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Evaluating Beneficial Use: Aquatic Life

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G1. Background and Rationale

Background

Ohio EPA has been evaluating streams using standardized biological field collection methods since the 1970s. Stream assessments are based on the experience gained through the collection of more than 28,300 fish population samples, nearly 15,100 macroinvertebrate community samples and close to 235,000 water chemistry samples. Aquatic life use assessments for the 2020 Integrated Report (IR) are based on biological and chemical data collected from primarily 2009-2018 at more than 4,750 wadeable stream, large river and Lake Erie shoreline sampling locations; some earlier data collected between 2003-2008 were retained for specific watershed and large river assessments. Ohio's Credible Data Law states that all data greater than five years in age will be considered historical, but that it can be used if the director has identified compelling reasons as to why the data are credible. In the case of biological monitoring data, the use of data older than five years is necessary. The use of historical data is necessary because not enough biological samples are gathered from enough locations each year to conduct a thorough assessment of aquatic life use status across the state. Owing to limited staff and budget resources, it may take up to 20 years to visit enough assessment units and sufficiently monitor them to make aquatic life use assessments. A more complete picture of statewide aquatic life use health is presented when data are utilized based on the longer timeframe. Since water resource quality in many watersheds in Ohio today is most susceptible to changing land use patterns that are often subtle, slow to evolve, and difficult to monitor and assess, the use of older data is justified.

Ohio's water quality standards (WQS) have seven subcategories of aquatic life uses for streams and rivers (see Ohio Administrative Code 3745-1-07, epa.ohio.gov/portals/35/rules/01-07.pdf). The WQS rule contains a narrative for each aquatic life use and the three most commonly assigned aquatic life uses have quantitative, numeric biological criteria that express the minimum acceptable level of biological performance based on three separate biological indices. These indices are the Index of Biotic Integrity (IBI) and Modified Index of Well-Being (MIwb) for fish and the Invertebrate Community Index (ICI) for aquatic macroinvertebrates. A detailed description of Ohio EPA's biological assessment and biocriteria program, including specifics on each index and how each was derived, is available (see Biological Criteria for the Protection of Aquatic Life, epa.ohio.gov/dsw/bioassess/BioCriteriaProtAqLife.aspx).

Procedures established in a specially designed 1983-1984 U.S. EPA study known as the *Stream Regionalization Project* (Whittier et al. 1987) were used to select reference, or least-impacted sites, in each of Ohio's five Level III ecoregions (Omernik 1987). Biological data from a subset of these sites in addition to supplemental data from other least-impacted Ohio reference sites were used to establish the ecoregion-specific biocriteria for each aquatic life use. Note that some criteria vary according to stream size and some indices do not apply in certain circumstances. Ohio's WQS rule stipulates that "biological criteria provide a direct measure of attainment of the warmwater habitat, exceptional warmwater habitat and modified warmwater habitat aquatic life uses" (OAC 3745-1-07(C)). The numeric biological criteria based on IBI, MIwb and ICI thresholds applicable to exceptional warmwater habitat (EWH), warmwater habitat (WWH), and modified warmwater habitat (MWH) waters are found in Table 7-1 of the WQS rule. Neither coldwater habitat (CWH) nor limited resource water (LRW) streams have numeric biological criteria at this time, so attainment status must be determined on a case-by-case basis. For sites and segments designated with these aquatic life uses, attainment status was determined by using biological data attributes (for example, presence and abundance of coldwater species in CWH streams) and/or interim assessment index targets (for example, those for LRW streams, Lake Erie lacustraries, Lake Erie shoreline) to assess consistency with the narrative aquatic life use definitions in the WQS.

General Determination of Attainment Status

A biological community at an EWH, WWH or MWH sampling site must achieve the relevant criteria for all three indices, or those available and/or applicable, to be in full attainment of the designated aquatic life use criteria. Partial attainment is determined if one criterion is not achieved while non-attainment results when all biological scores are less than the criteria or if poor or very poor index scores are measured in either fish or macroinvertebrate communities.

A carefully conceived ambient monitoring approach, using cost-effective indicators consisting of ecological, chemical and toxicological measures, can ensure that all relevant pollution sources are judged objectively based on environmental results. Ohio EPA relies on a tiered approach in attempting to link the results of administrative activities with true environmental measures. This integrated approach includes a hierarchical continuum from administrative to true environmental indicators. The six levels of indicators include: 1) actions taken by regulatory agencies (permitting, enforcement, grants); 2) responses by the regulated community (treatment works, pollution prevention); 3) changes in discharged quantities (pollutant loadings); 4) changes in ambient conditions (water quality, habitat); 5) changes in uptake and/or assimilation (tissue contamination, biomarkers, wasteload allocation); and, 6) changes in health, ecology or other effects (ecological condition, pathogens). In this process, the results of administrative activities (levels 1 and 2) can be linked to efforts to improve water quality (levels 3, 4 and 5), which should translate into the environmental results (level 6). Thus, the aggregate effect of billions of dollars spent on water pollution control since the early 1970s can now be determined with quantifiable measures of environmental condition.

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

Identifying the most probable causes of observed impairments revealed by the biological criteria and linking this with pollution sources involves an interpretation of multiple lines of evidence including water chemistry data, sediment data, habitat data, effluent data, biomonitoring results, land use data and biological response signatures within the biological data themselves. Thus, the assignment of principal causes and sources of impairment represents the association of impairments (defined by response indicators) with stressor and exposure indicators. The identified causes of impairment will serve as the target parameters for future total maximum daily load (TMDL) development or regulatory program actions.

Adequate sampling is necessary to represent the aquatic life use attainment status for large river assessment units (LRAUs, each average 32 miles in length) or watershed assessment units (WAUs, each an average 28 mi² in surface area). These assessment units are defined in Sections D1 and G2 of this report. Despite Ohio EPA's significant commitment to biological sampling efforts, 100 of Ohio's 1,538 WAUs (6.5

percent) are precluded from this analysis because of no or insufficient data. All large Ohio rivers with LRAU reaches have sufficient data to be evaluated for aquatic life use attainment. While some data may be available for some of the WAUs, many have no water quality monitoring data, or the scope of monitoring was judged to be too limited to adequately generate an assessment. Generally, at least two sample sites are minimally considered necessary for a WAU assessment, although under specific circumstances, a WAU may be evaluated with one site. Presently, Ohio EPA prefers that the principal investigators make informed decisions about the data relevance for a particular AU evaluation rather than institute specific guidance on minimum effort.

Recognizing the state's limited resources, one way to increase assessment unit coverage is to utilize all available relevant Level 3 credible data. While Ohio EPA uses data from a variety of sources, the data used to determine the aquatic life use status in this report were primarily collected by Ohio EPA. For this report and some past reports, additional biological data were provided by the Ohio Department of Natural Resources (ODNR), Northeast Ohio Regional Sewer District (NEORS), U.S. Geological Survey (USGS), the University of Toledo, the Ohio State University, National Center for Water Quality Research (NCWQR) at Heidelberg College, Midwest Biodiversity Institute (MBI), Cleveland Metroparks and EnviroScience, Inc. Those interested in providing data to Ohio EPA for aquatic life use attainment status determinations must attend appropriate training provided by Ohio EPA or its designee through the Ohio Credible Data Program Level 3 Certification, and document and retain competency in Ohio EPA biological sampling protocols. All data used to make attainment determinations are carefully reviewed for consistency with all Ohio EPA methods and guidance.

G2. Evaluation Method

Rivers and Streams: Large River Assessment Units (LRAUs)

Decades of monitoring work by Ohio EPA have resulted in an extensive data set that includes data for all 38 large river assessment units in Ohio with sampling spanning 2003-2018. The longitudinal sampling pattern (upstream to downstream and bracketing pollution sources and tributaries) used to measure fish community health, macroinvertebrate community condition and water chemistry allows WQS biocriteria attainment status to be rather precisely estimated based on linear distances. The length of the large river deemed to be in full attainment, as described in the previous section, is divided by the total assessed length of the large river and multiplied by 100 to yield a value between 0 (no miles in attainment) and 100 (all miles in attainment). An LRAU is considered meeting its designated aquatic life use only if a score of 100 is reported. In other words, if all miles are not in full attainment of the designated aquatic life use, the entire LRAU is listed as impaired and placed in IR Category 4 or 5, depending on whether a TMDL is required.

Rivers and Streams: Watershed Assessment Units (WAUs)

Beginning with the 2010 IR, the aquatic life use assessment methodology defined the WAU as the U.S. Geological Survey 12-digit hydrologic unit code watershed, or HUC12 (1,538 HUC12s averaging 28 mi² drainage areas), rather than the 11-digit HUC watershed (331 HUC11s averaging 130 mi² drainage areas) used in prior IRs. Reporting on the HUC12 scale provides information on a finer scale and allows for better reporting of watershed improvements.

This dramatic reduction in assessment unit size requires consideration of what constitutes adequate sampling within each HUC12 WAU and appropriate evaluation of the sampling results. The relatively small drainage area of the HUC12 WAU requires that the sites evaluated adequately characterize the smaller watershed. For that reason, three scores will be determined for each WAU when sufficient data make this possible. A headwater assessment score that characterizes the aquatic community of the WAU by itself will

occur by evaluating all sites with drainage area <20 mi² together. A wading stream score will be determined for all sites with drainage area between 20 mi² and 50 mi² that occur within the WAU. The wading stream score is necessary since a site between 20 mi² and 50 mi² characterizes the entire watershed upstream from the site, potentially two or more HUC12s, not just to the extent of the WAU boundary where the site resides. A principal stream score for sites >50 mi² will also be calculated, as these larger streams reflect a much greater land area than sites at a smaller drainage area. The final assessment unit score will be derived from these three scores. The table below represents this graphically.

Table G-1 — Watershed Assessment Unit Score Determination

WAU (HUC12)	Headwater Assessment — HA (<20 mi ²)			Wading Assessment — WA (≥ 20 mi ² <50 mi ²)			Intermediate Score (IS)	Principal Assessment — PA (≥ 50 mi ² <500 mi ²)			WAU Score
	Total Sites	# Sites Full	HA Score	Total Sites	# Sites Full	WA Score	$\frac{HA+WA}{2}$	Total Sites	# Sites Full	PA Score	$\frac{IS+PA}{2}$

While the smaller size of the HUC12 WAU greatly reduces the number of sites necessary to be assessed, this creates an emphasis on appropriate sampling locations within the assessment unit. To ensure that decisions regarding adequate coverage are uniformly carried out, a flow chart for the process was created (Figure G-1). The flow chart considers the drainage area associated with a minimal number of sites and incorporates questions as to spatial proximity of the sites within the watershed, land use consistency among sampling locations, and location of significant dischargers within the WAU. Final determination of adequate coverage is guided by the flow chart but can be overridden by the assessor in unique circumstances.

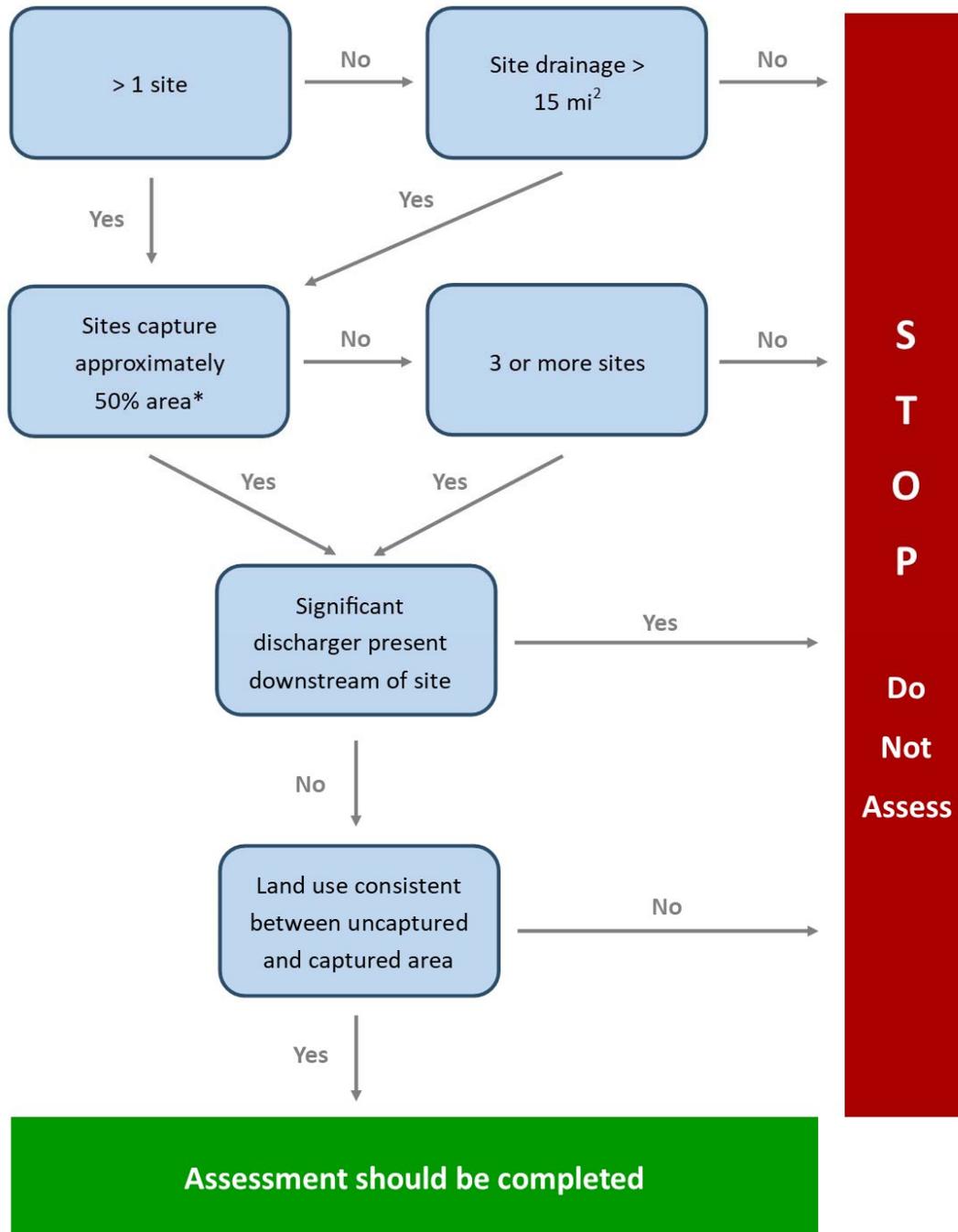
Once it is determined that sampling coverage is adequate to conduct a WAU assessment, the number of headwater sites demonstrating full aquatic life use attainment are divided by the total number of headwater sites within the WAU. The quotient is then multiplied by 100 to provide the headwater score.

Determining the wading stream and principal stream scores involve a similar approach. The wading stream score is based on the number of wading stream sites (sites draining a watershed between 20 mi² and 50 mi²) demonstrating full attainment of aquatic life use. The total number of wading stream sites in full attainment are divided by the total number of wading stream sites. The quotient is then multiplied by 100 to provide the wading stream score. The same methodology is used to produce the principal stream score, but the scoring is limited to those sites in the WAU draining >50 mi².

An intermediate WAU score is calculated as the average of the headwater and wading stream scores. The overall WAU score is derived by averaging the intermediate score and the principal stream score. For HUC12s without principal streams, the intermediate stream score will represent the overall WAU score. This procedure provides some weighting to the assessment when principal stream miles are present (more influence on the final watershed score by principal streams). This weighting is important in that full use or impairment within the principal streams reflects the overall condition of the much larger primary watershed. A manual scoring adjustment is made in those few instances when a WAU score, with many principal stream sites, is unduly affected by the results from one headwater or one wading site. A WAU meets its aquatic life designated use only if a score of 100 is reported. In other words, if all sites are not in full attainment of the designated aquatic life use, the WAU is listed as impaired and placed in IR Category 4 or 5, depending on whether a TMDL is required.

Additional synthesis of data was used to provide aggregate statewide statistics for Ohio's universe of assessed wading and principal streams and rivers (> 20 mi² drainage areas) and large rivers (> 500 mi² drainage areas). Baseline IR statistics generated beginning with the 2010 IR were used along with the updated 2020 IR results to track trends of attainment levels across Ohio's watersheds and large rivers to

quantify progress made in point and nonpoint source pollution controls and in meeting Ohio’s goals of 80 percent full aquatic life use attainment by 2020 for assessed WAU wading and principal stream and river sites and 100 percent full aquatic life use attainment by 2020 for assessed LRAU miles.



* If the WAU contains a large amount of open water, such as a lake or reservoir, that area will be deducted from the total drainage area for this criterion.

Figure G-1 — Flowchart for determining if WAU score can be derived based on available sampling locations.

Lake Erie Shoreline and Islands: Lake Erie Assessment Units (LEAUs)

Aquatic life use determinations are predicated on a narrative description of the aquatic community associated with the relevant use tier. In the absence of numeric criteria, the narrative expectation provides the impairment determination. In 1997, Ohio EPA completed the *Development of Biological Indices Using Macroinvertebrates in Ohio Nearshore Waters, Harbors, and Lacustraries of Lake Erie in Order to Evaluate Water Quality* (Ohio EPA, 1995). In 1999, *Biological Criteria for the Protection of Aquatic Life: Volume IV: Fish and Macroinvertebrate Indices for Ohio's Lake Erie Nearshore Waters, Harbors, and Lacustraries* was produced (Ohio EPA, 1997 Draft). Also, in 1999, *Biological Monitoring and an Index of Biotic Integrity for Lake Erie's Nearshore Waters* (Thoma, 1999) was published as a book chapter in *Assessing the Sustainability and Biological Integrity of Water Resources Using Fish Communities* (Simon, editor, 1999). The data analyses in these documents, including refinement of field sampling protocols and development of assessment indices, provide a foundation to establish numeric biological targets/expectations using IBI and MIwb scores for aquatic life use in Lake Erie along the Ohio shoreline and in lacustrary areas. The term lacustrary was coined to specify the zone where Lake Erie water levels have intruded into tributary river channels. The aquatic life use status of a lacustrary is included as part of the assessment of the tributary WAU or LRAU.

Excluding lacustraries, the status of the Lake Erie shoreline and islands is currently evaluated using fish community assessment targets for the Lake Erie IBI and MIwb based on night electrofishing at sites included in the four shoreline LEAUs: Lake Erie Western Basin Shoreline (including Maumee Bay); Lake Erie Sandusky Basin Shoreline; Lake Erie Central Basin Shoreline; and Lake Erie Islands Shoreline. All available fish data were collected within 100 meters of the mainland, bay or island shoreline. Status of LEAUs was determined by the percentage of sites in narrative full attainment of biological targets (scaled to prevailing shoreline habitat type) and where sufficient and current biosurvey data were available.

Ohio EPA was awarded a Great Lakes Restoration Initiative (GLRI) grant in 2010 to develop a comprehensive Lake Erie shoreline monitoring program. This 2011-2013 project included a strategy to design and implement a monitoring program for the Ohio Lake Erie shoreline zone (including bays, harbors and lacustraries) that can be maintained on an annual basis.

The GLRI grant was a collaborative effort between state agencies (Ohio EPA and ODNR) and major universities with Lake Erie basin research interests and expertise (the Ohio State University, University of Toledo, John Carroll University and Heidelberg University). Physical, chemical and biological parameters monitored from 2011-2013 provided data to support long-term trend analysis, establish background conditions in selected areas and conduct sampling related to the impacts of projects implemented in tributaries of the Lake Erie watershed. Data will be used to monitor the progress of implementation projects in Areas of Concern (AOCs) to restore beneficial uses, track implementation of WAPs, develop TMDLs for pollutants impairing beneficial uses, support Balanced Growth Initiative actions on the shoreline, and provide updated information for IRs, Lake Erie quality index updates, and updates to the Lake Erie Lakewide Management Plan (LAMP). More information about the Great Lakes Restoration Initiative and projects which have been proposed can be found at the Ohio Lake Erie Commission website (see Great Lakes Restoration Initiative, lakeerie.ohio.gov/GLRI.aspx).

Details of the monitoring conducted in 2017 and 2018 are provided in the study plans available at epa.ohio.gov/dsw/lakeerie/index.aspx#125073721-nearshore-monitoring. Of note for future Lake Erie assessments will be the collection of shoreline data for the National Aquatic Resource Survey (NARS) of coastal waters of the United States (the National Coastal Condition Assessment - NCCA) which was conducted during the summer of 2015. Coordinated by U.S. EPA in collaboration with Great Lake states,

these one-visit snapshots of lake water quality will be used to provide statistically valid national and regional assessments of Great Lakes resource condition. Additional information about the 2010 NCCA and the latest 2015 NCCA results, when available, can be found at the U.S. EPA NARS website (see National Aquatic Resource Surveys, epa.gov/national-aquatic-resource-surveys).

G3. Results

For the 2020 IR, new aquatic life data collected in 2017 and 2018 were incorporated into the assessment database. During this period, biosurvey data from 530 sampling sites located in 96 HUC12 WAUs, 40 sampling sites located in five LRAUs and 22 sampling events in four of the seven LEAUs were available to completely or partially update previously assessed AUs or provide new assessments for AUs with unknown aquatic life status. All data were collected by Ohio EPA or Level 3 Qualified Data Collector external sources. Watersheds intensively monitored during 2017 and 2018 included the Tuscarawas River basin, Sugar Creek basin, Whitewater River basin, Swan Creek basin, Toussaint River basin, lower Maumee River basin, Western Lake Erie tributaries, and Cuyahoga River basin. The large rivers comprehensively reassessed were the Tuscarawas River, Whitewater River, and Cuyahoga River. Detailed watershed survey reports for many of the basins mentioned above are or will be available from Ohio EPA's Division of Surface Water (see Biological and Water Quality Report Index, epa.ohio.gov/dsw/document_index/psdindx.aspx).

Summarized 2020 IR statistics for aquatic life assessments for large river, watershed and Lake Erie AUs as well as the comparable statistics from the 2002-2018 IRs are tabulated in Table G-4. More detailed aquatic life use results and statistics for each 2020 AU (watershed, large river and Lake Erie units), along with similar data from previous IRs, are provided via interactive maps at epa.ohio.gov/gis.aspx.

LRAUs

LRAUs in Ohio (38 LRAUs spanning 23 rivers with watersheds greater than 500 square miles and totaling 1,248 river miles) remained essentially unchanged in percent of monitored miles in full attainment compared to the same statistic reported in the 2018 IR (Table G-4, Figure G-2). Based on monitoring through 2018, the full attainment statistic now stands at 88.2 percent (1,097 of 1,243 assessed LRAU miles), up 0.7 percent from the 2018 IR. Significant large rivers assessed for the 2020 IR included the Tuscarawas River (2017), Whitewater River (2017), and Cuyahoga River (2017). Attainment statistics for these three rivers (five LRAUs) are as follows.

- Tuscarawas River: 88.8 percent full attainment over 103.2 miles
- Whitewater River: 100 percent full attainment over 8.3 miles
- Cuyahoga River: 77.9 percent full attainment over 24.2 miles

Progress toward the 100 percent by 2020 aquatic life use goal for Ohio's large rivers is depicted in Figure G-2. Between the 2002 and 2020 reporting cycles, the percentage of large river miles in full attainment has increased from 62.5 percent to 88.2 percent and nearly 100 percent of total miles have been assessed. While the 100 percent full attainment by 2020 goal for large rivers was not reached, Ohio EPA is committed to continued support of this effort. In 2020, the Agency will complete a statewide large river survey covering every LRAU, the results of which will be reported in the 2022 IR. This statewide survey is planned to occur every 10 years thereafter to continue monitoring long-term trends.

Figure G-3 shows the top five aquatic life use impairment causes across the state for LRAUs. Principal causes for LRAU impairments are commonly linked back to impoundments, whether that be directly through habitat/hydromodification or with sediment/nutrient/organic loading that is exacerbated by the impounded sections. Figure G-4 depicts the attainment status breakdown of the 38 LRAUs by designated or recommended (existing) aquatic life use. As would be expected, most LRAUs (78.9 percent) include reaches

assigned the base warmwater habitat (WWH) aquatic life use, for which attainment of biocriteria signifies meeting the fishable/swimmable goal of the Clean Water Act (CWA). For this cycle, about 40 percent of LRAUs with WWH segments are fully meeting the WWH use. About 36.8 percent of the LRAUs have segments assigned the more protective aquatic life use of exceptional warmwater habitat (EWH), and these have a higher rate of attainment. Three of the five LRAUs with modified warmwater habitat – impounded (MWH-I) segments are meeting the biocriteria for that sub-goal use.

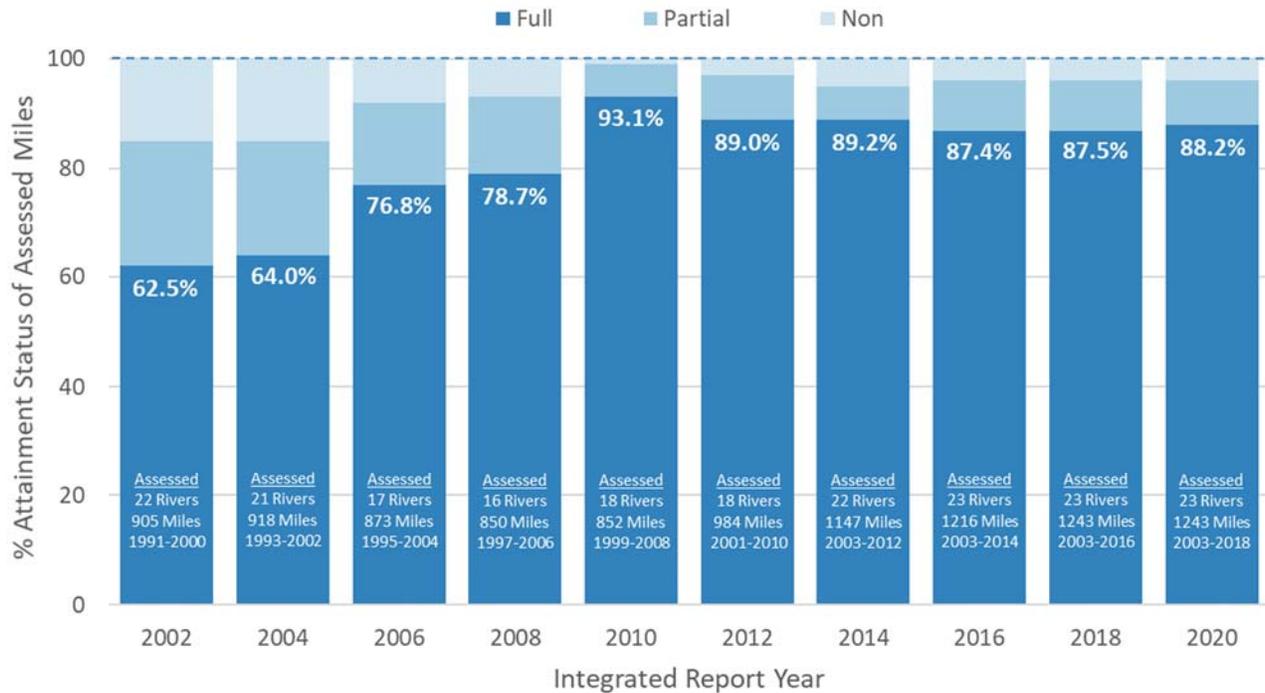


Figure G-2 — Percent attainment status and goal progress (“100% by 2020”) for monitored miles of Ohio’s large river assessment units (23 rivers/38 AUs/1247.54 miles total).

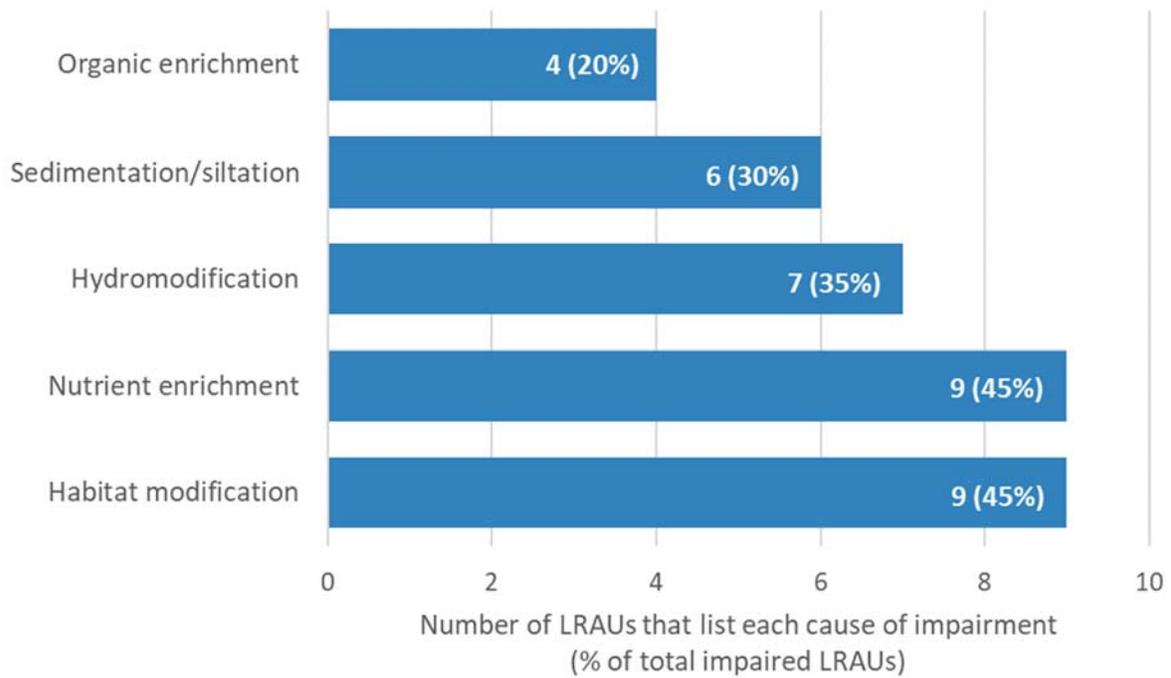


Figure G-3 — Top five causes of impairment in LRAUs.

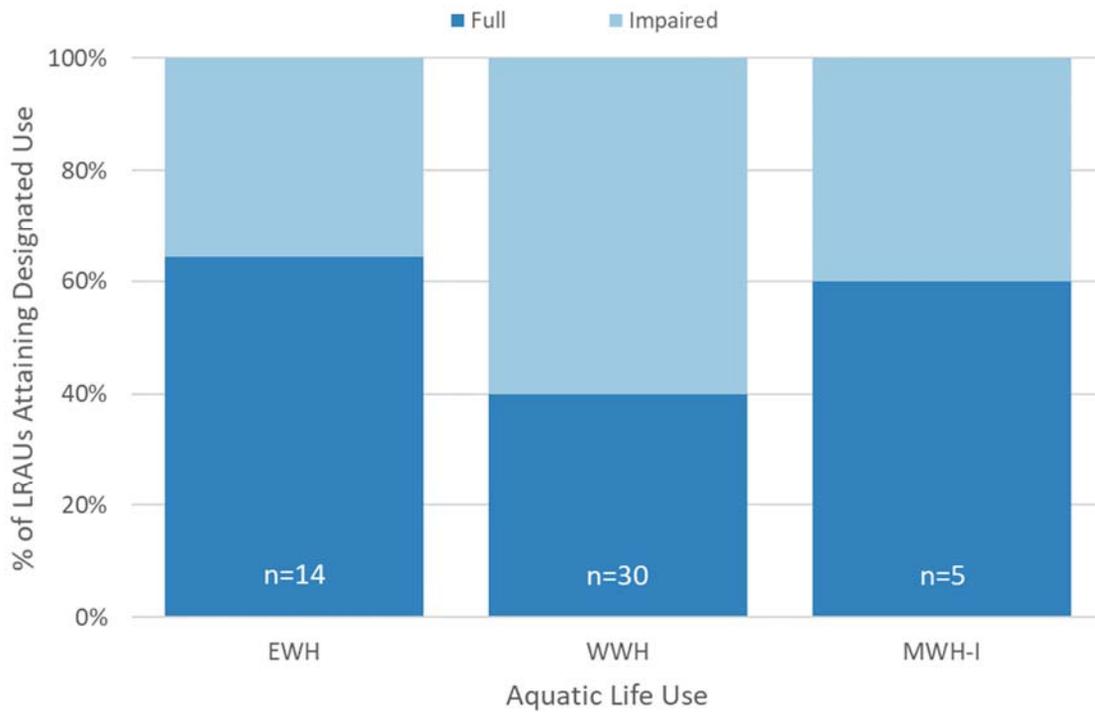


Figure G-4 — Summary of attainment status of LRAUs by aquatic life use.

EWH: exceptional warmwater habitat, WWH: warmwater habitat, and MWH-I: modified warmwater habitat – impounded. LRW: limited resource water and SSH: seasonal salmonid habitat not included due to negligible dataset size.

WAUs

For the 2020 IR, the average HUC12 WAU score remained essentially unchanged from the corresponding score reported in the 2018 IR (Table G-4, Figure G-6). Based on monitoring through 2018, the average HUC12 WAU score stands at 64.3, a 0.1-point increase from the 2018 IR and a 7.6-point increase from the HUC12 baseline year of 2010. The WAU score is roughly equivalent to the percentage of monitored sites with full aquatic life use attainment in WAUs assessed for this IR cycle. Included in Table G-4 and depicted in Figure G-6 is the corresponding average score based on the old HUC11 WAUs, which were tracked from 2002 through 2010.

Table G-2 depicts the breakdown of site full attainment based on the watershed size category used to determine an individual watershed's score based on available sites in the HUC12 WAU. As in previous reports, the results show that biological impairment is more likely at sites on small streams (more than four in 10 headwater sites are impaired) and that impairment lessens significantly as sites drain larger areas (nearly seven in 10 assessed principal stream and small river sites, 68.7 percent, are in full attainment).

Progress towards the 80 percent by 2020 aquatic life use goal for Ohio's wading and principal stream and river sites (those monitored sites draining watersheds between 20 and 500 square miles) is depicted in Figure G-5 for the 2020 IR cycle. Contrasted with the 2010 IR statistic, when the 2020 goal benchmark was established, the percentage of qualifying sites in full attainment has increased more than seven percentage points from 61.4 percent to 68.7 percent. While the 80 percent goal was not met, Ohio EPA will continue to fund implementation and monitoring across the state with the constant goal of improvement. Moving forward, it will be critical that resources be directed to follow-up monitoring in areas with implemented restoration and protection projects so that success of efforts can be documented and reflected in future goal statistics. This latter effort is now well underway in survey areas with TMDLs approved and implemented beginning in the late 1990s and is an ongoing activity in support of the Ohio EPA Nonpoint Source Program (see epa.ohio.gov/dsw/nps/index.aspx for more program information).

Figure G-7 shows the top five aquatic life use impairment causes across the state. Principal causes for HUC12 WAU impairments were those primarily related to landscape modification issues involving agricultural land use and urban development. These types of impairments would be most manifest in smaller streams. Over half of the impaired WAUs had at least one monitored site impaired by one of these individual causes and many WAUs had several sites affected by three or more of the five causes listed as responsible for the aquatic life use impairment. This would not be an unusual situation given the frequently close association between these impairment causes (for example, nutrients, sedimentation/siltation, habitat modifications and hydromodifications in rural/agricultural landscapes relying on channelization and field tiles for drainage).

Figure G-8 depicts the attainment status breakdown of the 1,538 WAUs by designated or recommended (existing) aquatic life use. As would be expected, most WAUs (87.6 percent) include streams assigned the base warmwater habitat (WWH) aquatic life use, for which attainment of biocriteria signifies meeting the fishable/swimmable goal of the Clean Water Act (CWA). For this cycle, about 32 percent of WAUs with WWH streams are fully meeting the WWH use. Assessment units with streams assigned more protective aquatic life uses (exceptional warmwater habitat-EWH, coldwater habitat-CWH or a dual use which includes both-EWH/CWH) are much more likely to be in full attainment (between 60 and 85 percent). Assessment units with streams assigned less than goal CWA uses (modified warmwater habitat-MWH and limited resource water-LRW) have lower achievement of the lessened expectations (between 22 and 45 percent full attainment). Both more protective and less than goal uses are only assigned after a use

attainability analysis has been conducted based on rigorous field data and this study determines that the assigned aquatic life use is the most appropriate to protect existing high-quality/unique biological communities or set reasonable restoration benchmarks for communities challenged by pervasive anthropogenic or natural influences.

Table G-2 — Breakdown by watershed size category of sites in full, partial and non-attainment in monitored WAUs based on data collected primarily from 2009-2018.

Watershed Size Category (mi ²)	# of Sites (% of total)	Number of Sites in Full Attainment (%)	Number of Sites in Partial Attainment (%)	Number of Sites in Non-Attainment (%)
0-20 (headwater)	2,242 (63.5%)	1,274 (56.8%)	445 (19.8%)	523 (23.3%)
20-50 (wading)	557 (15.8%)	354 (63.6%)	122 (21.9%)	81 (14.5%)
50-500 (principal)	734 (20.8%)	533 (72.6%)	135 (18.4%)	66 (9.0%)
Total	3,533	2,161 (61.2%)	702 (19.9%)	670 (19.0%)

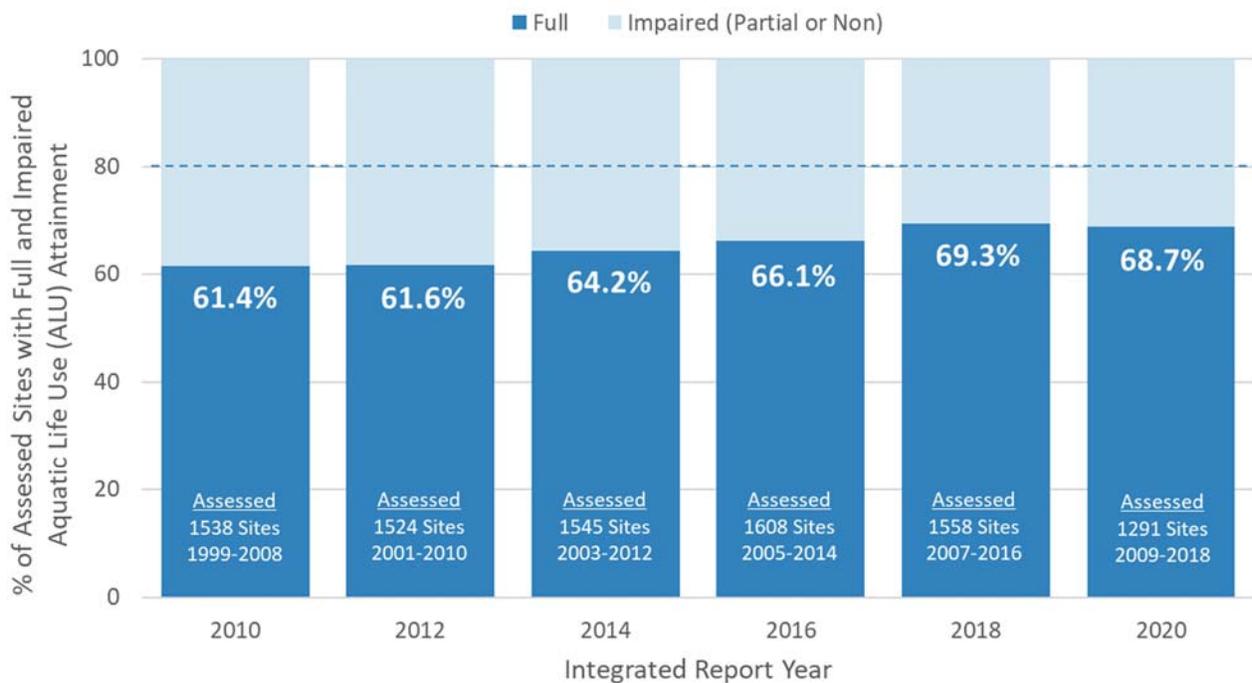


Figure G-5 — Status and trend of aquatic life use 80 percent by 2020 goal for wading and principal stream and river sites in Ohio based on the last six IR cycles.

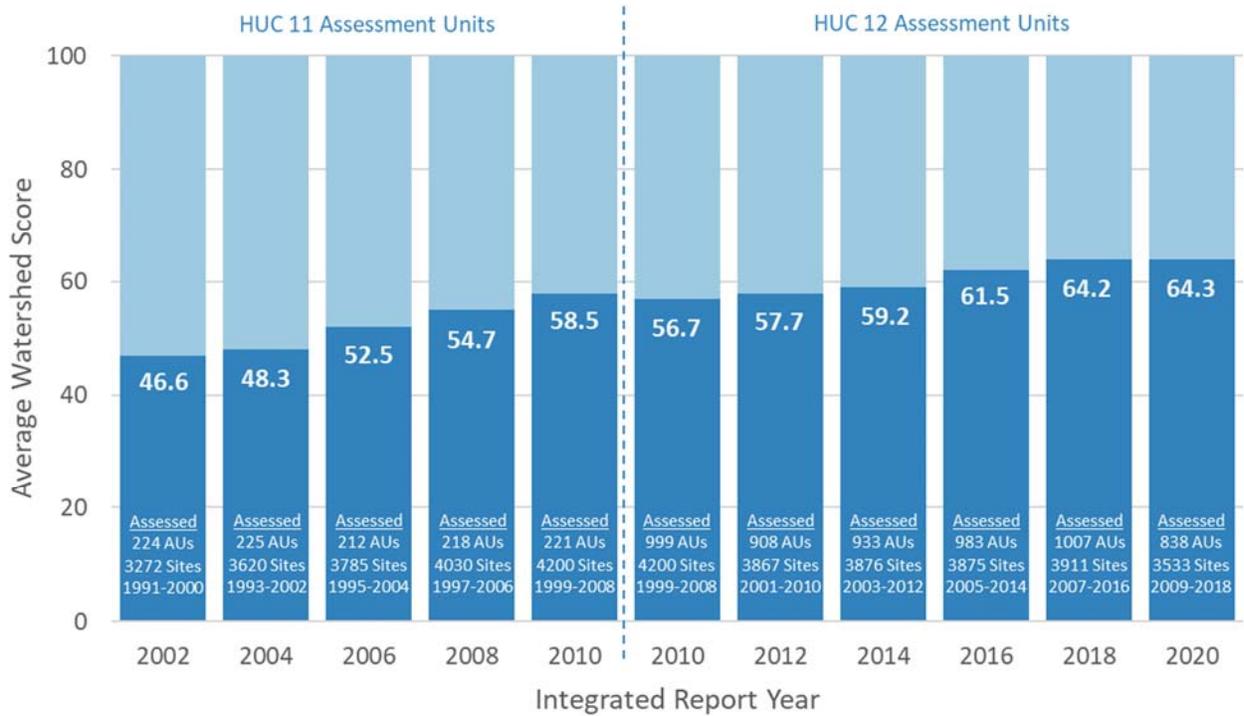


Figure G-6 — Average full attainment watershed score for monitored Ohio HUC11 watershed assessment units (IR cycles 2002-2010) and HUC12 watershed assessment units (IR cycles 2010-2018).

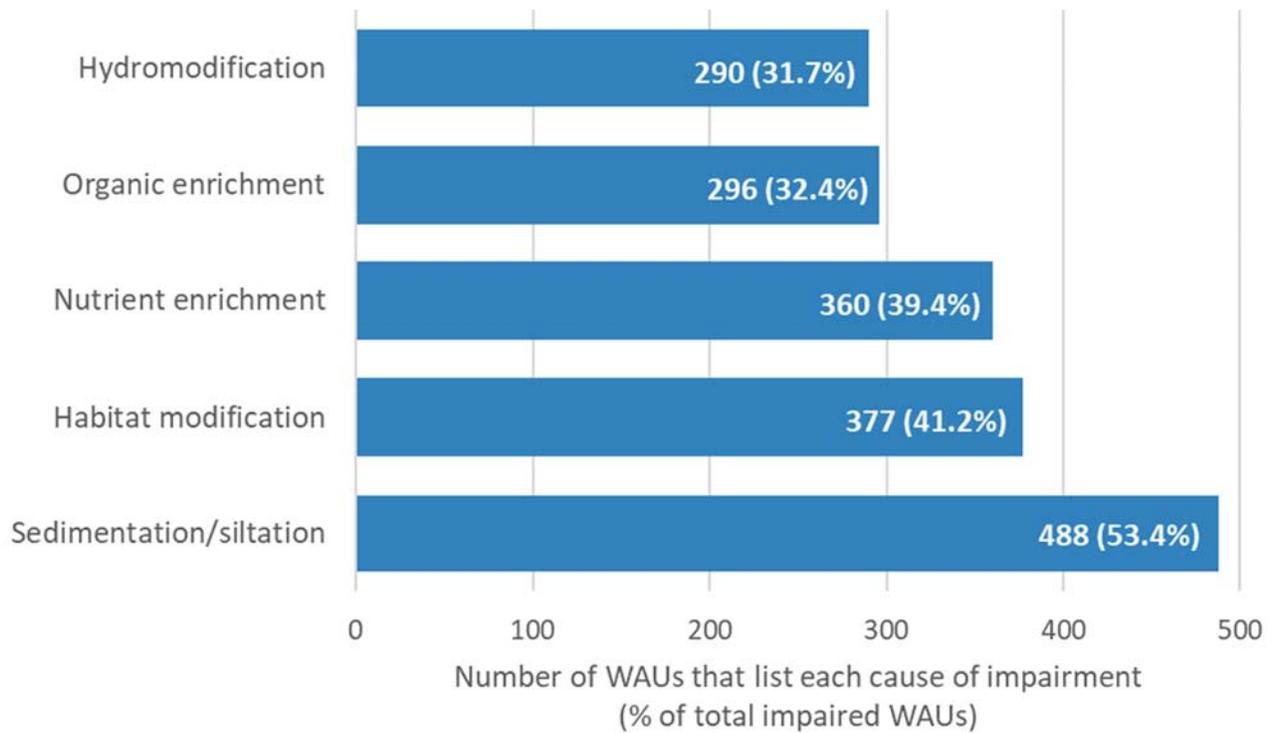


Figure G-7 — Top five causes of impairment in WAUs.

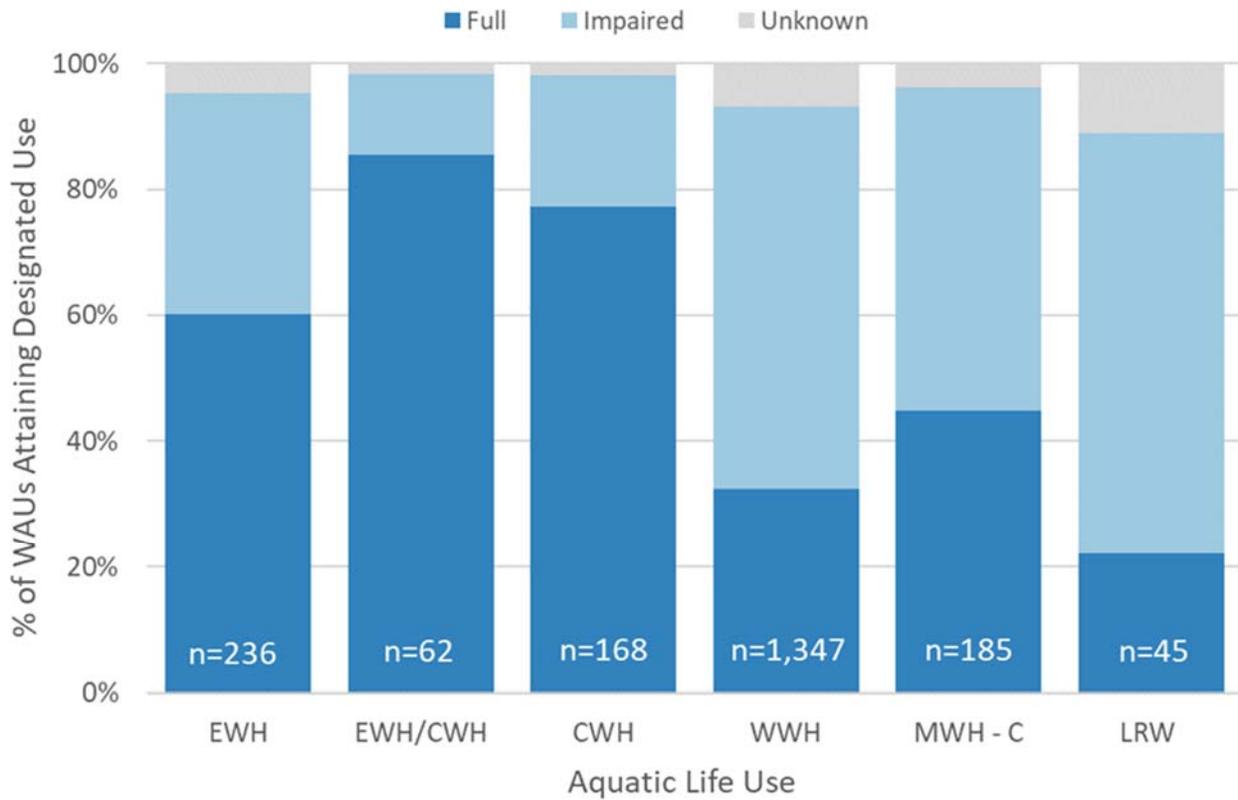


Figure G-8 —Summary of attainment status of WAUs by aquatic life use.

EWH: exceptional warmwater habitat, CWH: coldwater habitat, WWH: warmwater habitat, MWH-C: modified warmwater habitat – channel modified, LRW: limited resource water. MWH-I: modified warmwater habitat – impounded, MWH-MA: modified warmwater habitat – mine affected, and SSH: seasonal salmonid habitat not included due to negligible dataset size.

LEAUs

For previous IRs, assessments were based on past data collected in the mid-1990s through the early 2000s. Significant changes appear to be ongoing in Lake Erie, and, as a result, these older data are no longer being used to determine aquatic life use attainment status in the LEAUs. However, these data are used in the following discussion to highlight key trends in fish community condition over two time periods of sampling. Ohio EPA is in the process of developing new metrics for determining ALU attainment in all LEAUs. Section I4 of this report provides details about this work.

From 2011-2018, 161 fish community collections using electrofishing methods were taken from 35 sites spread over the shoreline LEAUs; these data serve as the core data set for assessment of Lake Erie status. For this cycle, and despite the rather limited amount of data, the assessment methodology as used in past IRs was once again used to determine aquatic life use status in the LEAUs. This included analysis of IBI and MIwb scores for all sampling passes available at a given sampling location compared to target expectations based on the prevailing bottom substrate type at that location (hard bottoms — bedrock, boulder, rubble or soft bottoms — sand, silt, muck). Results for the IBI and MIwb scores at 35 shoreline sites (excluding the shoreline located in Sandusky Bay and the Lake Erie Islands sites) compared to expectations are presented in Figure G-9 and Figure G-10.

All the shoreline LEAUs assessed remain Category 5 with significant impairment of sites due primarily to tributary loadings of nutrients and sediment, exacerbated by continued trophic disruptions caused by the proliferation of exotic species, algal blooms and shoreline habitat modifications. It is graphically apparent in Figure G-9 and Figure G-10 that most sampling events fail to meet expectations. Table G-3 below shows that fewer than 25% of the sampling events in the western, islands and Sandusky Basin shoreline LEAUs meet full attainment expectations. In the central basin 74% of the sampling events meet full attainment expectations.

Table G-3 — Sampling results attainment status for each of the shoreline LEAUs.

AUID	AU Name	# Sites	Electrofishing sampling results			
			Samples	# Full (% of total)	# Partial	# Non
041202000201	Lake Erie Western Basin Shoreline (including Maumee Bay)	11	93	23 (24.7%)	18	52
041202000101	Lake Erie Islands Shoreline	3	5	1 (20.0%)	2	2
041202000202	Lake Erie Sandusky Basin shoreline	4	25	5 (20.0%)	11	9
041202000203	Lake Erie Central Basin shoreline	17	38	28 (73.7%)	6	4

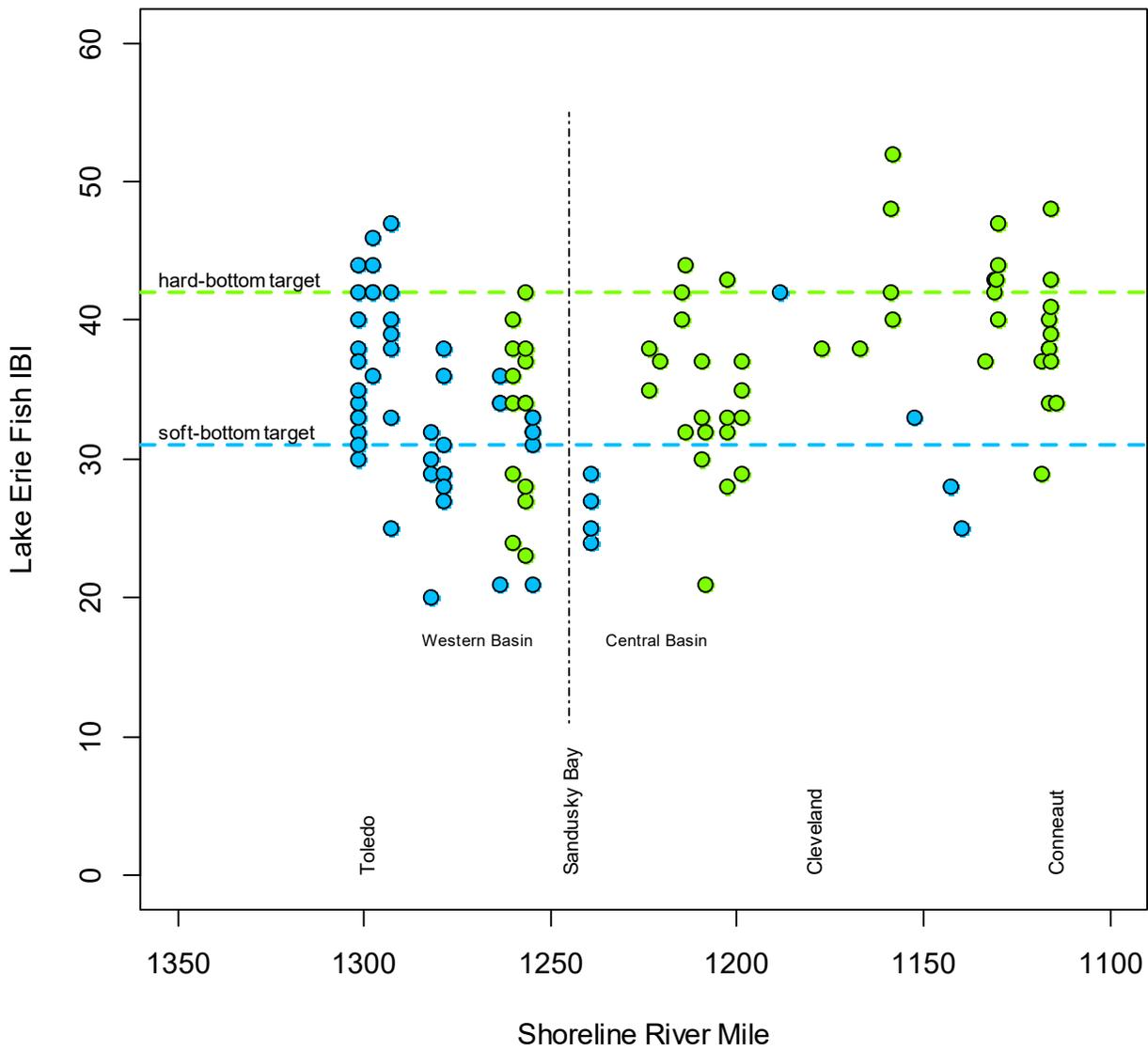


Figure G-9—IBI scores compared to habitat-scaled targets showing all sampling passes available for each site along the Lake Erie shoreline from Toledo to Conneaut, 2011-2018.

Figure does not include IBI scores for Sandusky Bay or Lake Erie Islands shoreline sites.

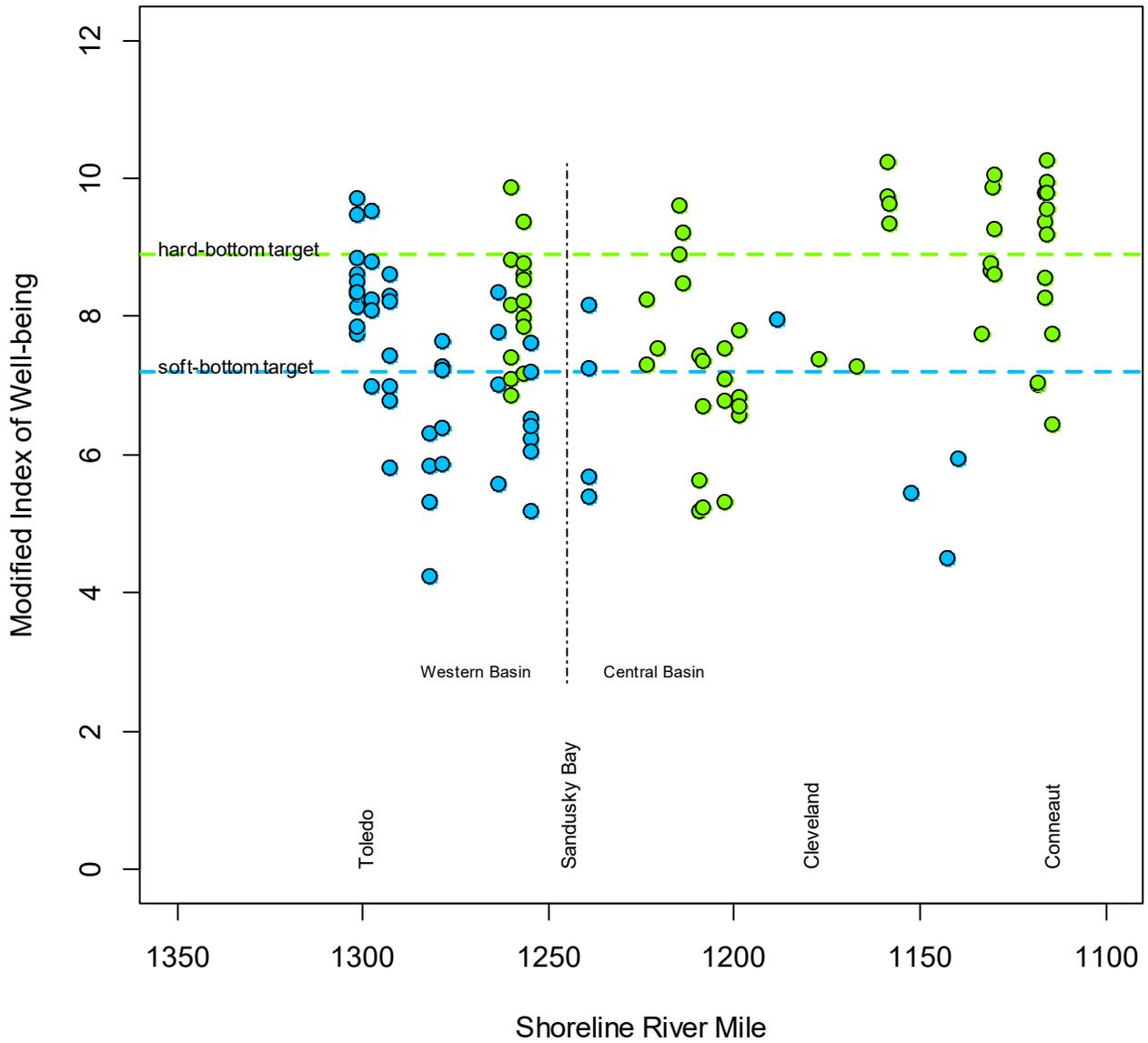


Figure G-10 — Average MIwb scores compared to habitat-scaled targets showing all sampling passes available for each site along the Lake Erie shoreline from Toledo to Conneaut, 2011-2018.

Figure does not include MIwb scores for Sandusky Bay or Lake Erie Islands shoreline sites.

For this IR, Ohio EPA incorporated multivariate statistical techniques to examine historical trends in LEAU ALU data. These techniques have been made accessible by the combination of modern computing power, open-source software, and highly approachable books¹, guides² and online texts³.

Distance measures evaluate a similarity distance between sites in terms of the species abundances. The most common distance measure used on biological assemblages is the Bray-Curtis⁴ distance. This distance is essentially the ratio between the total abundance of commonly held species between two sites, and the total abundance of all species collected at the two sites. With more species in common, the ratio will track closer to one. The other frequently used distance is Euclidean distance, and that can be thought of as the hypotenuse resulting if a given species abundance (or parameter measure) at two sites were taken as x-y coordinates (for instance, for three found at one site and four at the other, the coordinates would be 0,3 for the x; 0,4 for the y)⁵. Euclidean distances are more typically calculated for the environmental table after the environmental measures have been standardized based on how much each parameter at each assessment site deviated from the mean of all sites (z scores).

Once distance measures have been calculated for the biological matrix, groups of sites can be identified using hierarchical clustering. Essentially, the clustering algorithm identifies the two most similar sites (or least dissimilar) and joins them with a branch, finds the next two most similar objects (for instance, the sites joined previously are considered an object) and joins them, and so forth.

For the LEAU distance and hierarchical cluster analysis each electrofishing sampling event was considered. Ten cluster groups were derived with each group representing a different assemblage of fish species and abundance. These results were bifurcated by the Lake Erie period of rapid expansion of the invasive round goby (*Neogobius melanostomus*) in 1996. Assessment site sampling event results are presented by cluster group for pre and post 1996 sampling seasons in Figure G-11 and Figure G-12, respectively. These figures plot the results on an unprojected latitude and longitude matrix that can be easily interpreted as a map of Ohio's Lake Erie lacustraries and shoreline. Each figure includes a general description of the nature of the cluster groups.

A notable change in examining these two periods is the movement away from group 6, the primarily carp X goldfish group, in the Cuyahoga, Ottawa and Maumee lacustraries. This is generally attributed to water quality improvements in those urbanized/industrial areas and not due to the goby invasion. A shift away from an assemblage characterized by shorthead redhorse, white bass and silver chub in the lower Maumee after 1996, is more generally attributed to community changes due to the goby and expansion of flathead catfish.

1 Gauch, H.G., 1982. *Multivariate analysis in community ecology* (No. 1). Cambridge University Press.

2 McCune, B. and Mefford, M.J., 1999. PC-ord. *Multivariate analysis of ecological data, version, 4(0)*.

3 Oksanen, J., 2009. Multivariate analysis of ecological communities in R: vegan tutorial. URL:[<http://cc.oulu.fi/jarioksa/opetus/metodi/vegantutor.pdf>].

Zuur, A.F., Ieno, E.N., Walker, N.J., Saveliev, A.A. and Smith, G.M., 2009. Mixed effects models and extensions in ecology with R. Gail M, Krickeberg K, Samet JM, Tsiatis A, Wong W, editors. *New York, NY: Spring Science and Business Media*.

4 Beals, E.W. (1984). Bray-Curtis ordination: an effective strategy for analysis of multivariate ecological data. *Advances in Ecological Research*, 14, 1-55.

5 Euclidean distances are actually calculated from squared differences.

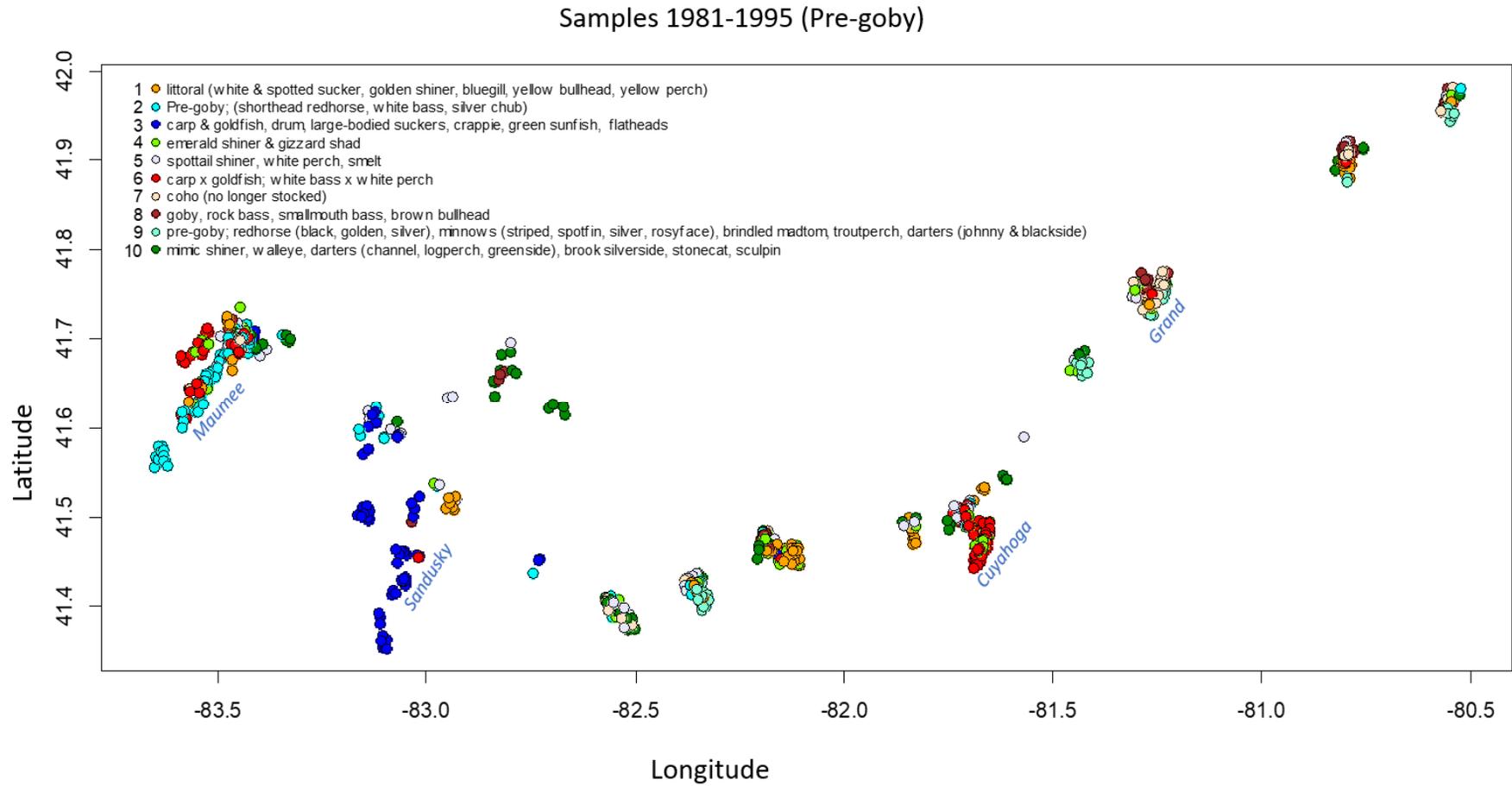


Figure G-11—Fish assemblage hierarchical cluster group of each electro-fishing sampling event in Lake Erie lacustraries and shoreline from 1981-1995 (pre-round goby invasion).

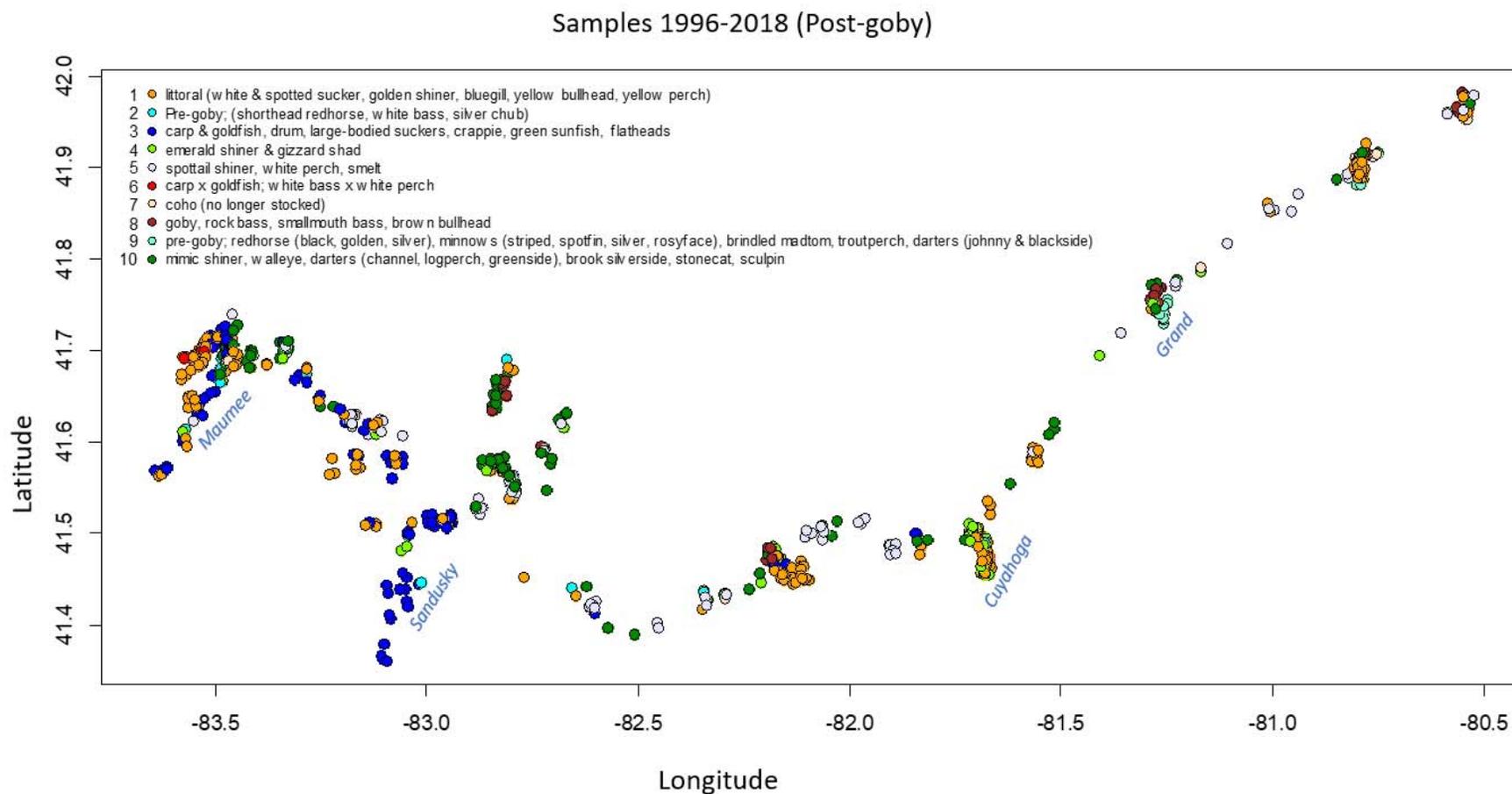


Figure G-12 — Fish assemblage hierarchical cluster group of each electro-fishing sampling event in Lake Erie lacustraries and shoreline from 1996-2018 (post-round goby invasion).

Table G-4 — Summary of aquatic life use assessment for Ohio's WAUs1, LRAUs and LEAUs: 2002-2020 IR cycles.

IR Cycle	2002 (1991-2000)	2004 (1993-2002)	2006 (1995-2004)	2008 (1997-2006)	2010 (1999-2008)	2012 (2001-2010)	2014 (2003-2012)	2016 (2005-2014)	2018 (2007-2016)	2020 (2009-2018)
HUC11 WAUs (331)										
No. AUs Assessed (% of total)	224 (68%)	225 (68%)	212 (64%)	218 (66%)	221 (67%)	-	-	-	-	-
No. Sites Assessed	3272	3620	3785	4030	4200	-	-	-	-	-
Average AU Scores										
Full Attainment	46.6	48.3	52.5	54.7	58.5	-	-	-	-	-
Partial Attainment	25.2	23.6	22.6	22.4	21.2	-	-	-	-	-
Non-Attainment	28.2	28.1	24.9	22.9	20.3	-	-	-	-	-
HUC12 WAUs (1538)										
No. AUs Assessed (% of total) ²	-	-	-	-	999 (65%)	908 (59%)	933 (61%)	983 (64%)	1,007 (65.5%)	838 (54.5%)
No. Sites Assessed	-	-	-	-	4200	3867	3876	3875	3911	3533
Average AU Score ³	-	-	-	-	56.7	57.7	59.2	61.5	64.2	64.3
% Sites Full Attainment	-	-	-	-	55.1	57.0	57.8	59.3	61.8	61.2
% Sites Partial Attainment	-	-	-	-	20.0	21.6	22.3	20.7	19.7	19.9
% Sites Non-Attainment	-	-	-	-	24.9	21.4	19.9	20.0	18.5	19.0
LRAUs (23 rivers/38 AUs totaling 1247.54 Miles)										
No. Rivers/AUs Assessed ⁴	22	21	17	16	18/30	18/31	22/37	23/38	23/38	23/38
No. Sites Assessed	422	425	374	278	265	312	332	358	370	364
No. Miles Assessed (% of total)	905 (70%)	918 (71%)	873 (68%)	850 (66%)	852 (69%)	984 (80%)	1,147 (92%)	1,216 (98%)	1,243 (99.7%)	1,243 (99.7%)
% Miles Full Attainment	62.5	64.0	76.8	78.7	93.1	89.0	89.2	87.4	87.5	88.2
% Miles Partial Attainment	23.0	21.4	15.1	13.9	5.5	7.5	6.3	8.7	8.8	8.2
% Miles Non-Attainment	14.5	14.6	8.1	7.4	1.4	3.5	4.5	3.9	3.7	3.6
LEAUs (4⁵)										
No. AUs Assessed	3	3	3	3	3	3	3	3	4 ⁵	4
No. Sites Assessed ⁶	92	111	93	49	34	23	38	45	47	35
% Sites Full Attainment	12.0	18.0	19.4	10.2	14.7	30.4	13.2	13.3	17.0	35.4⁷
% Sites Partial Attainment	13.0	14.4	16.1	22.4	17.7	30.4	34.2	31.1	25.5	22.9 ⁷
% Sites Non-Attainment	75.0	67.6	64.5	67.4	67.6	39.2	52.6	55.6	57.5	41.6 ⁷

¹ WAUs for the IR 2002-2010 cycles were based on HUC11s; WAUs transitioned to HUC12s for cycles beginning with 2010.

² 2010 statistics based on direct assessment of HUC12 AUs with data collected between 2005 and 2008 (n=545) and HUC11 extrapolated assessment of HUC12 AUs with data collected between 1998 and 2004 (n=454).

³ Statistic based on the average of available AU scores with up-to-date or acceptable data, derived as explained in Section G2.2.

⁴ LRAUs are assessed using data back to 2003 in statistics for IR cycles 2014-2020.

⁵ For the 2018 IR, LEAUs were refined to distinguish the Sandusky Bay shorelines and open water as a transition area between the western and central basins, resulting in four shoreline units that were assessed for aquatic life use.

⁶ Data for Lake Erie shoreline sites used in the 2002-2012 IR cycles were generally collected between 1993 and 2002; for the 2014-2020 IRs, data were collected 2011-2018.

⁷ Percentages are calculated upon number of sampling events in full attainment, partial attainment and non-attainment. Data are not grouped by site.