Fish Monitoring of the Littoral Zone at Shoreline Restoration Sites in Muskegon Lake

Carl R. Ruetz III[1] and Travis Ellens
Annis Water Resources Institute
Grand Valley State University
740 W. Shoreline Drive, Muskegon, Michigan 49441

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[1] Corresponding author; Office: 616-331-3946; E-mail: ruetzc@gvsu.edu

Introduction

Monitoring fish assemblages can provide information on the ecological health of freshwater habitats (Uzarski et al. 2005; Cooper et al. 2018). As such, fish monitoring can be used as a tool for assessing the effects of habitat restoration activities. An extensive shoreline restoration project was completed in Muskegon Lake during 2010 and 2011 (Ogdahl and Steinman 2014), which provided an opportunity to evaluate the ecological outcome of habitat restoration on the littoral fish assemblage. Fish surveys were conducted in Muskegon Lake during 2009-2011 as part of the original shoreline restoration project (Janetski and Ruetz 2015), providing pre-restoration data. The purpose of this survey was to evaluate the response of the littoral fish assemblage post restoration in Muskegon Lake.

Methods

Study sites.—Muskegon Lake is a large drowned river mouth that connects the Muskegon River to Lake Michigan (Steinman et al. 2008; Janetski and Ruetz 2015). Fish surveys were conducted at two restoration sites along the south shoreline: Heritage Landing and Grand Trunk (Table 1; Figure 1). One reference site (NW Reference) was sampled along the north shoreline (Table 1; Figure 1) to represent more natural shoreline conditions. In contrast, much of the wetland along the south shore of Muskegon Lake has been filled and shoreline hardened because of industrial activity and urban development (Alexander 2006; Steinman et al. 2008; Ogdahl and Steinman 2014).

Fish and environmental monitoring.—We sampled fish via fyke netting at each study site during 17-18 July 2018. Fyke nets were set during daylight hours and fished an average of 23.8 h (range = 22.8-24.3 h) at an average water depth of 87.7 cm (Table 2). Three fyke nets (4-mm mesh) were fished at each site following the protocol of Janetski and Ruetz (2015). Briefly, two fyke nets were set parallel to the shoreline with mouths facing each other and connected at the leads. The third fyke net was placed about 30-50 m from the parallel nets, perpendicular to the shoreline, with the net's mouth facing the shoreline. A detailed description of the fyke nets is provided in Breen and Ruetz (2006), and the type of fyke nets we used select for small-bodied fish (Ruetz et al. 2007). Each fish captured was identified to species, measured (total length), and released in the field; however, some specimens were preserved to confirm identifications in the laboratory. We calculated a fish-based index of biotic integrity (IBI) score for each site using an IBI developed by Uzarski et al. (2005) for Great Lakes coastal wetlands that was modified to better represent anthropogenic disturbance (based on land use and water quality) across a gradient of drowned river mouths (Appendix A). A high score suggests a "healthier" ecosystem, whereas a low score suggests a "degraded" ecosystem.

Environmental conditions were measured at each site. We measured water temperature (°C), dissolved oxygen (mg/L and % saturation), specific conductivity (µS/cm), total dissolved solids (g/L), turbidity (NTU), pH, and chlorophyll *a* (µg/L) in the middle of the water column using a YSI 6600 multi-parameter data sonde near the mouth of each fyke net. We measured water depth at the mouth of each fyke net, organic sediment depth (see Cooper et al. 2007b), and visually estimated the percent cover of submerged aquatic vegetation (SAV) for the length of the lead between the wings of each fyke net.

Results and Discussion

2018 Monitoring.—Environmental conditions were fairly consistent among the three fish sampling sites, although we tended to measure conditions more indicative of better water quality at the reference site compared with the two restoration sites (Table 2). Across the three sites, mean water temperature was 25.6 °C, dissolved oxygen concentration was 9.1 mg/L, specific conductivity was 355 μS/cm, total dissolved solids was 0.231 g/L, turbidity was 3.7 NTU, pH was 8.5, chlorophyll *a* was 8.0 μg/L, % SAV was 62, and organic sediment depth was 1.6 cm (Table 2). These values were within the range commonly recorded during summer in littoral habitats of Muskegon Lake (Bhagat and Ruetz 2011; Janetski and Ruetz 2015). The main difference among sites was that the reference site had the lowest specific conductivity and turbidity (Table 2), which was consistent with better water quality (Uzarski et al. 2005; Janetski and Ruetz 2015). However, percent coverage of SAV also was lowest where we set fyke nets at the reference site (Table 2).

We captured 801 fish comprising 18 species at three sites in Muskegon Lake during July 2018 (Table 3). The most abundant fishes across all sites were yellow perch (35%), largemouth bass (21%), round goby (17%), golden shiner (9%), bluntnose minnow (5%), bluegill (4%), pumpkinseed (3%), and rock bass (2%), which accounted for nearly 96% of the total catch (Table 3). Of the 18 fish species captured in 2018, two species were non-native to the Great Lakes basin (Bailey et al. 2004)—round goby (17%) and white perch (<1%; Table 3).

We observed difference in catch among the three sites in 2018. Catch was highest at the reference site followed by the restoration sites Grand Trunk and Heritage Landing (Table 3). The two most common species in the catch at each site during 2018 were yellow perch (68%) and largemouth bass (17%) at the reference site, golden shiner (29%) and largemouth bass (25%) at Grand Trunk, and round goby (53%) and largemouth bass (23%) at Heritage Landing (Table 3; Figure 2). Most of the fish captured were small (<10 cm TL; Table 3), which is common with the type of fyke net we used for monitoring (Ruetz et al. 2007). With respect to yellow perch and largemouth bass—two species important to recreational anglers (Becker 1983)—the size suggests these were young of the year and juveniles (Becker 1983; Janetski et al. 2013). Finally, we documented evidence of variation in the species composition of the catch among years at the three sites (Figure 2). The inter-annual variation was most obvious at the reference site (Figure 2a) and Heritage Landing (Figure 2b).

Fish-based IBI and assessing habitat restoration.—The IBI scores at the three sites ranged from 37-44 in 2018 (Figure 3) with a mean IBI score of 41 (Figure 4). The mean IBI score in 2018 was above the Muskegon Lake Area of Concern target of 36 (Figure 3) established for two fish-related beneficial use impairments: loss of fish habitat and degradation of fish populations. This is a positive in terms of evaluating the overall health of littoral habitats and fishes in Muskegon Lake, although this optimism should be tempered in that most drowned river mouth wetlands are considered to be at least moderately degraded when compared with coastal wetlands across the Great Lakes basin (Cooper et al. 2018). Among the three sites we sampled in Muskegon Lake during 2018, Grand Trunk had the highest IBI score, Heritage Landing had the lowest, and the reference site was intermediate to the two restoration sites (Figure 3). When we compared the mean IBI score in 2009 and 2010 (i.e., pre-restoration monitoring) with the IBI score for post-restoration monitoring for each site in 2018, we found no difference at the reference site and a modest decline at the two restoration sites (Figure 3). Based on the fish-based IBI, we did not find evidence that the fish assemblage positively responded to the restoration activities (see Table 1) at Heritage Landing and Grand Trunk.

We think the lack of a detectable response of the fish assemblage to habitat restoration in Muskegon Lake—measured based on the IBI score—could be due to (1) the fish sampling effort (i.e., three fyke nets fished annually) may be insufficient to overcome natural temporal (e.g., day to day) variability in the catch. If this is the case, then background “noise” may prevent “signal” detection. We found evidence of variation in the fish assemblage at the reference site over the 4 years of sampling (Figure 2a). For instance, yellow perch was the most common species in the catch during 2018 but was largely absent from the catch in previous years at the reference site

(Figure 2a). (2) At Heritage Landing, the location within the site where fyke nets were set differed between pre-restoration (2009-2010) and post-restoration (2018) monitoring because the area sampled pre-restoration was too deep for fyke netting in 2018. (3) The fish-based IBI for drowned river mouths was devised as a crude tool to assess the ecological health of littoral habitats at the spatial scale of the lake. This tool was developed with limited data from drowned river mouths and should be used cautiously. Future assessments of these habitat restoration activities should consider using other fish-based IBIs (e.g., Cooper et al. 2018) or multivariate statistical analyses to examine changes in the fish assemblage pre- versus post-restoration. Although the restoration activities at these sites (see Table 1) may not be of sufficient magnitude to expect a detectable response in the littoral fish assemblage given background levels of variation, fish mobility and sampling effort, cumulatively these habitat restoration efforts should improve the overall health of the ecosystem, especially over longer temporal scales (e.g., decades).

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References

Alexander, J. 2006. The Muskegon: the majesty and tragedy of Michigan's rarest river. Michigan State University Press, East Lansing.

Bailey, R.M., W.C. Latta, and G.R. Smith. 2004. An atlas of Michigan fishes with keys and illustrations for their identification. Miscellaneous Publications, Museum of Zoology, University of Michigan, No. 192.

Becker, G.C. 1983. Fishes of Wisconsin. University of Wisconsin Press, Madison.

Bhagat, Y., and C.R. Ruetz III. 2011. Temporal and fine-scale spatial variation in fish assemblage structure in a drowned river mouth system of Lake Michigan. Transactions of the American Fisheries Society 140:1429-1440.

Breen, M.J., and C.R. Ruetz III. 2006. Gear bias in fyke netting: evaluating soak time, fish density, and predators. North American Journal of Fisheries Management 26:32-41.

Cooper, M.J., G.A. Lamberti, A.H. Moerke, and 9 coauthors. 2018. An expanded fish-based index of biotic integrity for Great Lakes coastal wetlands. Environmental Monitoring and Assessment 90:580. doi.org/10.1007/s10661-018-6950-6.

Cooper, M.J., C.R. Ruetz III, D.G. Uzarski, and T.M. Burton. 2007a. Distribution of round gobies in coastal areas of Lake Michigan: are wetlands resistant to invasion? Journal of Great Lakes Research 33:303-313.

Cooper, M.J., D.G. Uzarski, and T.M. Burton. 2007b. Macroinvertebrate community composition in relation to anthropogenic disturbance, vegetation, and organic sediment depth in four Lake Michigan drowned river-mouth wetlands. Wetlands 27:894-903.

Janetski, D.J., and C.R. Ruetz III. 2015. Spatiotemporal patterns of fish community composition in Great Lakes drowned river mouths. Ecology of Freshwater Fish 24:493-504.

Janetski, D.J., C.R. Ruetz III, Y. Bhagat, and D.F. Clapp. 2013. Recruitment dynamics of age-0 yellow perch in a drowned river mouth lake: assessing synchrony with nearshore Lake Michigan. Transactions of the American Fisheries Society 142:505-514.

Ogdahl, M.E., and A.D. Steinman. 2014. Factors influencing macrophyte growth and recovery following shoreline restoration activity. Aquatic Botany 120:363-370.

Ruetz, C.R., III, D.G. Uzarski, D.M. Krueger, and E.S. Rutherford. 2007. Sampling a littoral fish assemblage: comparing small-mesh fyke netting and boat electrofishing. North American Journal of Fisheries Management 27:825-831.

Steinman, A.D., M. Ogdahl, R. Rediske, C.R. Ruetz III, B.A Biddanda, and L. Nemeth. 2008. Current status and trends in Muskegon Lake, Michigan. Journal of Great Lakes Research 34:169-188.

Uzarski, D.G., T.M. Burton, M.J. Cooper, J.W. Ingram, and S.T.A. Timmermans. 2005. Fish habitat use within and across wetland classes in coastal wetlands of the five Great Lakes: development of a fish-based index of biotic integrity. Journal of Great Lakes Research 31(Suppl. 1):171-187.

Table 1. Latitude (N) and longitude (W) for each fish sampling site in July 2018 as well as restoration details for the site (Ogdahl and Steinman 2014). Coordinates are the mean of the three fyke nets set at each site. Site locations are depicted in Figure 1.

Site	Lat (°)	Long (°)	Date of Restoration	Type of Restoration
NW Reference	43.24623	86.31478	NA	Reference site
Heritage Landing	43.23349	86.26202	April 2011	Shoreline & underwater fill removal
Grand Trunk	43.21865	86.29628	June 2010	Shoreline wetland restoration & unnderwater fill removal

Table 2. Mean ± 1 standard error (n = 3) of environmental conditions measured in July 2018. Water depth, water temperature (Temp), dissolved oxygen (DO), specific conductivity (SpecCond), total dissolved solids (TDS), turbidity, pH, chlorophyll *a* (Chl *a*), submerged aquatic vegetation (SAV; %), and organic sediment depth were measured at each fyke net.

Site	Depth (cm)	Temp (°C)	DO (mg/L)	DO (%)	SpecCond (µS/cm)	TDS (g/L)	Turbidity (NTU)	pH	Chl *a* (µg/L)	SAV (%)	Organic sediment depth (cm)
NW Reference	90±2	24.61±0.05	9.31±0.27	111.9±2.9	346±0	0.225±0.000	0.4±0.2	8.56±0.03	4.4±0.1	38±16	1.0±0.0
Heritage Landing	88±2	27.98±0.18	11.91±0.54	152.4±7.3	357±2	0.230±0.002	9.8±2.3	8.82±0.05	14.1±1.9	75±5	1.0±0.0
Grand Trunk	85±4	24.27±0.07	6.08±0.34	72.8±4.1	362±1	0.235±0.000	0.9±0.1	8.12±0.10	5.5±0.6	73±22	2.7±0.3

Table 3. Number and mean total length (TL; ranges reported parenthetically) of fishes captured by fyke netting at three sites (n = 3 nets/site) in Muskegon Lake during 18 July 2018.

		Grand Trunk		Heritage Landing		NW Reference	
Common name	Scientific name	Catch	TL (cm)	Catch	TL (cm)	Catch	TL (cm)
rock bass	*Ambloplites rupestris*	7	11.9 (2.7-17.8)	5	13.1 (2.7-21.4)	5	12.5 (7.5-21.3)
black bullhead	*Ameiurus melas*	0	--	1	28.4	1	31.1
yellow bullhead	*Ameiurus natalis*	2	4.2 (3.7-4.6)	0	--	0	--
bowfin	*Amia calva*	2	48 (38.1-57.9)	1	66.2	0	--
northern pike	*Esox lucius*	1	68.3	0	--	0	--
banded killifish	*Fundulus diaphanus*	4	7.9 (7.4-8.1)	2	5.2 (3.9-6.5)	1	7.8
pumpkinseed	*Lepomis gibbosus*	3	11.6 (8.3-15.7)	15	9.8 (6.1-16.6)	6	11.1 (6.1-18.4)
bluegill	*Lepomis macrochirus*	0	--	7	8.2 (7.6-9.3)	20	13.9 (6.1-18.3)
longnose gar	*Lepisosteus osseus*	0	--	0	--	1	18.1
smallmouth bass	*Micropterus dolomieu*	13	4.6 (3.8-5.5)	0	--	1	4.8
largemouth bass	*Micropterus salmoides*	64	4.3 (2.5-6.1)	46	4.4 (2.2-24.1)	59	4.7 (3.6-6.7)
white perch	*Morone americana*	1	18.0	0	--	0	--
silver redhorse	*Moxostoma anisurum*	0	--	1	50.1	1	54.2
round goby	*Neogobius melanostomus*	27	6.7 (3.3-8.5)	105	6.5 (2.5-11.3)	2	7.0 (4.7-9.3)
golden shiner	*Notemigonus crysoleucas*	74	4.8 (3.9-5.7)	0	--	0	--
tadpole madtom	*Noturus gyrinus*	1	5.9	0	--	0	--
yellow perch	*Perca flavescens*	31	8.0 (4.7-19.1)	16	8.8 (4.0-18.8)	237	6 (4.2-23.9)
bluntnose minnow	*Pimephales notatus*	22	6.1 (5.5-7.2)	1	7.5	15	6.3 (5.6-7.4)
	Total	252		200		349	

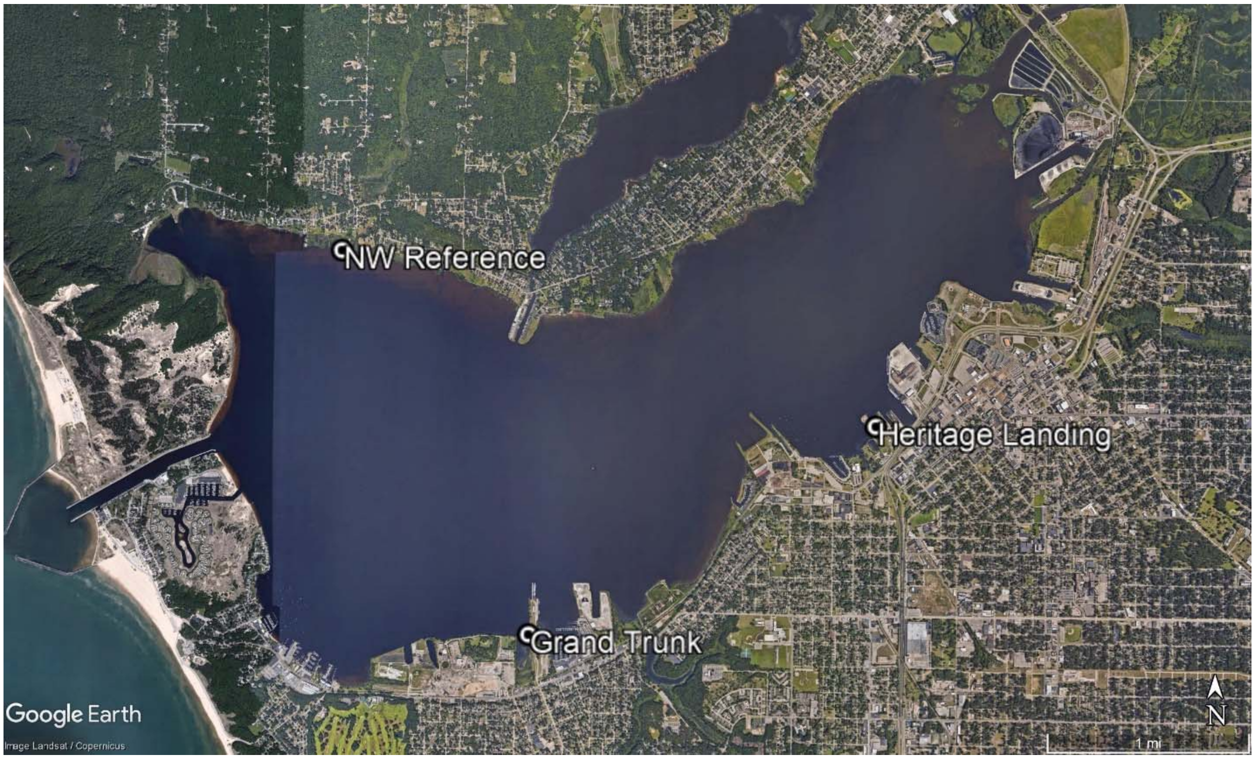

Figure 1. Map of Muskegon Lake showing the three sites surveyed for fishes. The latitude and longitude for each site is reported in Table 1.

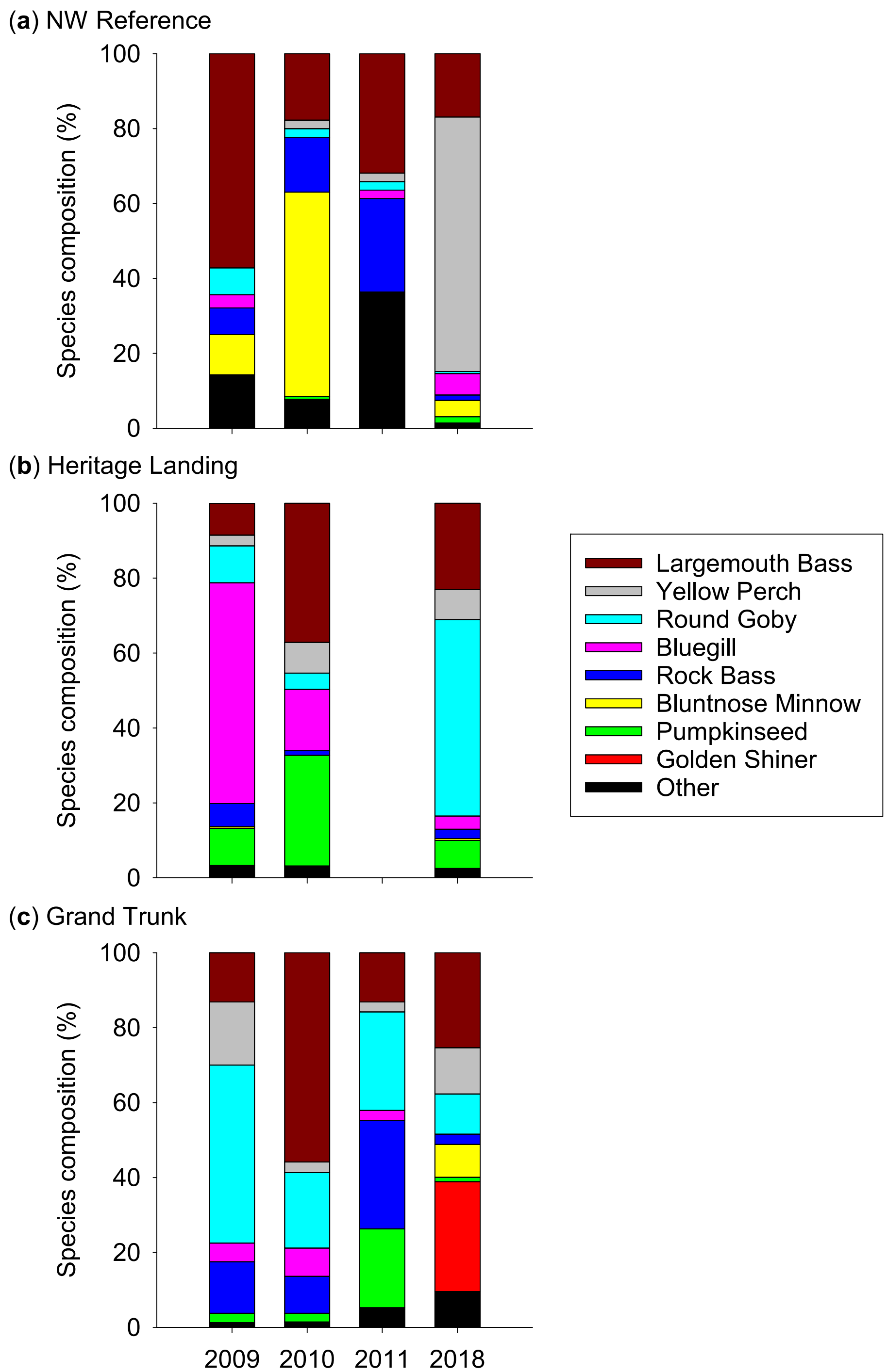

Figure 2. Fish species composition in the catch at three sites in Muskegon Lake over four years: (**a**) NW Reference, (**b**) Heritage Landing, and (**c**) Grand Trunk. Pre-restoration monitoring was conducted during 2009-2010 and post-restoration monitoring in 2011 and 2018 at the two restoration sites (i.e., Heritage Landing and Grand Trunk). "Other" includes all fish species not listed in the legend. Three fyke nets were fished at each site. The number of fish captured varied among sampling events (Appendix B).

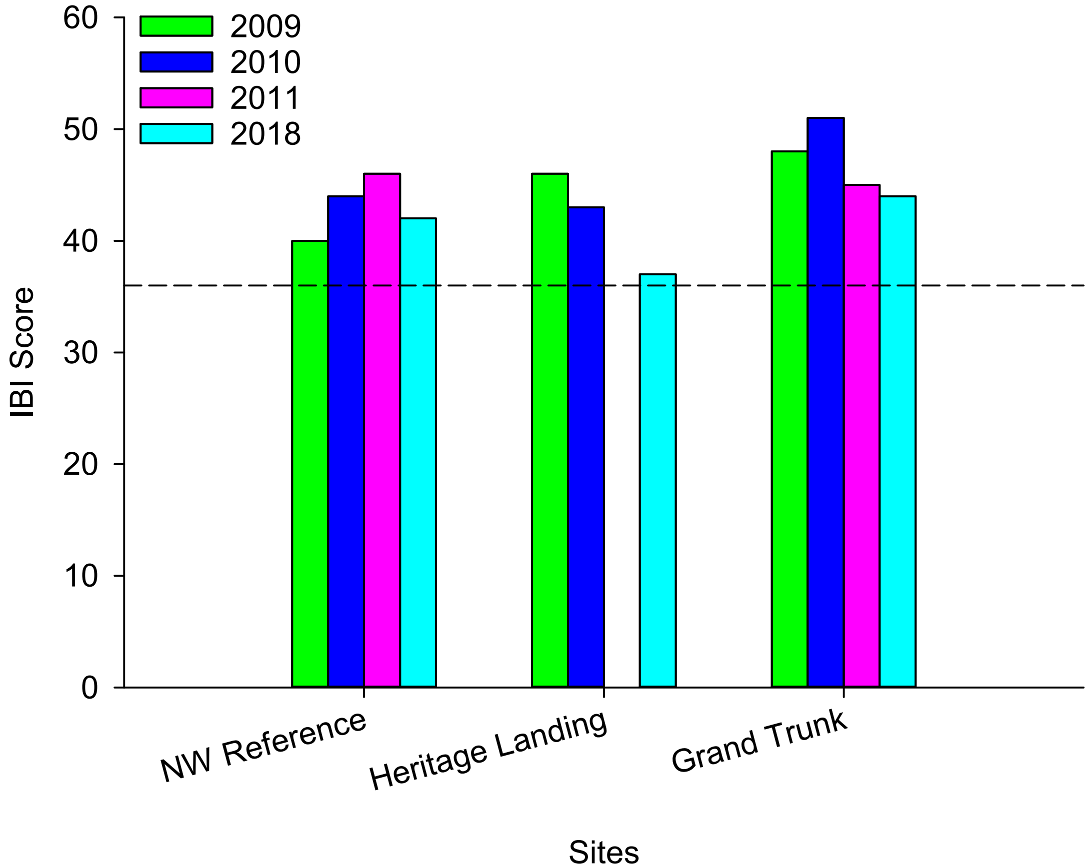

Figure 3. Scores from the fish-based index of biotic integrity (IBI) for three sampling sites in Muskegon Lake. The dashed line represents the numerical delisting target of 36 for the Muskegon Lake Area of Concern (Appendix A). Note that Heritage Landing was not sampled in 2011 due to dredging at the site.

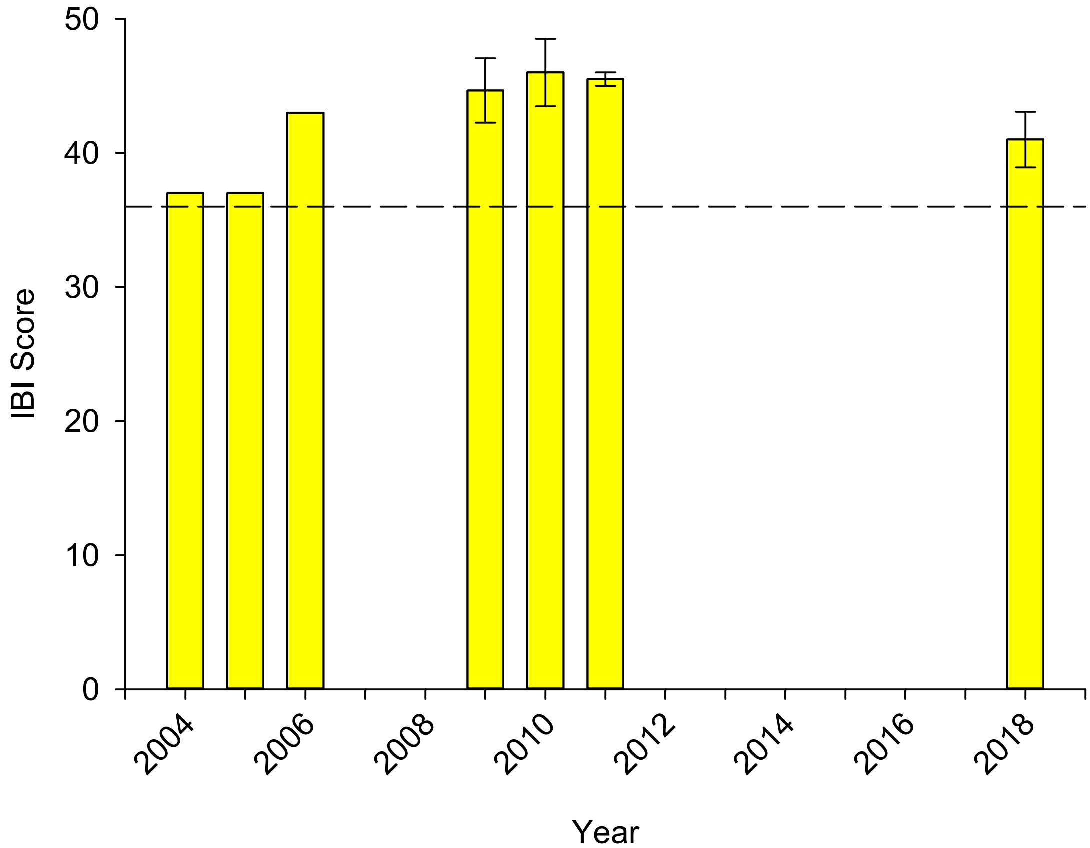

Figure 4. Scores from the fish-based index of biotic integrity (IBI) for Muskegon Lake. The dashed line represents the numerical delisting target of 36 for the Muskegon Lake Area of Concern (Appendix A). Bars are missing for years without fish data. The IBI scores calculated for 2004-2006 were based on one sampling site (see Cooper et al. [2007a] for location of site with submerged aquatic vegetation) that was not part of fish sampling in later years. Mean values (± 1 standard error) were reported for 2009 (n = 3 sites), 2010 (n = 3 sites), 2011 (n = 2 sites), and 2018 (n = 3 sites) based on data for the three sites that were the subject of this report.

Appendix A

We provide additional details regarding the development of a fish-based index of biotic integrity (IBI) used in this report as well as a description of how the IBI was used to set a delisting target for two beneficial use impairments (BUIs; loss of fish habitat and degradation of fish populations) in the Muskegon Lake Area of Concern (see Ruetz [2011] for additional details).

A multi-metric index—termed IBI—was used to set quantitative delisting targets for Muskegon Lake based on annual fish-sampling records collected by the Annis Water Resources Institute (AWRI) in 2004-2006. The IBI approach is widely used across the United States to monitor water quality. Fish are integrators of the overall habitat and water quality; fish also respond to both episodic and cumulative anthropogenic disturbances in an ecosystem. Fish sampling for calculating IBI scores only was required annually because the fish themselves are integrators of time (i.e., the fish assemblage is there continuously). A fish-based IBI can be used to address questions concerning both fish populations and habitat because the IBI is an indicator of both fish community health and overall ecological health of the water body.

A typical IBI includes metrics such as number and composition of species sampled, focuses on indicator species that are particularly sensitive to water quality and habitat alterations, and considers groups of organisms that have similar feeding modes. Once the sampling is complete, a "score" is calculated for each metric in the IBI. The final IBI score is the total of all metrics and is indicative of ecosystem health. A high score suggests a "healthier" ecosystem, whereas a low score is indicative of a "degraded" ecosystem.

The IBI used for setting delisting targets in Muskegon Lake is modified from a fish-based IBI developed for Great Lakes coastal wetlands (Uzarski et al. 2005). The IBI developed by Uzarski et al. (2005) was modified to better represent anthropogenic disturbance (based on land use and water quality) across a gradient of drowned river mouth lakes. The modified, fish-based IBI consisted of 11 metrics (Table A1). A revised fish-based IBI was recently published by Cooper et al. (2018) for Great Lakes coastal wetlands, which could be considered in future assessments.

At least three pieces of evidence suggested that fish populations and, therefore, habitat were no longer severely degraded in Muskegon Lake at the time the target was developed prior to 2009 (Ruetz 2011). First, the fish-based IBI scores calculated based on data collected during 2004-2006 suggested that the ecosystem health of Muskegon Lake was comparable to Pentwater Lake, a drowned river mouth lake that did not suffer the types of severe environmental degradation experienced by Muskegon Lake. Second, the 1987 Remedial Action Plan noted that Muskegon Lake experienced marked improvements in water and habitat quality, including an excellent fishery for numerous fish species, following the construction of a wastewater treatment system. Finally, assessments by the Michigan Department of Natural Resources suggested that Muskegon Lake supported good fishing for several fish species with self-sustaining populations (O'Neal 1997; Hanchin et al. 2007). Therefore, the proposed target for delisting the loss of fish habitat and degradation of fish populations BUIs in Muskegon Lake was to maintain or improve the lake's ecosystem health over a 3-year time span beginning in 2009. The numerical target was set as the average IBI score of $\geq$36, which was determined based on the mean IBI score during 2004-2006 minus one standard deviation. This target was achieved based on sampling during 2009-2011 (Figure 3).

References

Cooper, M.J., G.A. Lamberti, A.H. Moerke, and 9 coauthors. 2018. An expanded fish-based index of biotic integrity for Great Lakes coastal wetlands. Environmental Monitoring and Assessment 90:580. doi.org/10.1007/s10661-018-6950-6.

Cooper, M.J., C.R. Ruetz III, D.G. Uzarski, and T.M. Burton. 2007a. Distribution of round gobies in coastal areas of Lake Michigan: are wetlands resistant to invasion? Journal of Great Lakes Research 33:303-313.

Hanchin, P.A., R.P. O'Neal, R.D. Clark, Jr., and R.N. Lockwood. 2007. The walleye population and fishery of the Muskegon Lake system, Muskegon and Newaygo counties, Michigan in 2002. Michigan Department of Natural Resources, Fisheries Special Report 40, Ann Arbor.

O'Neal, R.P. 1997. Muskegon River Watershed Assessment. Michigan Department of Natural Resources, Fisheries Special Report 19.

Ruetz, C.R., III. 2011. Muskegon Lake Area of Concern: evaluating targets for delisting two beneficial use impairments (loss of fish habitat and degradation of fish populations) and responses of fish to habitat restoration. Final Report (submitted 30 November 2011).

Uzarski, D.G., T.M. Burton, M.J. Cooper, J.W. Ingram, and S.T.A. Timmermans. 2005. Fish habitat use within and across wetland classes in coastal wetlands of the five Great Lakes: development of a fish-based index of biotic integrity. Journal of Great Lakes Research 31(Suppl. 1):171-187.

Table A1. Metrics for fish-based index of biotic integrity (IBI) for drowned river mouths. The IBI is modified from Uzarski *et al*. (2005). Fish sampling should be conducted with fyke nets (Cooper *et al*. 2007a) at shallow (depth ≤1 m) sites with submerged aquatic vegetation. At least three fyke nets should be fished at each site. The catch of fish is then standardized across nets at a site to calculate IBI scores.

Preliminary Drowned River Mouth Lake IBI – SAV habitat only

1. Percent omnivore abundance:			
>70% score = 0	50 to 70% score = 3	<50% score = 5	
2. Percent piscivore richness:			
<25% score = 0	25 to 35% score = 3	>35% score = 5	
3. Percent carnivore (insectivore+piscivore+zooplanktivore) richness:			
<70% score = 0	70-80% score = 3	>80% score = 5	
4. Smallmouth bass (*Micropterus dolomieu*) mean catch per net-night:			
0 score = 0	>0 to 5 score = 3	>5 score = 5	
5. Insectivorous Cyprinidae richness:			
>3 score = 0	>1 to 3 score = 3	0 to 1 score = 5	
6. Percent Centrarchidae abundance:			
0-30 score = 0	>30 to 60 score = 3	>60 to 80 score 5	>80 score = 7
7. Centrarchidae richness:			
0 to 1 score = 0	>1 to 3 score = 3	>3 score = 5	
8. Mean evenness:			
<0.2 score = 0	0.2 to 0.6 score = 3	>0.6 score = 5	
9. Rock Bass (*Ambloplites rupestris*) catch per net-night:			
0 to 1 score = 0	>1 to 5 score = 3	>5 score = 5	
10. Bluegill (*Lepomis macrochirus*) abundance per net-night:			
0 to 3 score = 0	>3 to 20 score = 3	>20 to 30 score = 5	>30 score = 7
11. *Lepomis* catch per net-night:			
>50 score = 0	>20 to 50 score= 3	>5 to 20 score = 5	0 to 5 score = 7

Appendix B

Table B1. Number of fish captured in three fyke nets fished at each site (NW Reference, Heritage Landing, and Grand Trunk) over four years. No sampling was conducted at Heritage Landing in 2011.

Year	NW Reference	Heritage Landing	Grand Trunk
2009	28	212	160
2010	130	159	213
2011	44	--	38
2018	349	200	252