site at RM 0.6 at the historic fish shelf had a LQHEI of 55 in 2011, but the score in 2012 was 47.5. The post-construction LQHEI at the Heron Rookery fish shelf at RM 3.6 was 60.8 which was a significant improvement over the pre-construction score of 45.8. Of further note in the results at the 3 recently constructed fish shelves that the LQHEI scores have increased from the historical baseline through 2012 by +13.3 (Lily Pad Fish Shelf – RM 4.3), +5.8 (Back Channel Monkey Island Fish Shelf – RM 3.9), and +12 (Monkey Island LDB Fish Shelf) even though the revised NOAA target was met only at the latter site. The LQHEI has also increased at the High Banks Bluff slag removal and riparian restoration site (RM 4.0) by +12 points and meeting the revised NOAA restoration target.

Another way to visualize changes in the biological condition as expressed by the primary biological indices is to use the Area of Degradation and Attainment Values (ADV/AAV; Yoder et al. 2005). This methodology was used to illustrate the degree of change between the Ohio EPA surveys of 1982, 1992, and 1997 and the MBI 2010-12 surveys in the Black River lacustuary. The ADV/AAV term is an expression of the degree to which a biological index value is either above or below the biocriterion and the distance of river over which it occurs. It computes a unitless value based on the polygon that is formed when the results are graphically depicted to reveal a longitudinal profile of the index results over a reach of river. As such it is an expression of the "quantity" of biological attainment or impairment. When normalized to a fixed distance (e.g., per mile) it can be an effective indicator of the degree of change which is taking place between survey years and through time within a river reach or study area as a whole.

The ADV/AAV for each of the six survey years are shown in Figure 4. As was observed in the description of the BUI/NOAA targets and attainment table, the fish assemblage indices have each shown consistent improvement towards attainment of the LIBI and MIwb lacustuary biocriteria since 1982 and continuing, albeit at a less pronounced rate, through 2012. The AAV values of zero (0) prior to 1992 indicate the extent and severity of the historical impacts prior to the issuance of water quality based permits to municipal and industrial point sources. The MIwb seems to have preceded the LIBI in these improvements which is a typical ordering in the

recovery of river fish assemblages. The appearance of AAV for the LIBI in 2012 is noteworthy and evidence that the recovery is including functional as well as structural improvements.

The macroinvertebrate results are nearly the inverse of the fish results and reflect a worsening trend in assemblage response since 1992 (no LICI data was available for 1982). ADVs were the highest in 2011 followed by 2010 and 2012. These results indicate a worsening of the macroinvertebrate assemblage post-point source pollution controls of the late 1980s and early 1990s. Determining the possible causes of this trend is a major objective of our analyses.

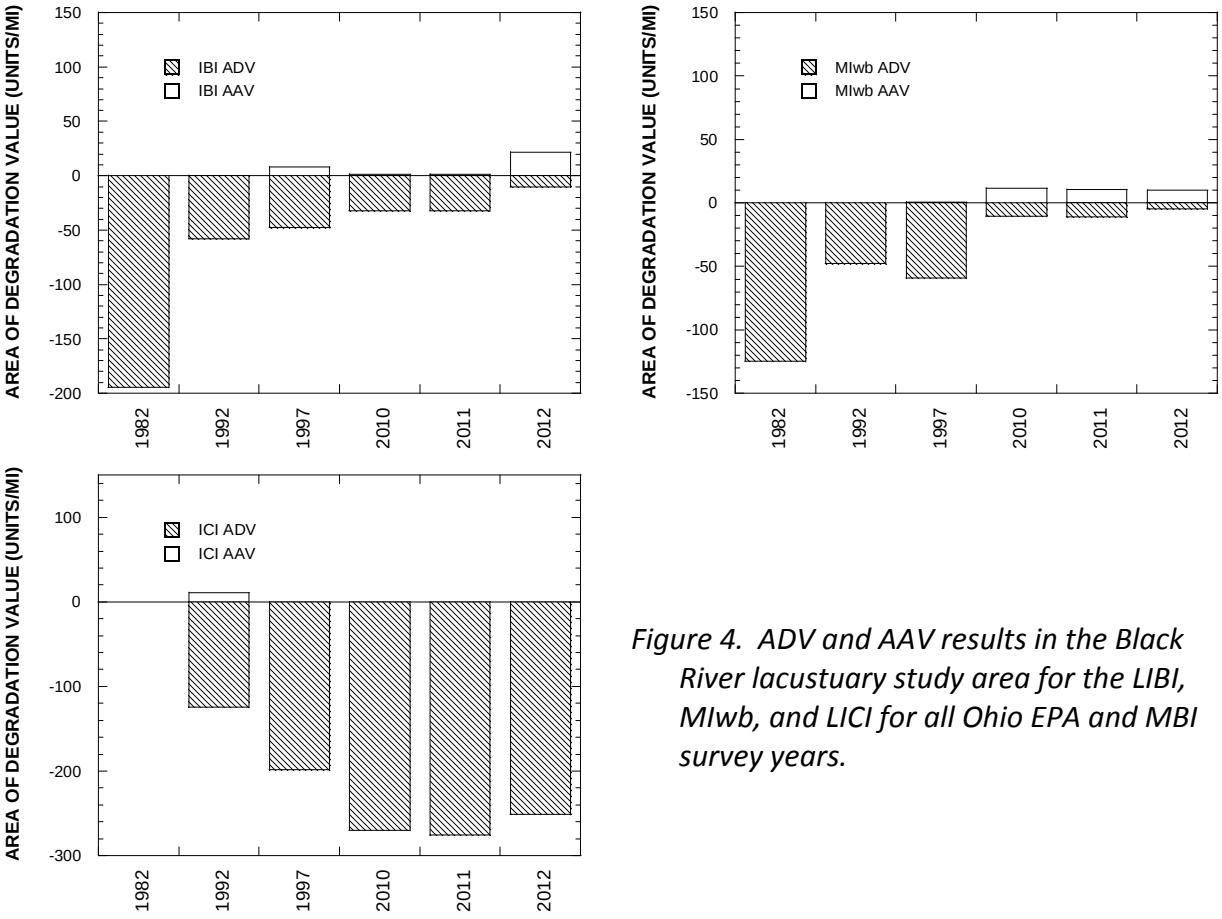


Figure 4. ADV and AAV results in the Black River lacustuary study area for the LIBI, MIwb, and LICI for all Ohio EPA and MBI survey years.

Black River Lacustuary Fish Assemblage

An average of 383.8 individual fish/km with an average weight of 70.8 kg/km was collected at 19 boat electrofishing sites in the Black River and French Creek lacustuary between RM 5.21 and RM 0.60 during 2010-12. The species that predominated in terms of numbers and biomass in 2012 are listed Tables 6 and 7. More detailed results for each sampling site appear in Appendix B. In 2012 the fish assemblage was dominated numerically by Gizzard Shad *(Dorosoma cepedianum)*, Bluegill Sunfish *(Lepomis macrochirus)*, Largemouth Bass *(Micropterus salmoides)*, and Emerald Shiner *(Notropis atherinoides)* comprising >54% by numbers. Biomass was dominated by Common Carp *(Cyprinus carpio)*, Largemouth Bass *(Micropterus salmoides)*,

Table 6. Numerically predominant fish species (>1.0% by numbers) collected by boat electrofishing in the Lacustuary portion of the Black River and French Creek, 2012.

Species	Number/km	%Number
Bluegill Sunfish (Lepomis macrochirus)	81.3/km	17.9%
Gizzard Shad (Dorosoma cepedianum)	71.8/km	15.8%
Largemouth Bass (Micropterus salmoides)	57.4/km	12.7%
Emerald Shiner (Notropis atherinoides)	37.9/km	8.4%
Green Sunfish (Lepomis cyanellus)	29.6/km	6.5%
White Perch (Morone Americana)	28.5/km	6.3%
Pumpkinseed sunfish (Lepomis gibbosus)	25.2/km	5.6%
White Sucker (Catostomus commersonii)	18.3/km	4.0%
Bluntnose Minnow (Pimephales notatus)	17.3/km	3.8%
Golden Shiner (Notemigonus crysoleucas)	15.5/km	3.4%
Golden Redhorse (Moxostoma erythrurum)	8.4/km	1.9%
Sand Shiner (Notropis stramineus)	8.4/km	1.9%
Common Carp (Cyprinus carpio)	7.7/km	1.7%
Round Goby (Neogobius melanostomus)	7.2/km	1.6%
Spotted Sucker (Minytrema melanops)	6.8/km	1.5%
Smallmouth Bass (Micropterus dolomieu)	5.9/km	1.3%
Rock Bass (Ambloplites rupestris)	5.6/km	1.2%

Table 7. Predominant fish species in terms of biomass (>1.0% by weight) collected by boat electrofishing in the Lacustuary portion of the Black River and French Creek, 2012.

Species	Kg/km	%Biomass
Common Carp (Cyprinus carpio)	7.46/km	29.0%
Largemouth Bass (Micropterus salmoides)	1.90/km	7.4%
Channel Catfish (Ictalurus punctatus)	1.88/km	7.3%
Smallmouth Buffalo (Ictiobus bubalus)	1.85/km	7.2%
Gizzard Shad (Dorosoma cepedianum)	1.68/km	6.5%
Bluegill Sunfish (Lepomis macrochirus)	1.47/km	5.7%
Golden Redhorse (Moxostoma erythrurum)	1.46/km	5.7%
Flathead Catfish (Pylodictis olivaris)	1.30/km	5.0%
Freshwater Drum (Aplodinotus grunniens)	1.28/km	4.9%
Spotted Sucker (Minytrema melanops)	1.05/km	4.1%
Pumpkinseed Sunfish (Lepomis gibbosus)	0.74/km	2.9%
Green Sunfish (Lepomis cyanellus)	0.47/km	1.8%
Bigmouth Buffalo (Ictiobus cyprinellus)	0.43/km	1.7%
Rock Bass (Ambloplites rupestris)	0.42/km	1.6%
Smallmouth Bass (Micropterus dolomieu)	0.38/km	1.5%
Shorthead Redhorse (Moxostoma macrolepidotum)	0.31/km	1.2%

Channel Catfish *(Ictalurus punctatus)*, and Smallmouth Buffalo *(Ictiobus bubalus)*, which comprised >50% by weight. Overall, the Lower Black River fish assemblages that we observed during 2010-12 are comprised of a mix of species that are tolerant of turbid water and soft or fine substrates with the presence of some large river obligate species.

TREND ANALYSIS

Trend analysis is conducted by the examination of index scores plotted along the longitudinal continuum (i.e., upstream to downstream) of a river or stream. The objective is to examine for any patterns that might suggest a specific source and/or type of impact and also to characterize the severity and extent of departures from a threshold or benchmark on a river or stream segment basis. For the Black River lacustuary the results from each sampling year were plotted against river mile. Major sources of potential impact and influence are depicted across the top of each plot. This allows for the visual examination of any patterns in response as the river flows from upstream to downstream.

Scores for the LIBI were consistently poor in 1982, poor to fair in 1992, and poor to good in 1997 (Figure 5). The 2012 LIBI data was included to show the significant overall improvements

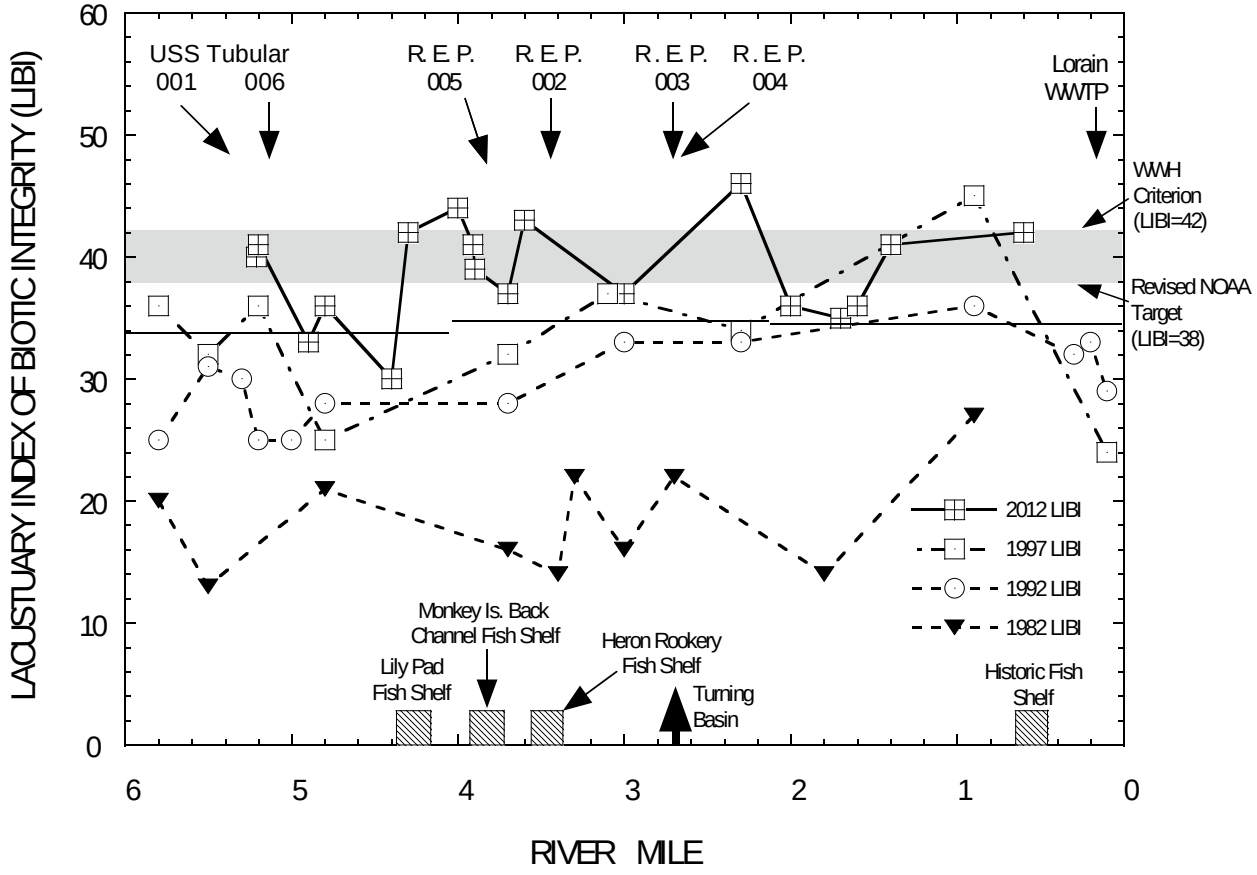


Figure 5. Black River LIBI scores for 1982, 1992, 1997, and 2012 with Ohio BUI delisting and revised NOAA targets (as indicated) and historical baselines for segments A, B, and C (solid lines) from Table 2.

that have occurred over the preceding 30 years (Figure 5). In 2010-12 the majority of scores ranged from fair to good with only a few sites scoring in the poor range (Figure 6). Incremental improvements since 2010 were apparent in the LIBI in each successive MBI survey year. In 2012 marginal attainment of the interim LIBI lacustuary biocriterion was evident at 5 locations scattered along the entire study area. Only one site had attained in 2010-11. In terms of patterns suggestive of ongoing pollutional impacts, some of these are suggested at least locally downstream from of the USS Tubular 001 and 006 discharges, very localized areas downstream from REP 005 and 002, and upon entry of the river into the navigation channel. Confirming these observations would require a more in depth assessment of effluent characteristics and chemical parameters in the water and sediment.

The MIwb results for 1982, 1992, and 1997 (Figure 7) show that the response of this measure preceded the LIBI by several years with marginal attainment of interim lacustuary biocriterion occurring as early as 1992 and well above the 1982 results. This is a common observation as the MIwb reacts to increases overall fish abundance after the abatement of acute impacts even without the appearance of sensitive and intolerant species whereas the LIBI includes a greater sensitivity to the functional attributes of the assemblage. It is therefore not uncommon to observe the MIwb to improve ahead of the LIBI, sometimes by several years.

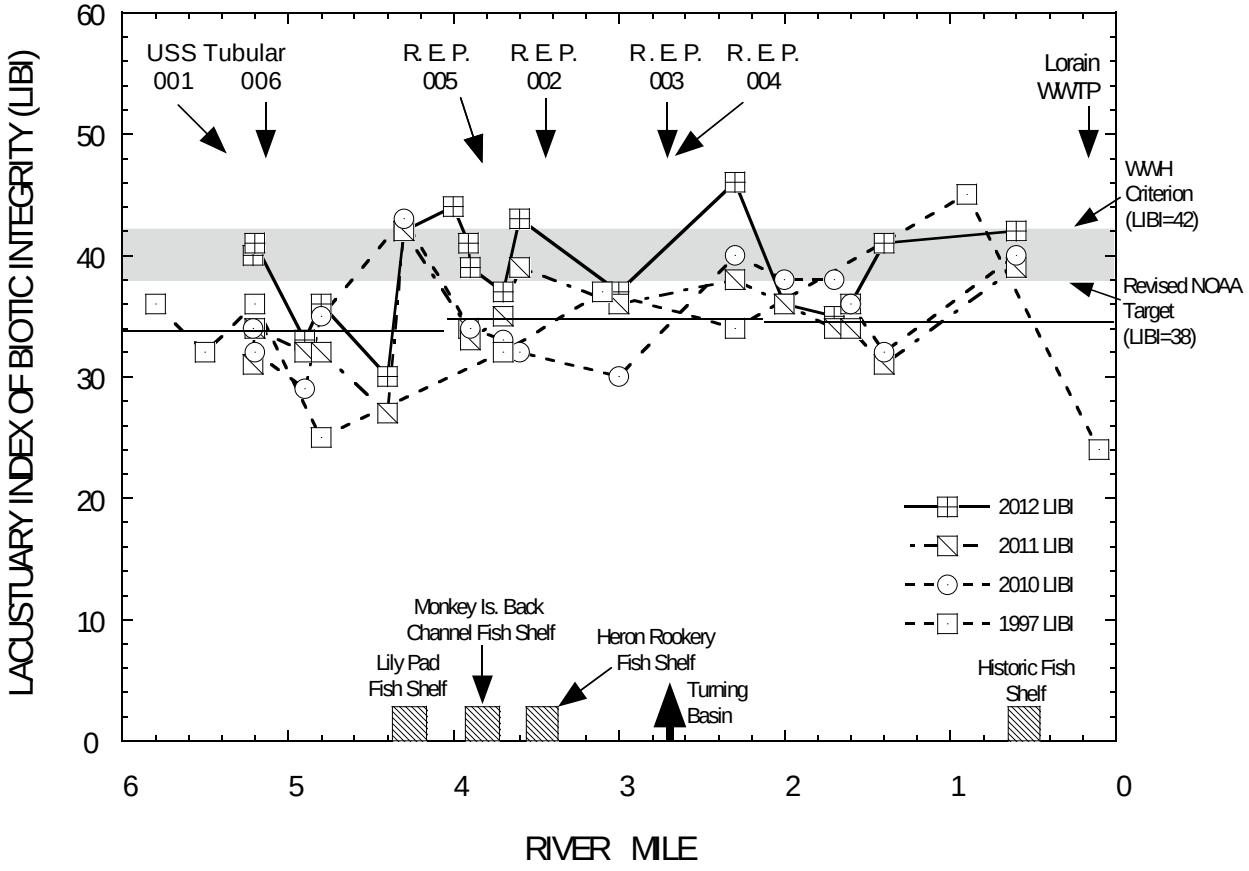


Figure 6. Black River LIBI scores for 2010-12 with Ohio BUI delisting and revised NOAA targets (as indicated) and historical baselines for segments A, B, and C (solid lines) from Table 2. The 1997 Ohio EPA results are included for comparison.

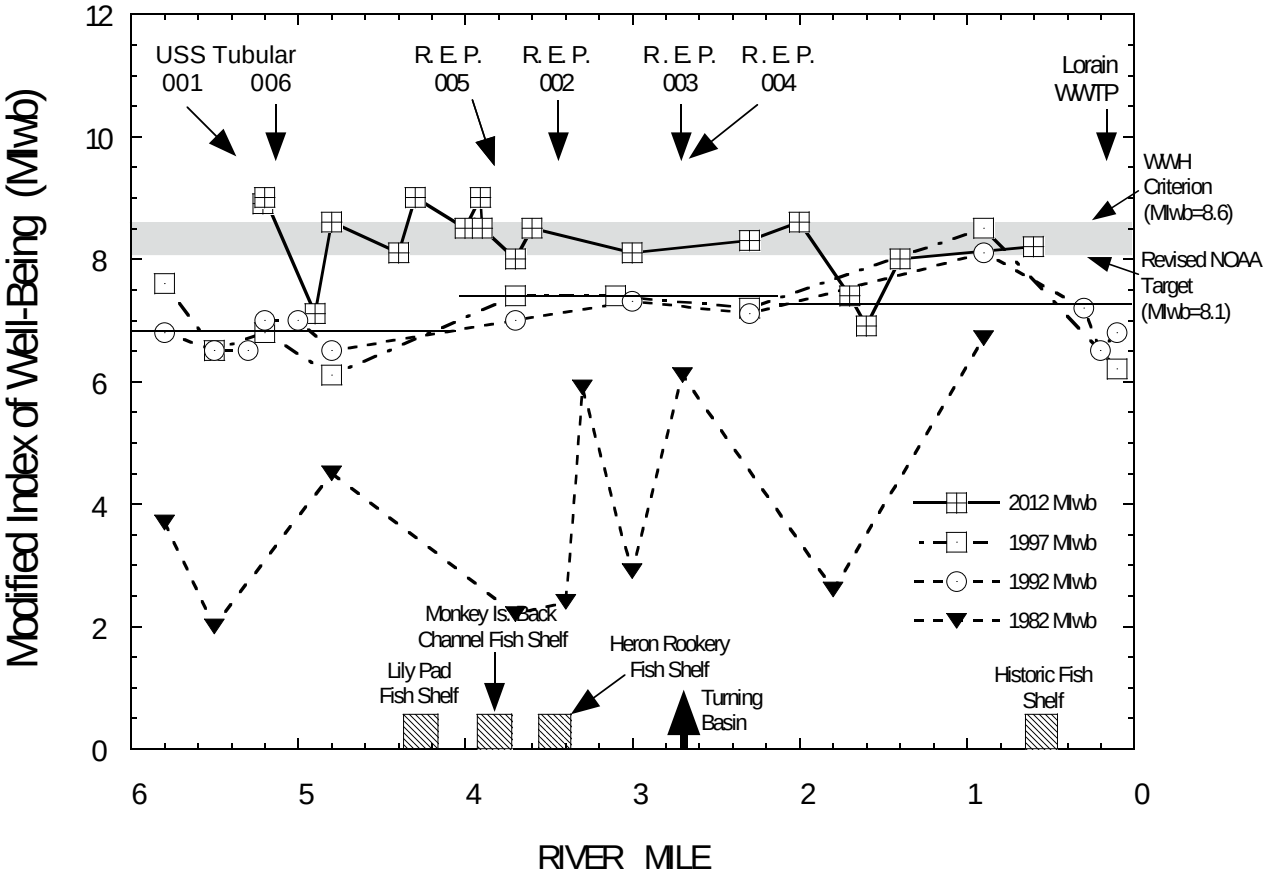


Figure 7. Black River lacustuary MIwb scores for 1982, 1992, 1997, and 2012 with Ohio BUI delisting and revised NOAA targets (as indicated) and historical baselines for segments A, B, and C (solid lines) from Table 2.

The 2010-12 MIwb results (Figure 8) were more consistently similar between each of the three years. Attainment of the interim lacustuary biocriterion was similar in all three years and exceeded the interim lacustuary biocriteria in all except six sites in 2012. Pollution impact zones were also less visible than with the LIBI, but were evident downstream from USS Tubular 001 and 006 and at the beginning of the navigation channel. The MIwb can be sensitive to acute impacts that result in wholesale reductions of species and abundances, but less so to more subtle and chronic impacts.

Macroinvertebrate Assemblage

Macroinvertebrate assemblages in the Black River lacustuary (RM 5.6 to 0.1) consistently scored well below the interim Lake Erie lacustuary criterion (LICI = 42) in 1992, 1994, and 1997 (Figure 9). The only exceptions were two sites in 1992 at the upper boundary of the lacustuary. These scores were higher in 1992 and due to elevated flows during July-September 1992 that were 7-10 times higher than in 1997. This resulted in the lacustuary effect being reduced at this site and reflecting free-flowing riverine habitat. Flow was also more constant over the artificial substrates which enhanced colonization by rheophilic taxa which resulted in higher LICI scores. Macroinvertebrates in the Black River continued to score below the interim Lake Erie

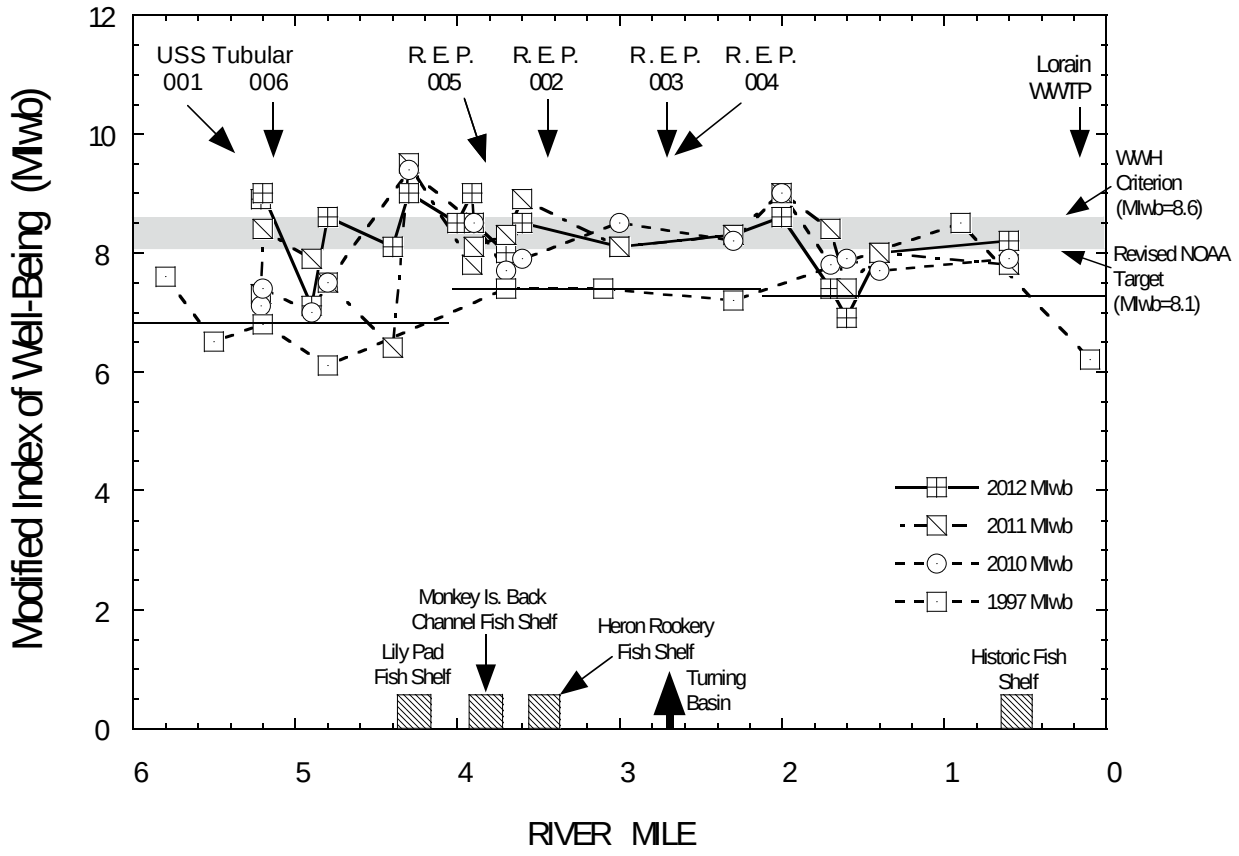


Figure 8. Black River lacustuary MIwb scores for 2010-12 with Ohio BUI delisting and revised NOAA targets (as indicated) and historical baselines for segments A, B, and C (solid lines) from Table 2. The 1997 Ohio EPA results are included for comparison.

lacustuary criterion (LICI = 42) and the NOAA target (LICI = 25) in 2010-12 (Figure 9) with the results worsening in 2010-12 compared to the previous Ohio EPA surveys. All LICI values in 2010-12 were below the NOAA target.

Zones of localized impact were not as apparent as in the fish results partly due to the overall poor and very poor performance of the macroinvertebrate assemblage. No macroinvertebrate results were available from 1982 (samples were not collected), but it is likely the results would have been reflective of the acute impacts that occurred during that time period.

Habitat Assessment

The quality of physical habitat was determined visually using the Lacustuary Qualitative Habitat Evaluation Index (LQHEI). The LQHEI characterizes and scores sites based on the diversity and types of habitat attributes that are important for fish assemblages in particular. Characterization of habitat attributes using the LQHEI includes an assessment of six metrics; 1) substrate type and quality, 2) in-stream cover, 3) shoreline morphology, 4) quality of the riparian zone and degree of bank erosion, 5) presence and quality of aquatic vegetation and presence and

density of invasive species, and 6) bottom slope and depth. Each variable is visually observed in the field and recorded on a LQHEI data form. Each metric has a corresponding subtotal, all of which are summed to obtain the LQHEI score. The LQHEI has an effective range of 20-100 depending on the quality of the habitat. Values >60 are generally regarded as being sufficient to support fish assemblages that meet the minimum goal of the Ohio EPA Lake Erie lacustuary biocriteria and values >80 indicate exceptional quality habitat. LQHEI scores <45 reflect deficiencies that would likely preclude meeting the lacustuary biocriteria. Narrative ratings are exceptional (≥80), good (≥60), fair (45-59), poor (30-44), and very poor (<30) quality. LQHEI scores were recorded at each site during the first sampling pass in 2010 and in the first sampling pass for each of the subsequent years. An additional LQHEI was recorded at RM 3.6 in 2011, where restoration construction took place between sampling visits within the same year. LQHEI scores ranged from 35 at RM 1.40 in 2010 to 62 at RM 4.0 on 2012 (Figure 10).

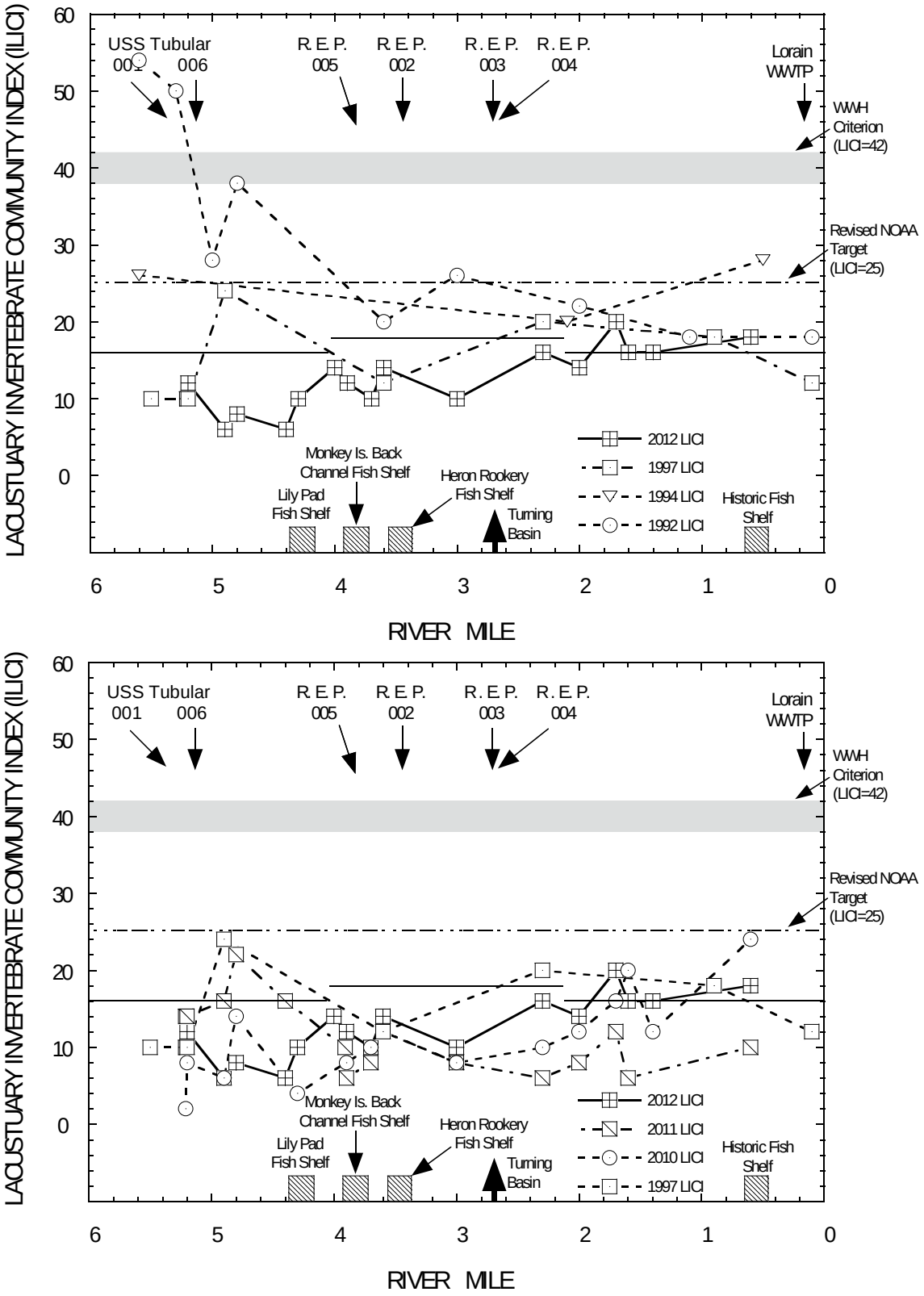


Figure 9. Black River LICI scores for 1992, 1994, 1997 and 2012 (upper) and 2010-12 (lower) with Ohio BUI delisting and revised NOAA targets (as indicated) and historical baselines for segments A, B, and C (solid lines) from Table 2.

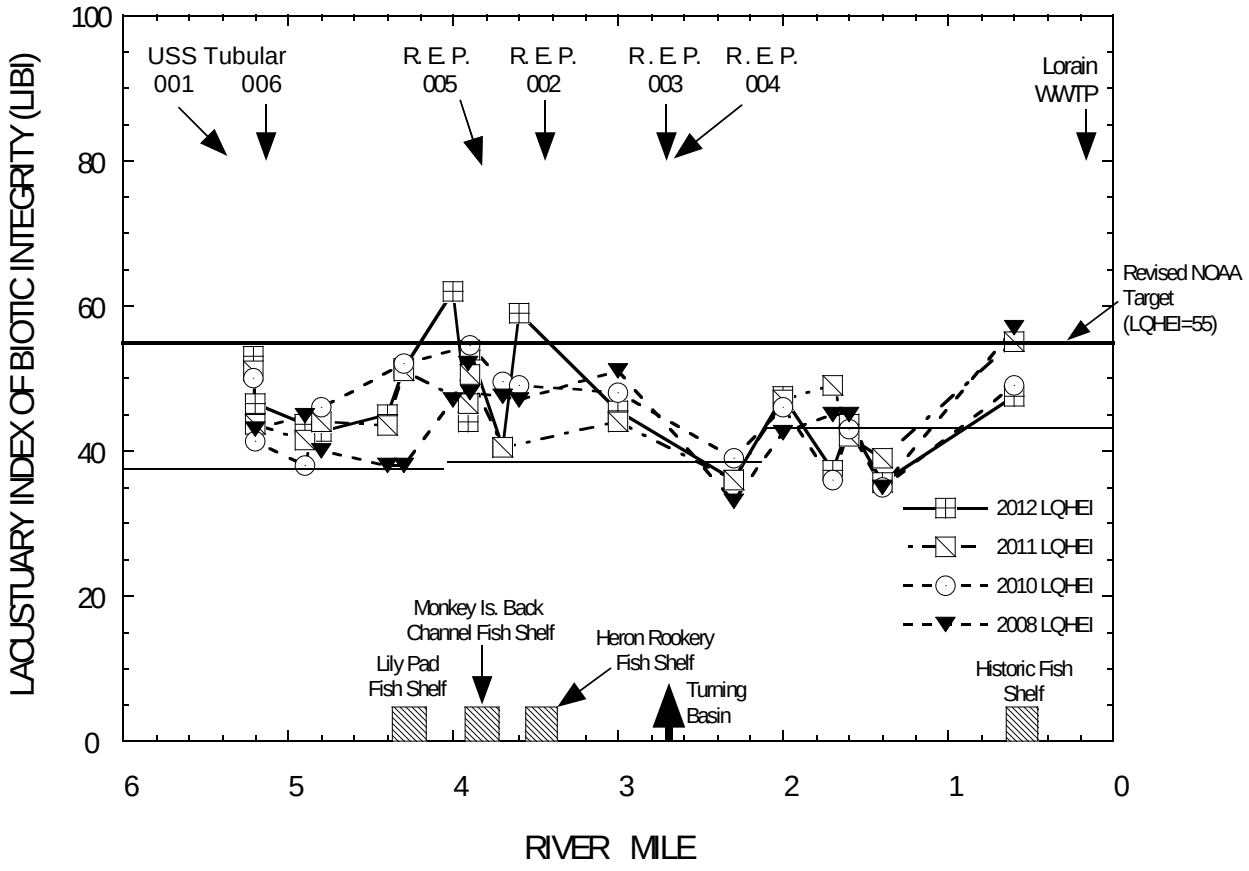


Figure 10. Black River LQHEI scores for 2008 and 2010-12 with revised NOAA targets (as indicated) and historical baseline values (solid lines) from Table 2.

RESTORATION SITES MONITORING RESULTS

Pre-construction and post-construction biological and habitat data was collected at project restoration sites to gage the response of the fish and macroinvertebrate assemblages and habitat attributes. Data collected at the RM 4.3, 4.0, 3.9, and 3.6 locations currently provide the pre- and/or post-construction data for the AARA and NOAA Phase I and II Projects. A description of each project follows:

Lily Pad Fish Shelf (RM 4.3)
At this site, the bank was stabilized, slag was removed, toe rock and instream rock were placed, and erosion control blankets and native plantings were installed. Over the adjacent floodplain area, steel slag was removed and vegetative cover was reestablished over a total of 23 acres. The excavation of slag from the floodplain occurred in March-August 2010. Installation of the rock toe and the fish shelf occurred in September 2010. The first sampling pass at this site occurred August 3-6, 2010, during the floodplain excavation; the second pass occurred in October 2010.

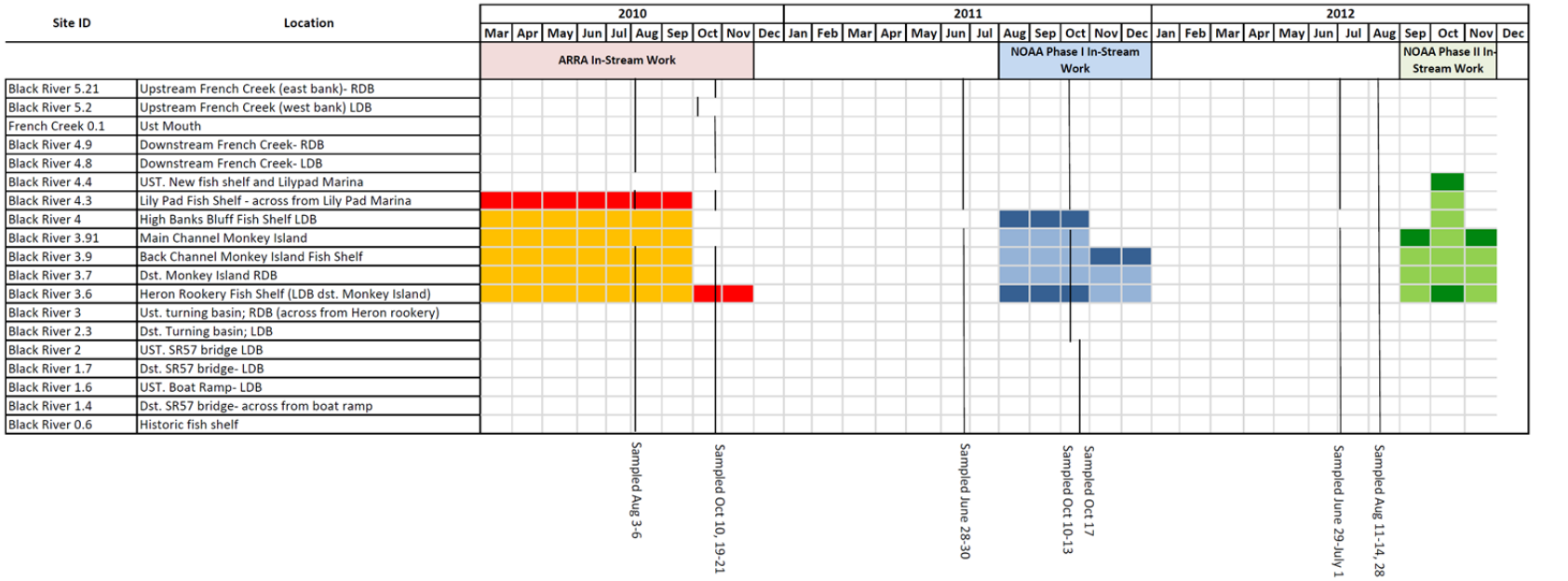
High Banks Bluff (RM 4.0)
Rock was placed to create a fish shelf along the base of the sheer bluff at this site. In addition, steel slag was removed from the top of the bluff and the area was restored to create a natural riparian buffer that includes wetlands. The fish shelf was constructed August 1 – October 15, 2011. Sampling occurred at this site in 2012. However, construction may have indirectly affected downstream sites sampled in October 2011.

Back Channel Monkey Island Fish Shelf (RM 3.9)
At this site, the bank was stabilized through the placement of soil lifts, branch layering, erosion control blankets, and native plantings. Invasive Phragmites was removed and native vegetation was restored. Various habitat structures, including fish habitat shelves, boulder clusters, and rootwads were installed instream. Construction at this site was completed October 31 – December 15, 2011; no sampling occurred during the construction period.

Heron Rookery Fish Shelf (RM 3.6)
Fish shelves were constructed at this site and riparian habitat was improved through the demolition of an abandoned boat house and with subsequent vegetation restoration. Severely eroding banks were stabilized through the installation of toe rock, soil lifts, erosion control blankets, and native plantings. Construction in this area was ongoing from August 1 to October 15, 2011 and the site was sampled during October 10-13, 2011.

A presentation of pre- and post-construction photos appears in Appendix D. The temporal relationship of the 19 sampling sites to the in-stream construction activities conducted for the ARRA and NOAA Phase I, II, and III Projects is depicted in Figure 11.

Figure 11. Correspondence of ARRA and NOAA Phase I, II, and III instream habitat enhancement projects to the 19 biological and habitat sampling sites, 2010-12.



Dark colors represent actual construction. Lighter colors below darker colors indicate restoration sites that are downstream of construction and may have been affected indirectly.

"Pre-construction" sampling in 2010 for ARRA occurred during construction and immediately following construction for some sites.
"Pre-construction" sampling in 2011 for NOAA Phase I occurred during construction for some sites, which was also post-construction for the ARRA project.
2012 sampling occurred prior to any construction for NOAA Phase II. This is likely the best dataset for true "post-construction" monitoring for both ARRA and NOAA Phase I.

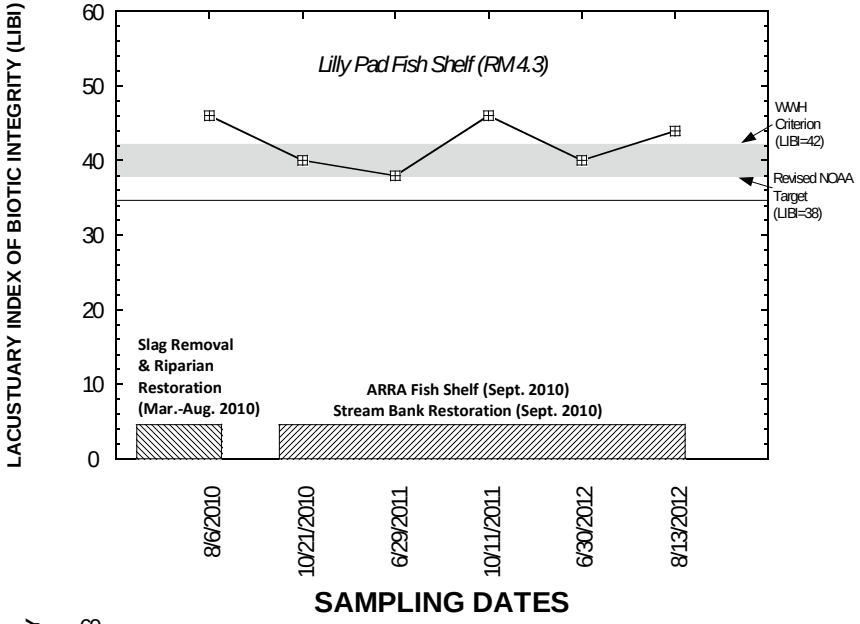
Assessment of Biological and Habitat Goals and Targets

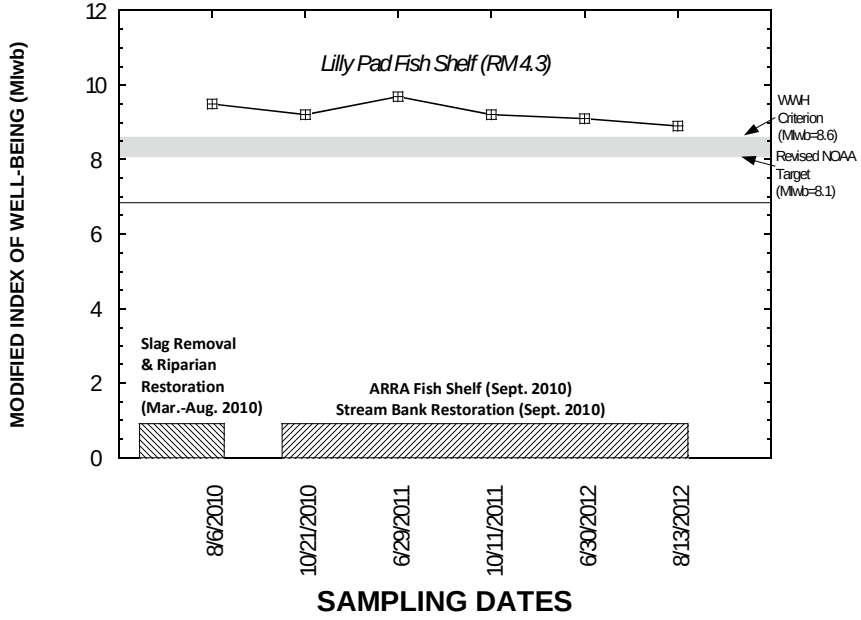
Of the 19 Black River lacustuary biological and habitat sampling sites, one site each are located at each of the four restoration sites. The data collected at these sites represents pre-construction and post-construction conditions. When analyzed in conjunction with the historic baseline (Table 2) it serves to evaluate the site-specific response to each restoration project.

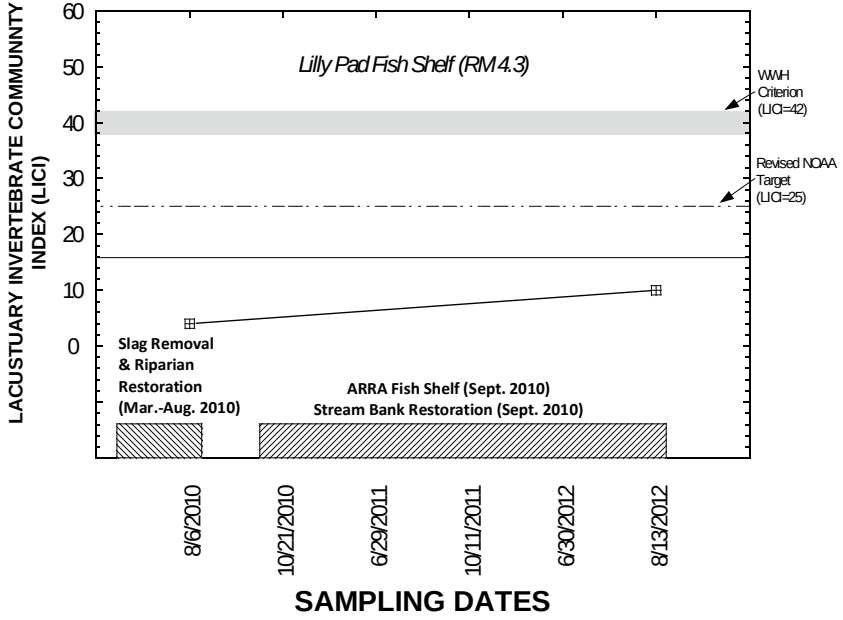
Lily Pad Fish Shelf *(RM 4.3)*
This site was sampled during and following the removal of slag and restoration of the riparian zone. The results show the fish assemblage to be meeting all goals and targets throughout the period from 2010 to 2012. LIBI and MIwb scores were above the NOAA targets and met the BUI delisting criteria with the exception of the LIBI being in nonsignificant departure for 3 of the 6 samples (Figure 12). There is no historic data form this site, but all fish index values in 2010-12 were well above the historic baseline based on 1997 data. The macroinvertebrate assemblage reflected LICI scores well below all baselines and targets and was consistent with the performance in the Black River throughout the 2010-12 surveys (Figure 12). An improvement in habitat quality as measured by the LQHEI occurred when compared to the 2008 baseline that preceded any restoration measures at this site (Figure 12). The LQHEI increased from 38 in 2008 to 52 in 2010 remaining at that level in 2011 and 2012.

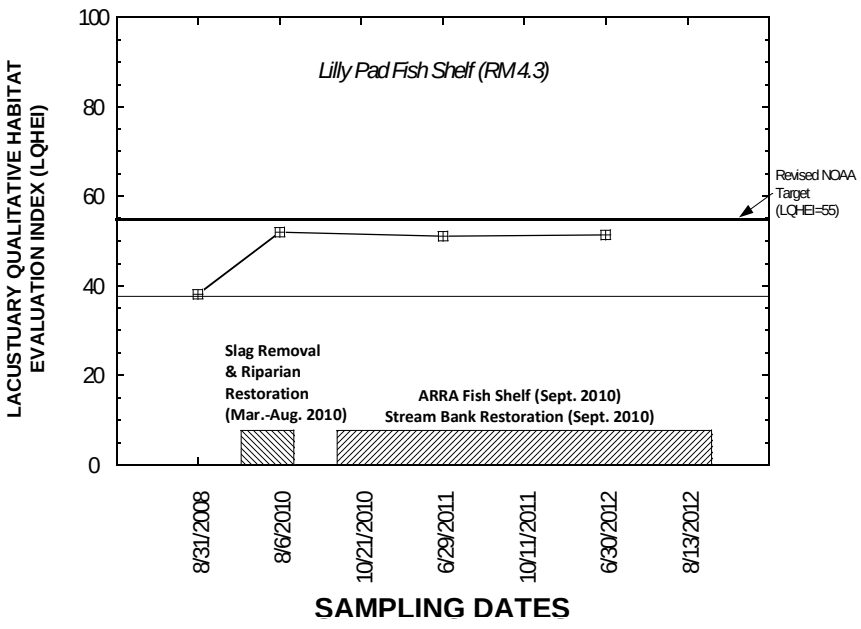
The area where this fish habitat shelf was constructed experienced an increased level of fine sediment deposition in 2012. However, large boulders remain exposed along the perimeter of the shelf and within boulder clusters that were constructed within the shelf. The toe rock and fish habitat shelf are providing important structure for key fish species, particularly bluegill, logperch, and northern hog sucker all of which have increased in abundance at this site following shelf construction. Severely eroding river banks that were present prior to construction are no longer present. The bank has been stabilized, slag has been removed, toe rock placed, and erosion control blankets and native plantings installed. Steel slag was removed and vegetative cover re-established within an approximately 23-acre restored floodplain, including native tree and shrub plantings. Wetland habitat has also re-developed in this area. Even though the LQHEI scores fell below the NOAA target, they are very close and may improve as the habitat attributes mature through time.

High Banks Bluff *(RM 4.0)*
This site was sampled in 2012 only thus there are no trends to depict for the LIBI, MIwb, or LICI. The LIBI and MIwb scores of 44 and 8.5, respectively, meet the NOAA targets and the Ohio BUI delisting criteria (ns departure for the MIwb). The LICI score of 14 was below all targets and was similar to the historical baseline. While no direct pre-construction biological data was collected the similarity of the restoration components and the close proximity to RM 3.91 the results from that site were used to draw some inferences about pre-construction conditions. Based on the LIBI score of 34 obtained at RM 3.91 in 2011 a post-construction improvement was inferred. The LQHEI of 62 was a significant improvement over the 2008 score of 47 and meets all targets.


LACUSTUARY INDEX OF BIOTIC INTEGRITY (LIBI)
Lilly Pad Fish Shelf (RM 4.3)
WWH Criterion (LIBI=42)
Revised NOAA Target (LIBI=38)
Slag Removal & Riparian Restoration (Mar.-Aug. 2010)
ARRA Fish Shelf (Sept. 2010) Stream Bank Restoration (Sept. 2010)
8/6/2010
10/21/2010
6/29/2011
10/11/2011
6/30/2012
8/13/2012
SAMPLING DATES


MODIFIED INDEX OF WELL-BEING (Miwb)
Lilly Pad Fish Shelf (RM 4.3)
WWH Criterion (Miwb=8.6)
Revised NOAA Target (Miwb=8.1)
Slag Removal & Riparian Restoration (Mar.-Aug. 2010)
ARRA Fish Shelf (Sept. 2010) Stream Bank Restoration (Sept. 2010)
8/6/2010
10/21/2010
6/29/2011
10/11/2011
6/30/2012
8/13/2012
SAMPLING DATES


LACUSTUARY INVERTEBRATE COMMUNNTY INDEX (LICI)
Lilly Pad Fish Shelf (RM 4.3)
WWH Criterion (LICI=42)
Revised NOAA Target (LICI=25)
Slag Removal & Riparian Restoration (Mar.-Aug. 2010)
ARRA Fish Shelf (Sept. 2010) Stream Bank Restoration (Sept. 2010)
8/6/2010
10/21/2010
6/29/2011
10/11/2011
6/30/2012
8/13/2012
SAMPLING DATES

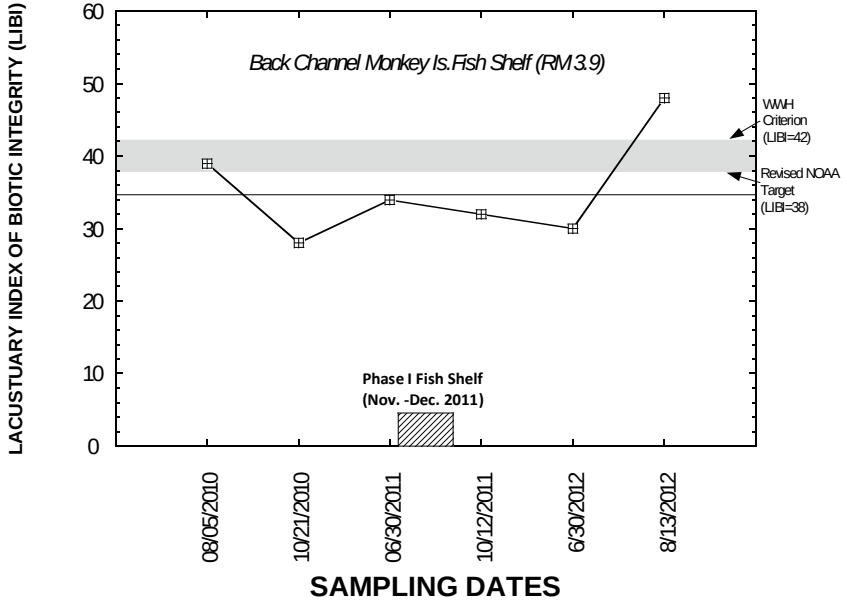

LACUSTUARY QUALITATIVE HABITAT EVALUATION INDEX (LQHEI)
Lilly Pad Fish Shelf (RM 4.3)
Revised NOAA Target (LQHEI=55)
Slag Removal & Riparian Restoration (Mar.-Aug. 2010)
ARRA Fish Shelf (Sept. 2010) Stream Bank Restoration (Sept. 2010)
8/31/2008
8/6/2010
10/21/2010
6/29/2011
10/11/2011
6/30/2012
8/13/2012
SAMPLING DATES

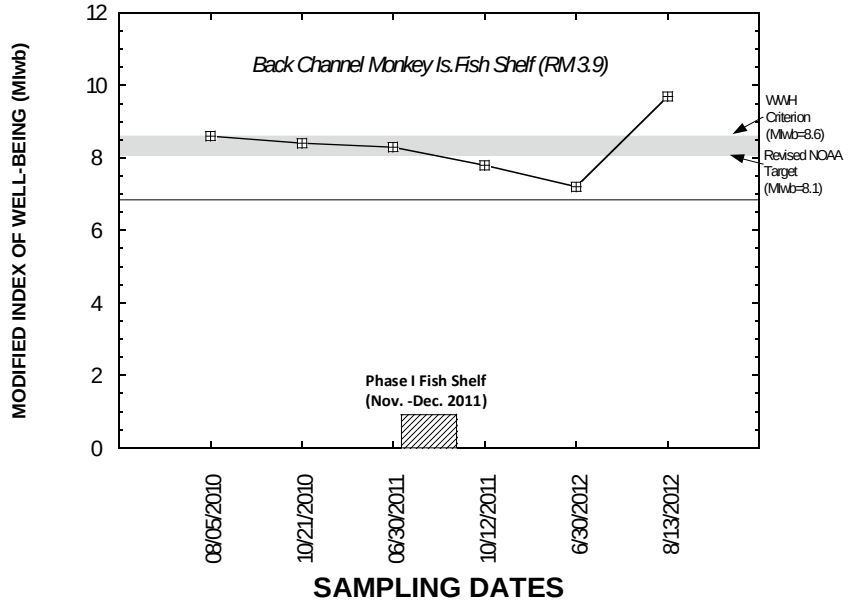
Back Channel Monkey Island Fish Shelf *(RM 3.9)*

Eroding banks that were present prior to construction are no longer present. Banks have been stabilized through the placement of soil lifts, installation of branch layers, placement of erosion control blankets, and native plantings. Invasive Phragmites in this segment has been removed and native vegetation restored. Various fish habitat structures (fish habitat shelves, boulder clusters, and rootwads) were installed following the 2011 field sampling and now provide habitat for key fish species, particularly northern hog sucker and silver redhorse each of which have increased in abundance at this site. LIBI and MIwb scores both increased during the post-construction sampling in 2012 each meeting all targets and criteria (Figure 13). LICI values ranged from a pre-construction score of 8 in 2010 to a post-construction score of 12 in 2012 (Figure 13). The LQHEI scores were at or just below the NOAA target of 55, but represent an overall albeit modest increase from the score of 48 in 2008.

Heron Rookery Fish Shelf *(RM 3.6)*

Riparian habitat has improved through the demolition of an abandoned boat house structure and subsequent vegetation restoration. Severely eroding banks that were present along the heron rookery prior to construction are no longer present. The banks have been stabilized through the placement of toe rock, placement of soil lifts, installation of erosion control blankets, and native plantings. Fish shelves are providing structure for key fish species, particularly smallmouth bass, white crappie, bluegill, and brook silverside, all of which have increased in abundance at this site. LIBI scores increased steadily through construction and into post-construction meeting all targets and goals beginning in October 2011 and through 2012 (Figure 14). MIwb scores showed a less pronounced overall increase through 2012 when all targets and goals were met (Figure 14). LICI values failed to meet any of the targets or goals remaining just below the historic baseline (Figure 14). The LQHEI showed a positive response increasing from scores of 45.8-49 in 2008, 2010, and June 2011 to 60.8 on October 2011 immediately following construction of the Phase I fish shelf. The LQHEI of 59 in 2012 is essentially similar to the October 2011 score and met the NOAA target for habitat. In 2012 low river flows and low lake levels resulted in exposing parts of the fish shelf, but the effects seemed negligible given the 2012 fish assemblage and LQHEI results.


LACUSTUARY INDEX OF BIOTIC INTEGRITY (LIBI)
Back Channel Monkey Is.Fish Shelf (RM 3.9)
WWH Criterion (LIBI=42)
Revised NOAA Target (LIBI=38)
Phase I Fish Shelf (Nov. -Dec. 2011)
08/05/2010
10/21/2010
06/30/2011
10/12/2011
6/30/2012
8/13/2012
SAMPLING DATES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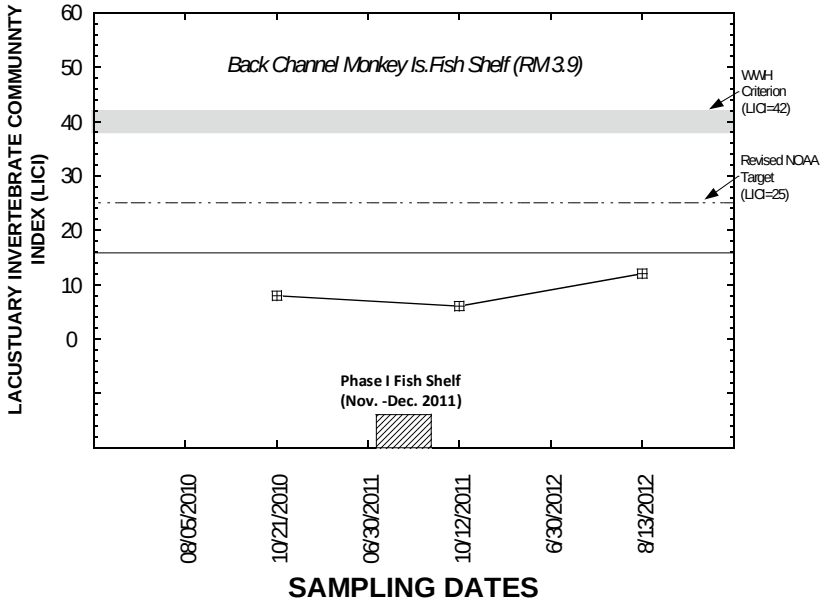
Back Channel Monkey Is.Fish Shelf (RM 3.9)
WWH Criterion (Miwb=8.6)
Revised NOAA Target (Miwb=8.1)
Phase I Fish Shelf (Nov. -Dec. 2011)
08/05/2010
10/21/2010
06/30/2011
10/12/2011
6/30/2012
8/13/2012
SAMPLING DATES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Back Channel Monkey Is.Fish Shelf (RM 3.9)
WWH Criterion (LICI=42)
Revised NOAA Target (LICI=25)
Phase I Fish Shelf (Nov. -Dec. 2011)
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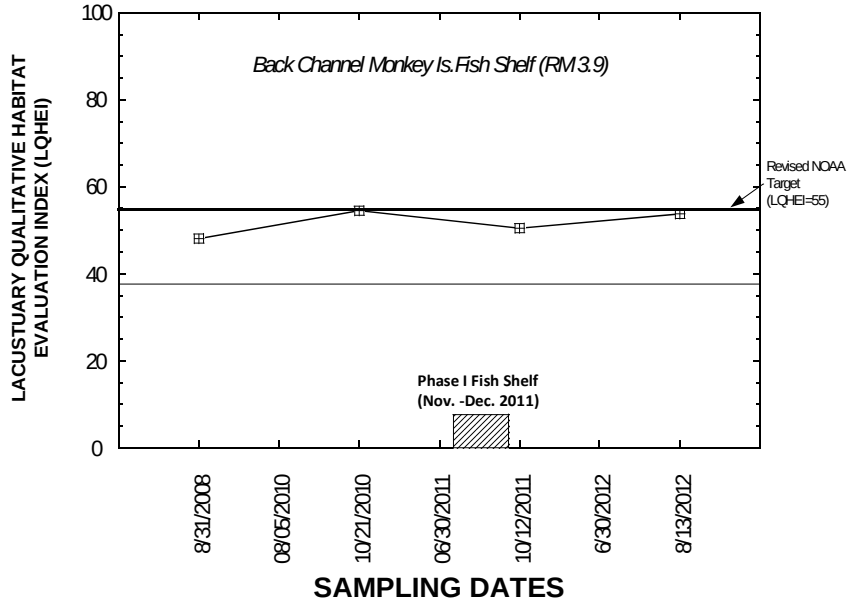
10/21/2010
06/30/2011
10/12/2011
6/30/2012
8/13/2012
SAMPLING DATES


LACUSTUARY QUALITATIVE HABITAT EVALUATION INDEX (LQHEI)
Back Channel Monkey Is.Fish Shelf (RM 3.9)
Revised NOAA Target (LQHEI=55)
Phase I Fish Shelf (Nov. -Dec. 2011)
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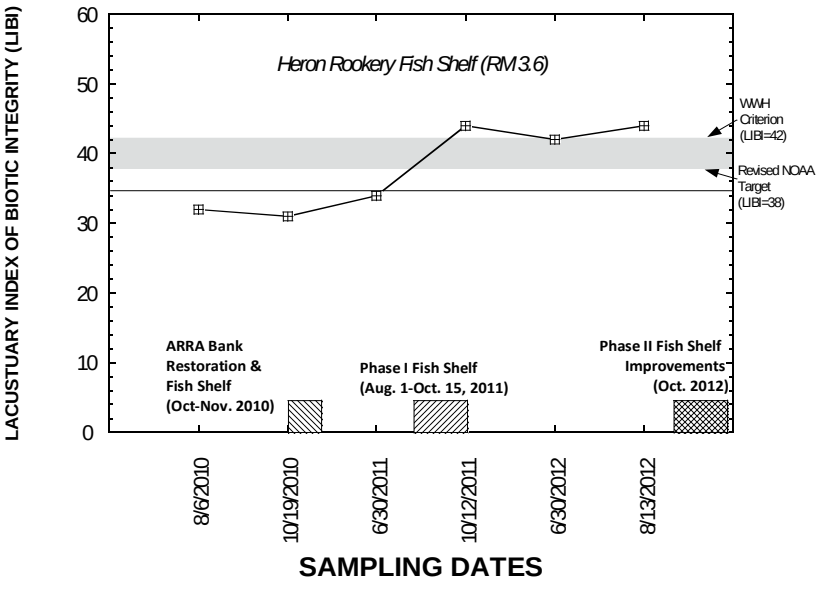
08/05/2010
10/21/2010
06/30/2011
10/12/2011
6/30/2012
8/13/2012
SAMPLING DATES


LACUSTUARY INDEX OF BIOTIC INTEGRITY (LIBI)
Heron Rookery Fish Shelf (RM 3.6)
WWH Criterion (LIBI=42)
Revised NOAA Target (LIBI=38)
ARRA Bank Restoration & Fish Shelf (Oct-Nov. 2010)
Phase I Fish Shelf (Aug. 1-Oct. 15, 2011)
Phase II Fish Shelf Improvements (Oct. 2012)
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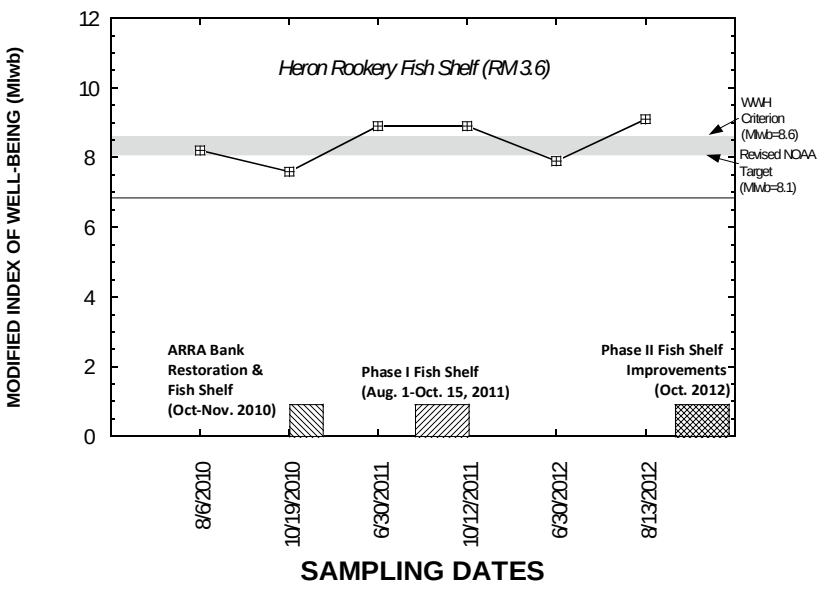
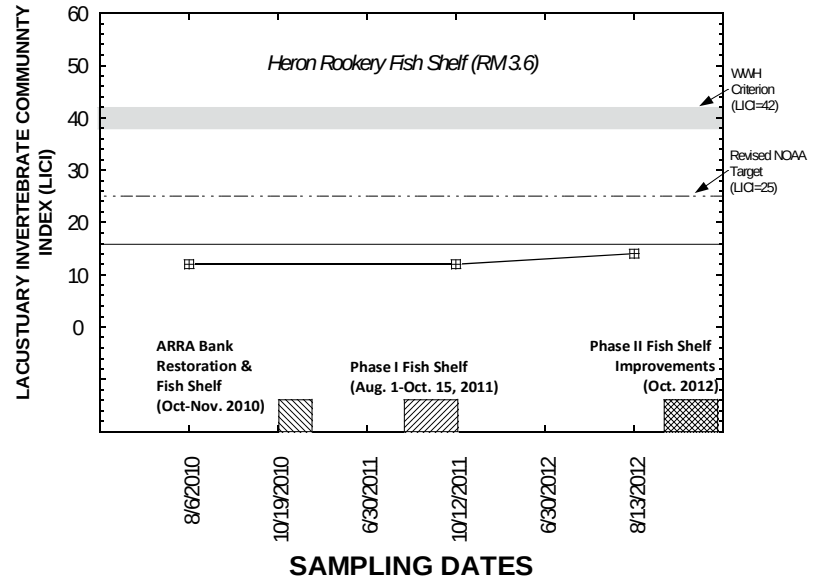
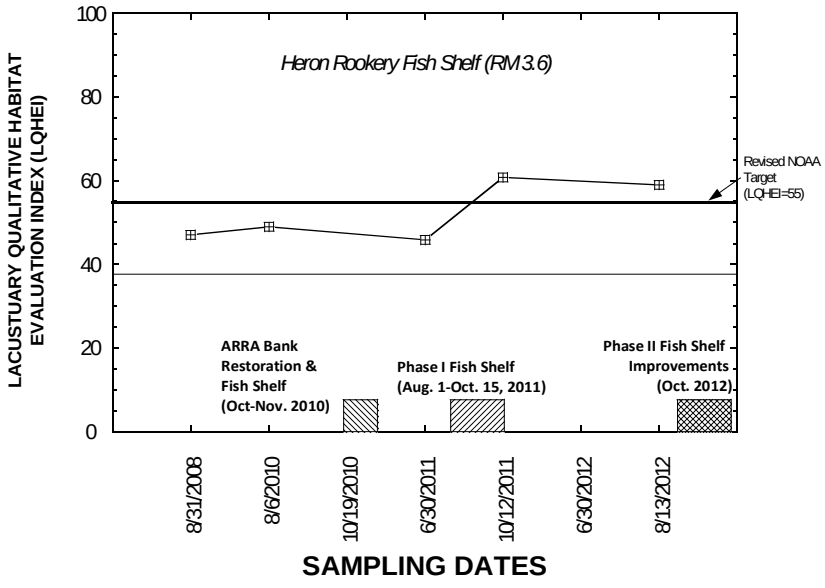
10/19/2010
6/30/2011
10/12/2011
6/30/2012
8/13/2012
SAMPLING DATES


MODIFIED INDEX OF WELL-BEING (Miwb)
Heron Rookery Fish Shelf (RM 3.6)
WWH Criterion (Miwb=8.6)
Revised NOAA Target (Miwb=8.1)
ARRA Bank Restoration & Fish Shelf (Oct-Nov. 2010)
Phase I Fish Shelf (Aug. 1-Oct. 15, 2011)
Phase II Fish Shelf Improvements (Oct. 2012)
8/6/2010
10/19/2010
6/30/2011
10/12/2011
6/30/2012
8/13/2012
SAMPLING DATES


LACUSTUARY INVERTEBRATE COMMUNNTY INDEX (LICI)
Heron Rookery Fish Shelf (RM 3.6)
WWH Criterion (LICI=42)
Revised NOAA Target (LICI=25)
ARRA Bank Restoration & Fish Shelf (Oct-Nov. 2010)
Phase I Fish Shelf (Aug. 1-Oct. 15, 2011)
Phase II Fish Shelf Improvements (Oct. 2012)
8/6/2010
10/19/2010
6/30/2011
10/12/2011
6/30/2012
8/13/2012
SAMPLING DATES


LACUSTUARY QUALITATIVE HABITAT EVALUATION INDEX (LQHEI)
Heron Rookery Fish Shelf (RM 3.6)
Revised NOAA Target (LQHEI=55)
ARRA Bank Restoration & Fish Shelf (Oct-Nov. 2010)
Phase I Fish Shelf (Aug. 1-Oct. 15, 2011)
Phase II Fish Shelf Improvements (Oct. 2012)
8/31/2008
8/6/2010
10/19/2010
6/30/2011
10/12/2011
6/30/2012
8/13/2012
SAMPLING DATES

Development and Assessment of Interim Targets for Native Species Richness and Percent Top Carnivores

Two of the goals for the ARRA and NOAA restoration projects include a 30% increase in top carnivores and a 10% increase in native species richness. Neither the historical or current baseline for these indicators was specified in detail hence the need to derive the endpoints. This was done by reach in the Black River lacustuary using 1997 as the historical baseline and 2010 as the current baseline (Table 8). Reach level derivation was done because the sites sampled by Ohio EPA in 1997 and by MBI in 2010-12 do not match and there were more sites sampled for the latter. This allows for an equitable comparison of current results to the historical baseline. The three reaches include:

1. Upper Reach (C): RM 4.0 to RM 5.21.
2. Middle Reach (B): RM 2.4-4.0; and,
3. Lower Reach (A): mouth to RM 2.3.

Native species richness and the proportion of top carnivore baselines were calculated for reach A, B, and C and expressed as the reach mean. The NOAA targets are for a 10% increase in species richness and a 30% increase in %top carnivores. Both the baseline values and NOAA targets are depicted in Table 8. For example the average native species richness at all sites in Reach A (RM 4.0-RM 5.21) is 14.25 species for the historical baseline (1997) and only slightly higher at 14.4 species for the current baseline (2010). The species richness goal was derived by adding 10% of the baseline results in a target of 15.7 species for the historical baseline and 15.8 species for the current baseline. Given that species counts are integer data these endpoints are equivalent and a sample with 16 or more species at a site in reach C would meet either target. The same procedure was used to derive the goals for a 30% increase in %top carnivores except that these endpoints are continuous variables and can have non-integer results (Table 8).

The status of these targets was then assessed using both the historical and current baseline years (Table 9). Comparisons to the historical baseline are represented by a solid circle and the current baseline by a solid square. Attainment of a target is reflected by a blue symbol and non-attainment with a red symbol. Yellow shaded cells in this table indicate samples not yet collected or that were collected prior to shelf construction and hence were not used to determine attainment of NOAA targets. We assessed attainment of the goals for each individual sample at the four project sites (Table 9).

Lily Pad Fish Shelf *(RM 4.3) – Reach C*
All of the species richness goals were met at this site. The top carnivore goal was met for the second pass in 2011 for the historical baseline and for both baselines for the second pass in 2012 (failed to attain either target in the first pass of 2012).

High Banks Bluff *(RM 4.0) – Reach C*
The fish assemblage during 2012 at this site met the native species richness targets. The %top carnivore goal was met for the historical baseline only.

Table 8. Basis for deriving top carnivore and native species targets for fish shelf construction based on 1997 and 2010 sample years.

Site	Fish Shelf	Construction Period	Segment	1997 Baseline		2010 Baseline	
				●Native Species Richness Target[1]	●Percent Carnivore Target[2]	■Native Species Richness Target[1]	■Percent Carnivore Target[2]
Black 4.4	NOAA Phase II Fish Shelf	October 2012	Segment C: RM 4.0-5.21	14.25 + 1.43 = 15.68	7.67 + 2.3 = 9.97%	14.4 + 1.44 = 15.84	15.43 + 4.63 = 20.06%
Black 4.3	NOAA Phase I Fish Shelf	Sept 2010					
Black 4.0	NOAA Phase I Fish Shelf	August-October 2011					
Black 3.91	NOAA Phase II Fish Shelf	November 2012	Segment B: RM 2.4-4.0	15.25 + 1.53 = 16.78	8.98 + 2.69 = 11.67%	14.75 + 1.48 = 16.23	17.17 + 5.15 = 22.32%
Black 3.9	NOAA Phase I Fish Shelf	October 2011					
Black 3.6	AARA Fish Shelf	October 2010					
Black 0.6	Historic Fish Shelf	2002	Segment A: RM 0-2.3	13.5 + 1.35 = 14.85	9.28 + 2.78 = 12.06%	14.0 + 1.40 = 15.4	22.65 + 6.79 = 29.44%

Back Channel Monkey Island Fish Shelf *(RM 3.9) – Reach B*
The species richness goals were not attained in the first pass of 2012 (pre-construction), but met both baselines during the second pass in October 2012 (post-construction). For top carnivores only the second pass in October 2012 met the historical baseline target.

Heron Rookery Fish Shelf *(RM 3.6) – Reach B*
The species richness historical and baseline targets were met for the second pass in 2012, but were not attained in 2011 or the first pass of 2012. The top carnivore target for the historical baseline was met for three of the four samples in 2011 and 2012. Only 1 of 4 samples met the baseline target and that being for the first pass in 2012

Historical Shelf *(RM 0.6) – Reach A*
The status of this 10 year old project is reported as a comparison to the newer projects in 2010-12. The historical and baseline species richness targets were not met in 2011. The historical baseline was met in 2012 and for the baseline target for the first pass only. The top carnivore goal met the historical baseline for all samples, but did not meet the baseline target.

[1] 10% increase over baseline.
[2] 30% increase over baseline.

Table 9. Table of native species richness and percent top carnivores and attainment of targets on the basis of historical (solid circles) and current baseline (solid squares) results. Samples meeting targets are in blue; those failing to meet targets are red.

Site	Native Species Goal				Top Carnivore Goal			
	Pass 1 – 2011	Pass 2 – 2011	Pass 1 – 2012	Pass 2 – 2012	Pass 1 – 2011	Pass 2 – 2011	Pass 1 – 2012	Pass 2 – 2012
Lily Pad Fish Shelf	22 ●/■	18 ●/■	18 ●/■	20 ●/■	4.6 ●/■	15.6 ●/■	7.6 ●/■	18.4 ●/■
High Banks Bluff	Constr: (Oct 2011)		17 ●/■	-	Constr: (Oct 2011)		19.5 ●/■	-
Back Channel Monkey Is.	Constr: (Oct 2011)		13 ●/■	21 ●/■	Constr: (Oct 2011)		9.5 ●/■	16.3 ●/■
Heron Rookery	16 ●/■	15 ●/■	16 ●/■	21 ●/■	9.9 ●/■	18.7 ●/■	24.5 ●/■	15.7 ●/■
Historic Fish Shelf	14 ●/■	11 ●/■	19 ●/■	15 ●/■	25.4 ●/■	23.4 ●/■	18.4 ●/■	21.2 ●/■

Summary

The species richness targets were met for both the historical and baseline in samples (except one sampling pass at the Historic Shelf) by 2012 (Table 9). This indicates an improvement over historical and baseline results that coincide with post-construction conditions, especially when compared with the historical baseline of 1997. The %top carnivore target was the most consistently met in 2012 for the historical baseline, but not for the current baseline at 3 of the four current restoration sites. Still, these results show an improvement over the historical baseline. The tendency for structural metrics like species richness to exhibit recovery sooner than functional metrics like top carnivores is consistent with these results. Future monitoring should reveal if this indeed the case.

MULTIVARIATE ANALYSIS

Analysis of potential responses of the fish and macroinvertebrate assemblages to legacy and/or present day pollutional effects was undertaken to determine what impacts those effects might have on being able to detect changes stemming from the restoration of physical habitat. While substantial improvements in the fish assemblage indicators have been observed in the Black River lacustuary since 1982 and tracking through 1992 and 1997 to 2010-12, the macroinvertebrate assemblage response has been almost the inverse by comparison. As a result of the virtual non-response and LICI values remaining in the poor and very poor ranges we undertook alternate analyses using a battery of multivariate statistical tests.

Non-metric Multidimensional Scaling (NMS)

Ordinations of the fish and macroinvertebrate assemblage data in the Black River lacustuary including data collected by Ohio EPA in 1982 (fish only), 1992, 1997, and 2002-3 (fish and macroinvertebrates) and all data collected by MBI in 2010-12 were conducted with Non-metric Multidimensional Scaling (NMS). NMS is an ordination technique that is well suited to data that are non-normally distributed which is a trait of these datasets. Bray-Curtis dissimilarity measures were used as a measure of distance with relative abundance data log transformed. This was used to explore how sites differed across years, along a gradient of percent lacustuary, and among restoration treatments (i.e., shelf vs. lack of a shelf). We included all species in the analyses to maximize any differences due to the presence of sensitive species that might occur in low numbers in the historically impacted Black River lacustuary, but nonetheless are important indicators of improving conditions (e.g., improved habitat resulting from fish shelf construction).

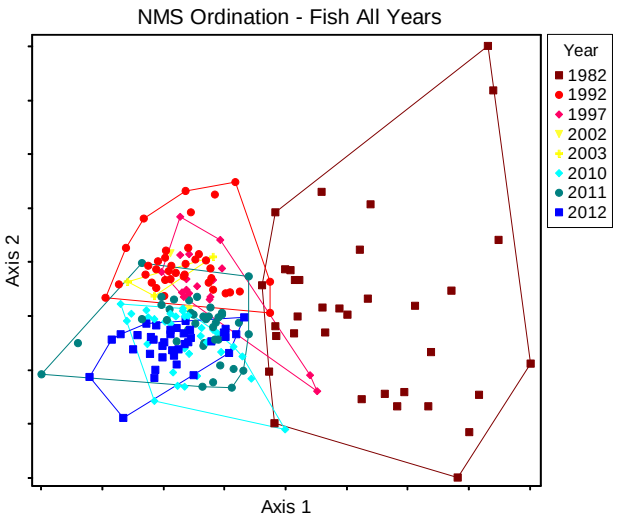


Figure 15. NMS ordination of fish data from the Black River lacustuary color coded by year.

Fish Assemblage

The NMS ordination results color coded by year (Figure 15) illustrate a strong deviance of the 1982 data from all other years of data, with the 1990s and early 2000s clustering together. The fish assemblage data collected by MBI during 2010-12 separated itself from either cluster. This pattern demonstrates the strong pollution gradient that has historically existed, particularly during the early 1980s prior to the first major reductions in point source impacts and the dredging of contaminated sediment during 1989-90 (U.S. EPA 1998).

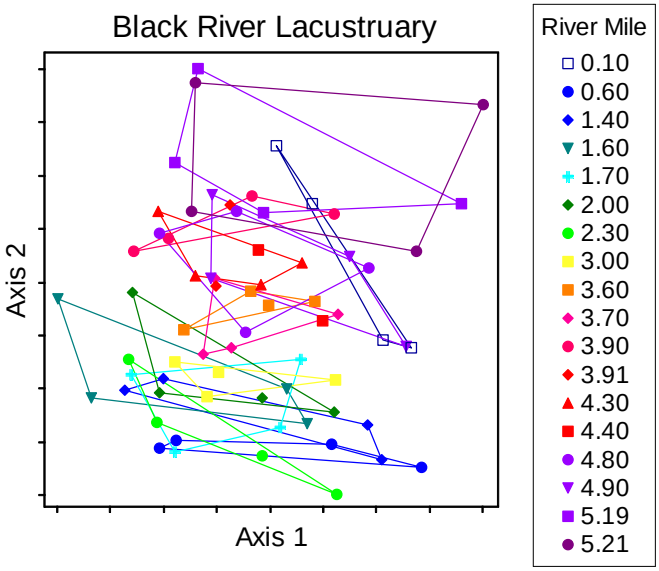


Figure 16. NMS ordination of fish data from the Black River lacustuary from 2010-12 color coded by river mile. Sites with open squares at RM 0.1 are in French Creek.

NMS ordination with fish data from 2010-2012 was clustered by river mile (Figure 16). This yielded an upstream to downstream pattern in the similarity within the fish assemblage with collections at the same site being the most similar. Assemblage differences increased with distance downstream in the Black River lacustuary (sites with open squares represent the French Creek site at RM 0.1).

Figure 17 depicts the same ordination with samples coded by site year and the presence or absence of a fish shelf. Unlike the river mile gradient, there is no clear pattern among sites with and without shelves. Changes to the shelves need to

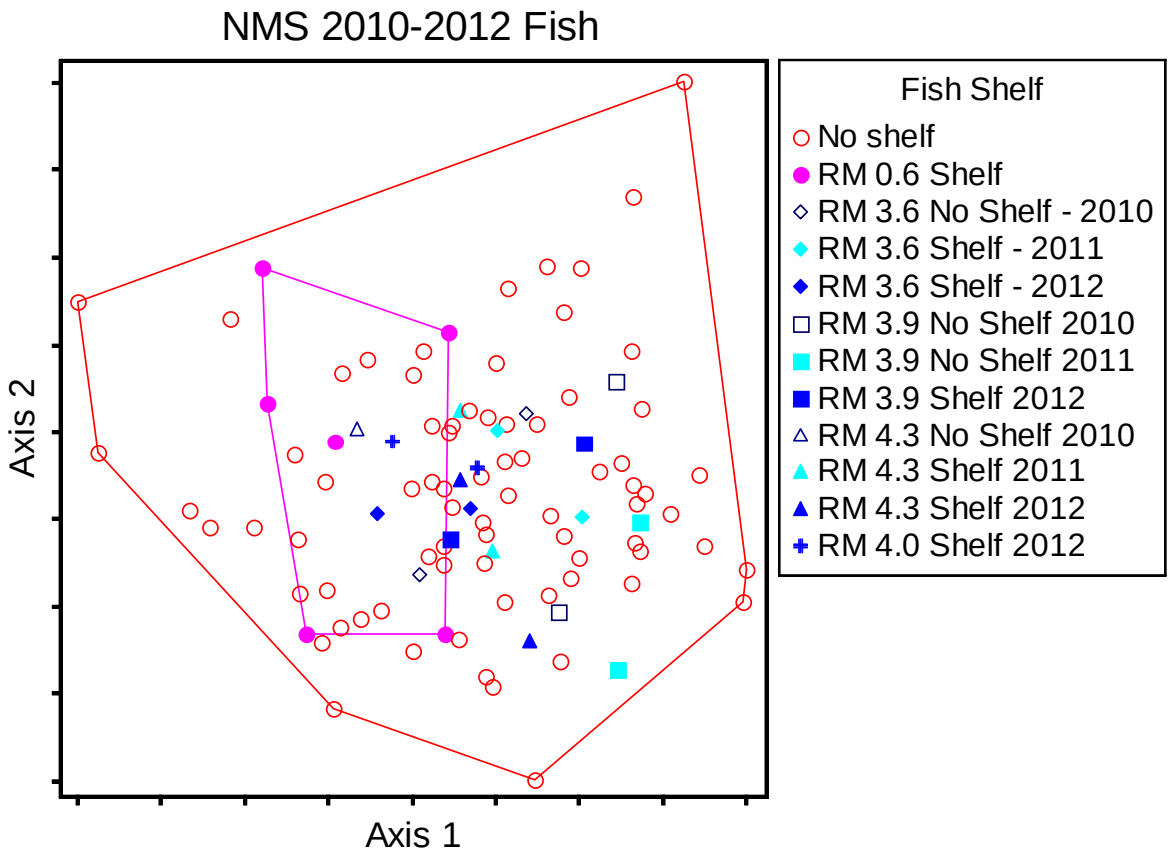


Figure 17. NMS ordination of fish data from the Black River lacustuary during 2010-12 color coded by site, presence of a fish shelf, and year of sampling.

be assessed individually, relative to the general levels of stressors that exist at a site that are not affected by the presence of a fish shelf. However, the lack of separation of the fish shelf sites alone is not an indication of the relative ineffectiveness of the restoration. Multivariate analyses are likely too coarse to reveal site-specific differences between sampling dates.

Macroinvertebrates

The NMS ordination for the macroinvertebrate assemblage in the Black River lacustuary is illustrated in Figure 18. The data from the 1992 year grouped distinctly from the 2010-12 data, but unlike the fish assemblage, the data from 1997 grouped with the 2010-12 data.

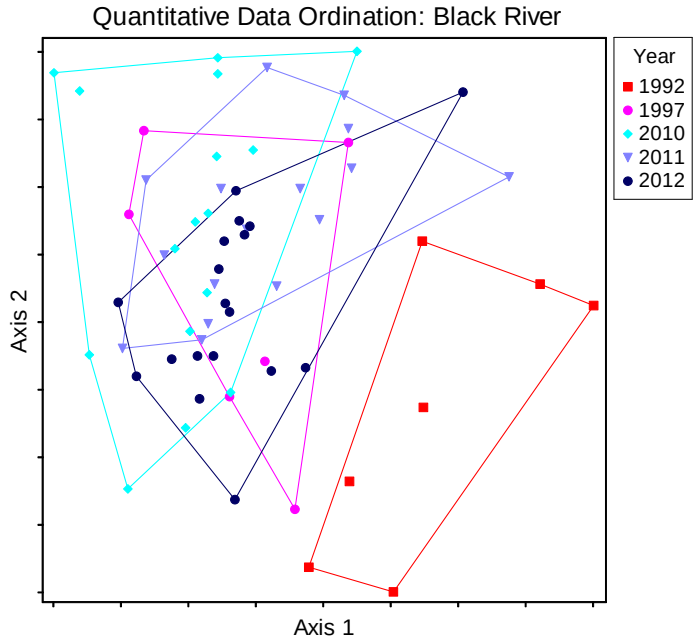


Figure 18. NMS ordination of fish data from the lacustuary portions of the Black River watershed color coded by year.

When the analysis was limited to the 2010-2012 period there was a strong gradient of sites grouping by river mile, or location within the lacustuary (Figure 19). The fish shelf sites were most closely related to nearby sites at the same or closely located river miles than whether the site was pre- or post-shelf construction. This does not mean that the shelves themselves are not having a positive effect, but that location in the lacustuary and more broad-scale influences along a longitudinal gradient are likely masking any effects from the fish shelf construction. In addition, there could also be a time lag inherent to the shelf construction that may take more time to become evident or to emerge from the strong longitudinal pattern in the

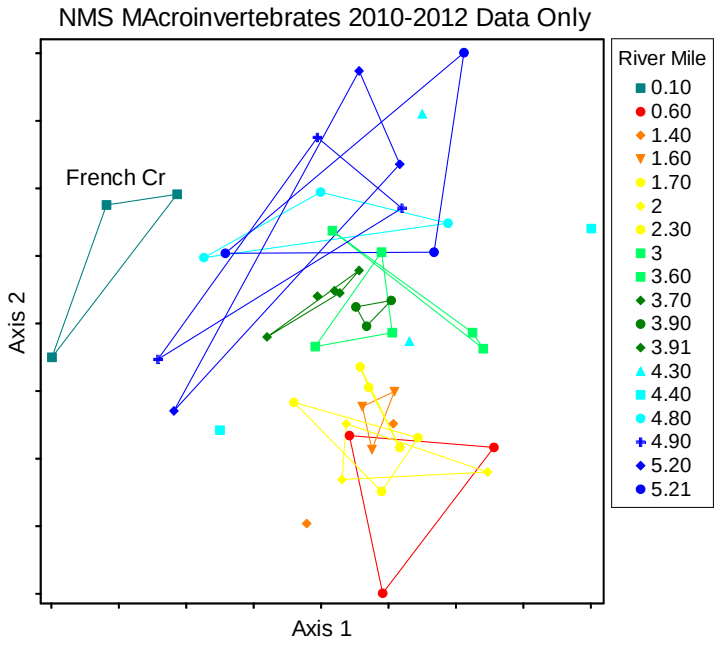


Figure 19. NMS ordination of 2010-12 fish data from the Black River lacustuary color coded by river mile location. The site at RM 0.1 on French Creek at the mouth is labeled accordingly.

data. This is very suggestive of lingering or current effects from past and/or present pollutional influences on the macroinvertebrate assemblage.

Conclusions from Ordination Analyses

The ordination analyses showed a general historical pattern in that the results of the earliest Ohio EPA surveys separated from the 1997 and 2010-12 surveys. This clearly reflects the history of point source pollution controls from the baseline of severely impacted conditions and acute toxicity. The analyses also revealed a strong longitudinal gradient in both the fish and macroinvertebrate assemblages in the Black River lacustuary that corresponds with the concentration gradient of dissolved materials as measured by conductivity (Figure 20). This seems to reflect a strong chemical pollution gradient in the lacustuary and the highest values (e.g., >800-1000 µS/cm) were measured in the vicinity of the newly installed fish shelves. It was therefore difficult to assess the influence of the fish shelves on the basis of the multivariate ordinations given their strong response to larger scale influences.

Analysis of Available Stressor Data

One critical need in assessing the influences of potential stressors is having chemical and physical data about the stressors themselves. It has been established by prior Ohio EPA and other studies that chemical/physical water quality and pollution impacts to the Black River lacustuary include a variety of stressor agents including organic enrichment from wastewater discharges, nutrients and sediments from nonpoint sources in the upper watershed, and toxic releases from steelmaking operations both past and present. Establishing a current baseline to include an analysis of source inputs and instream water quality, including sediment chemistry, is needed to more thoroughly establish if additional controls are needed. Although major steps have been taken to reduce the impact of legacy pollution, current evidence exists that indicates that full recovery remains incomplete.

When the limited chemical data from 2010-12 was examined (Figure 20) a strong association with river mile and conductivity (specific conductance) was revealed that indicates a pattern of decreasing dissolved materials in a downstream direction through the lacustuary and towards the mouth (Figure 20). There was some annual variation in conductivity with the highest values occurring in 2010 and 2012 (Figure 20). Within each year there were within season patterns with all values >1000 µS/cm measured in late June or early July of 2010 and 2012. Even within that variability a distinct longitudinal pattern was evident and suggests input from sources upstream form the lacustuary. The conductivity values observed entering the upper portion of the Black River lacustuary are highly elevated in comparison to regional reference values. Median values in reference rivers in the Erie/Ontario Lake Plain (EOLP) ecoregion are 447 µS/cm and the extremes (2 interquartile ranges above the median) are <900 µS/cm (Ohio EPA 1999). Most of the values downstream to RM 3.0 near the turning basin and where lake water intrusion would provide added dilution exceeded the highest regional reference values. The high values in 2010 and 2012 during low river flows and low lake levels suggest dry weather

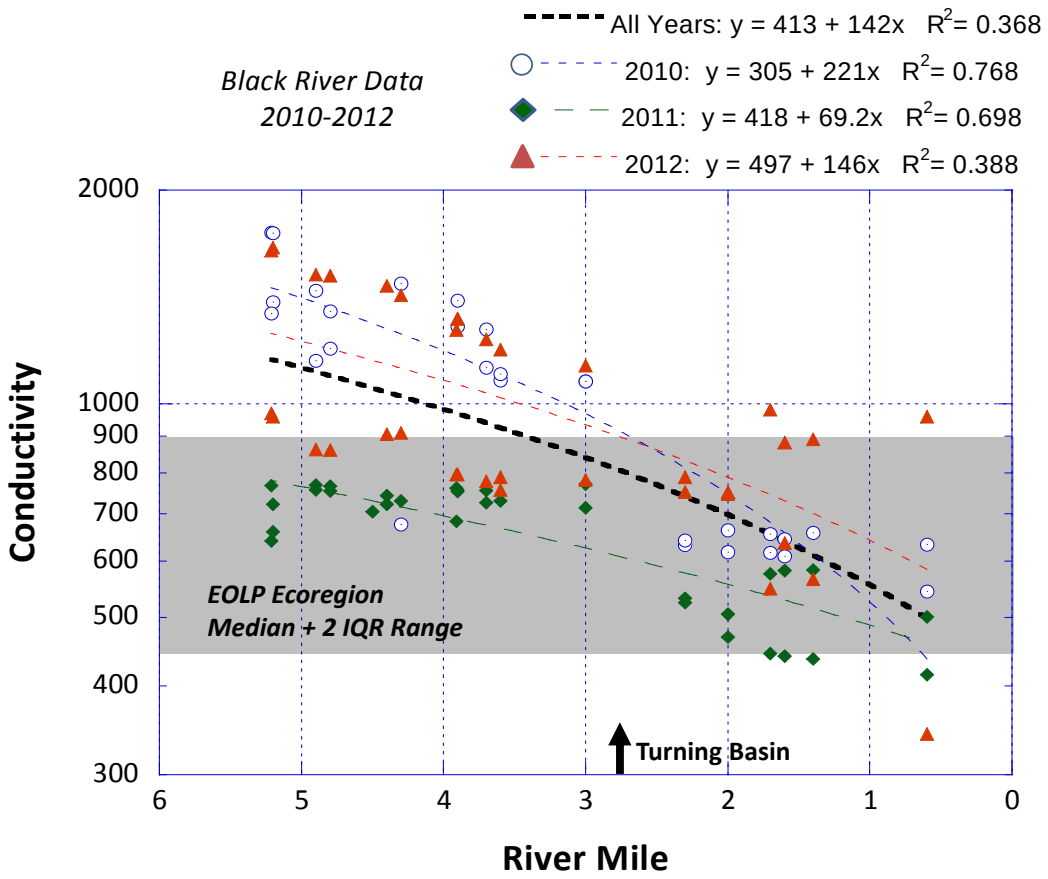


Figure 20. Plot of conductivity (µS/cm at 25°C) vs. river mile for the Black River lacustuary during 2010, 2011 and 2012. Plots are linear regression curves for all data combined and for each year. Shaded area is the range of reference conductivity values from the median + 2 IQRs above the median.

inputs. Sources upstream from the estuary seem likely given the comparatively uninterrupted decline through the lacustuary (Figure 20). Investigating the source(s) would be useful and assure that water quality is not a continuing deterrent to biological recovery. This pattern of degraded chemical water quality certainly corresponds to the response of the macroinvertebrate assemblage in 2010-12.

To better assess this assertion, a preliminary analysis of the relationship between conductivity and macroinvertebrate taxa was conducted by using data across all of the Lake Erie lacustuaries sampled by Ohio EPA (1993). A weighted stressor value (WSV) approach was used to rank macroinvertebrate taxa in accordance with their correspondence to conductivity values. Certain freshwater macroinvertebrate taxa groups (e.g., mayflies) have been reported as being especially sensitive to salinity (Pond 2010). For parameters where associations between taxa distribution and abundance are strong field-based response thresholds have been derived as management endpoints (Cormier et al. 2008). The WSVs were ranked from lowest to highest with the lower 15% designated as taxa "sensitive" to conductivity and the upper 15% as taxa "tolerant" to elevated conductivity. On the basis of these designations conductivity-based

sensitive taxa richness and a proportion of conductivity sensitive macroinvertebrate metrics were derived.

Figure 21 illustrates the observed relationship between taxa richness and the proportion of conductivity sensitive taxa vs. conductivity across all Ohio Lake Erie lacustuaries. The result is a threshold of decline with increasing conductivity for both the taxa richness and the proportional metrics. The conductivity-based macroinvertebrate metrics vs. river mile show a particularly strong response in the proportional metric vs. river mile that separates between sites upstream and downstream form the turning basin (Figure 22). This corresponds to the boundary between poor-very poor LICIs and fair LICIs in 2012 previously discussed. The pattern for the taxa richness metric is much less distinct. This analysis reinforces the suggestion that conductivity or an associated stressor is limiting to macroinvertebrates in the Black River. The source(s) are not apparent in this analysis, but the high values do appear to originate outside of the lacustuary.

Our experience and work with rivers and streams with elevated conductivity strongly suggests that the habitat sensitive species that would be expected to be the most responsive to the habitat restoration projects are also being negatively influenced by the high concentrations of dissolved solids. An assessment of the source(s) and any remaining toxicity from contaminated sediments in the Black River lacustuary is needed to make sure pollutional effects do not continue to interfere with biological recovery.

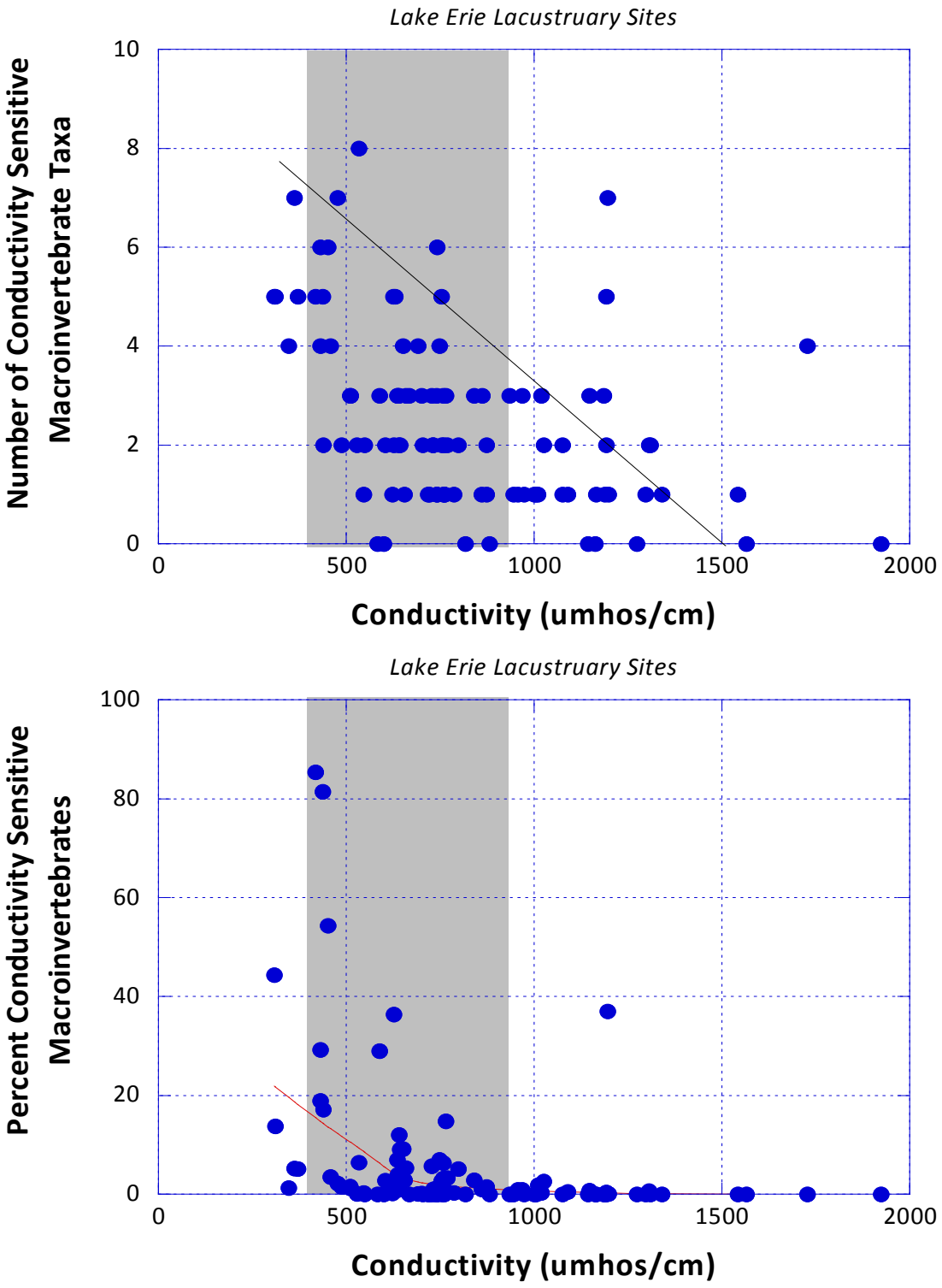


Figure 21. Plot of conductivity sensitive macroinvertebrate taxa richness (upper) and the proportion of conductivity sensitive macroinvertebrates vs. conductivity (µS/cm) across all Ohio Lake Erie lacustuaries from data in Ohio EPA (1993) and this study. Shaded areas are the reference median + 2 IQR above the median for the EOLP ecoregion.

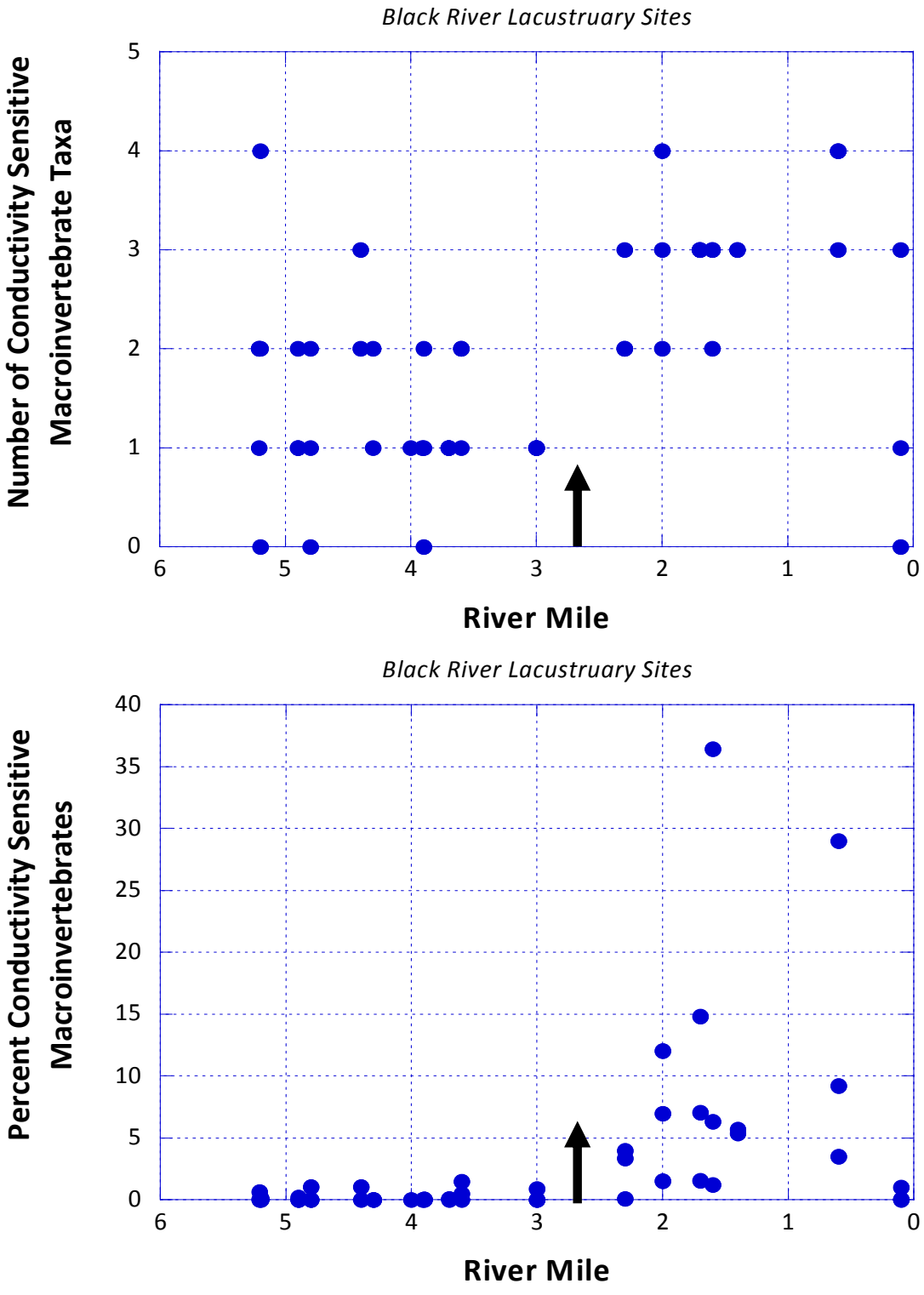


Figure 22. Plot of conductivity sensitive macroinvertebrate taxa richness (upper) and the proportion of conductivity sensitive macroinvertebrates (lower) by river mile in the Black River lacustuary for 2010-12. The turning basin is indicated by a vertical arrow.

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