

## Muskegon Lake Area of Concern

### **Targets for Delisting Two Beneficial Use Impairments: *Loss of Fish Habitat and Degradation of Fish Populations***

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#### Historical Fish Habitat & Population Issues and Description of Impairments:

Muskegon Lake (4,149 acres) is located on the eastern shore of Lake Michigan (Muskegon County, Michigan). The lake was formed by the combination of sand dunes constricting the flow of the Muskegon River before it enters Lake Michigan and inundation of the ancient river valley, which formed when historic Great Lakes levels were much lower. Muskegon Lake and the immediate watershed (52 square miles) were designated as an Area of Concern (AOC) in 1985 because of possible negative impacts of Muskegon Lake on Lake Michigan due to contaminated water, nutrient enrichment, and habitat degradation.

“[P]rior to 1973, Muskegon Lake received direct discharges of industrial process wastewater, municipal wastewater treatment plant effluent, combined stormsewer overflows and urban runoff. These discharges degraded water and habitat quality of Muskegon Lake and tributaries .... [N]utrient enrichment, solids and toxicant loadings resulting in nuisance algal blooms, reduced oxygen concentrations in the water column, tainted fish and contaminated sediments. Development of petroleum, chemical and heavy industries in the ... AOC ... contaminated groundwater” [Remedial Action Plan 1987, page 1].

A wastewater treatment facility was constructed in 1973 to improve water quality in Muskegon Lake. Industrial and municipal discharges were diverted away from Muskegon Lake to the Muskegon County Wastewater Management System, which “... greatly improved water and habitat quality in Muskegon Lake by reducing the loadings of nutrients, oils, solids and toxicants” (Remedial Action Plan 1987, pages 1-2). These improvements allowed the lake, once again, to be an excellent fishery for walleye, largemouth bass, yellow perch, and northern pike (Remedial Action Plan 1987, pages 1-2).

Muskegon Lake has good-to-excellent fishing for northern pike *Esox lucius*, walleye *Sander vitreus*, smallmouth bass *Micropterus dolomieu*, largemouth bass *M. salmoides*, yellow perch *Perca flavescens*, bluegill *Lepomis macrochirus*, pumpkinseed *L. gibbosus*, black crappie *Pomoxis nigromaculatus*, channel catfish *Ictalurus punctatus*, flathead catfish *Pylodictis olivaris*, migratory rainbow trout *Oncorhynchus mykiss*, and Chinook salmon *O. tshawytscha* (O’Neal 1997). The results of a more recent creel survey conducted in 2002 suggested that the overall fishery in Muskegon Lake was “relatively good” (Hanchin *et al.* 2007). Fish effort (hours fished/acre) and harvest (fish harvested/acre) were higher in Muskegon Lake compared with Michigan’s other large inland lakes (Hanchin *et al.* 2007).

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Walleye is the only species currently stocked in Muskegon Lake, although brown trout *Salmo trutta* and Chinook salmon are stocked in the Muskegon Lake channel (MDNR 2007). Periodic assessments of young-of-the-year walleye in Muskegon Lake suggest very low natural reproduction in the system (MDNR 2004). The current walleye population that spawns in the Muskegon River is characterized as having average-to-high density, fast growth, low total mortality, and low angler harvest (Hanchin *et al.* 2007). Native fish species that were extirpated or are considered threatened in Muskegon Lake include lake sturgeon *Acipenser fulvescens*, white bass *Morone chrysops*, and muskellunge *Esox masquinongy* (O'Neal 1997). The Michigan Department of Natural Resources is considering reintroductions of white bass and muskellunge to Muskegon Lake. However, the presence of a large northern pike population could prove problematic for muskellunge reintroduction, and the presence of non-native white perch *Morone americana* (known competitors with white bass) could interfere with white bass reintroduction (O'Neal 1997). A small population of lake sturgeon use Muskegon Lake to gain access to the Muskegon River (Schneeberger *et al.* 2005). Nevertheless, declines of lake sturgeon, white bass, and muskellunge, along with natural walleye reproduction failure, are not unique to Muskegon Lake and are common among many drowned river mouth lakes connecting to Lake Michigan, although Muskegon River has a much larger spawning population of walleye than any of the other drowned river mouth lakes (Schneider and Leach 1979).

#### Restoration Targets:

Delisting beneficial use impairments (BUIs) at Great Lakes AOCs should require the establishment of quantitative targets with defensible endpoints (George and Boyd 2007). We propose to use a multi-metric index—termed an index of biotic integrity or IBI—to set quantitative delisting targets for Muskegon Lake based on annual fish-sampling records collected by the Annis Water Resources Institute (AWRI) from 2004 to 2006. The IBI approach is widely used across the United States to monitor water quality (e.g., Drake and Valley 2005). Fish that live in the water body are integrators of the overall habitat and water quality; they also reveal both episodic and cumulative, human-induced disturbances in a system. Fish sampling for calculating IBI scores will only be required annually because fishes are integrators of time (i.e., the fish community is there continuously). A fish-based IBI can therefore be used to address questions concerning both fish populations and fish habitat because the IBI is an indicator of both fish community health and overall ecological health of the lake. Overall ecological health of a lake is linked to aquatic habitat, and aquatic habitat is linked to the overall health of the fish community.

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 sampling is completed, scientists calculate a “score” for each metric in the IBI. The final IBI score is the sum of all metrics and is indicative of ecosystem health. A high score suggests a relatively “healthy” ecosystem, whereas a low score is indicative of a “degraded” one.

The IBI proposed for use in setting delisting targets in Muskegon Lake was 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 human-induced disturbance (based on land use and water quality) across a gradient of drowned river mouth lakes<sup>2</sup>. For instance, the disturbance gradient suggested that Pentwater Lake was indicative of a “healthier” ecosystem and Kalamazoo Lake was more indicative of a “degraded” ecosystem among lakes sampled by AWRI (see Figure 1 for list of lakes). The modified, fish-based IBI consists of 11 metrics (Table 1) and also is being used to set delisting targets for fish populations and habitat in the White Lake AOC.

The IBI scores calculated during 2005 and 2006 suggest two clusters of lakes in the sample (Figure 1): a group with scores >33 indicative of “healthier” ecosystems and another with scores ≤33 representing “degraded” ecosystems.<sup>3</sup> Moreover, Pentwater Lake has been used as a reference system when setting targets for other BUIs in the Muskegon Lake AOC (i.e., *restriction of fish and wildlife consumption* and *eutrophication or undesirable algae*). Therefore, the finding that Pentwater, Muskegon, and White lakes form a group among the lakes AWRI sampled (Figure 1) suggests that they are “healthier” than Kalamazoo and Pigeon lakes. In Great Lakes coastal wetlands, Uzarski *et al.* (2005) found anthropogenic disturbance (based on land use and water quality) was typically high for Pigeon Lake, which supports our findings. However, among wetlands across all five Great Lakes, the drowned river mouth systems AWRI sampled tended to be average or more impacted in terms of anthropogenic disturbance (Uzarski *et al.* 2005).

At least three pieces of evidence suggest that fish populations and, therefore, habitat are no longer severely degraded in Muskegon Lake. First, the fish-based IBI calculated from recent years suggests that the ecosystem health of Muskegon Lake is 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, more recent assessments by the Michigan Department of Natural Resources suggest that Muskegon Lake supports good fishing for several fish species with self-sustaining populations (O’Neal 1997; Hanchin *et al.* 2007).

The proposed target for delisting the *loss of fish habitat* and *degradation of fish populations* BUIs in Muskegon Lake is *to maintain or improve the lake’s ecosystem health over a 3-year time span beginning in 2009* (assuming funding is secured). The numerical target will be measured as an average IBI score of  $38 \pm 2$ , which is based on the mean and standard deviation<sup>4</sup> IBI score for Muskegon Lake during the past 3 years (Figure 1). If after 3 years of monitoring the target is not achieved (i.e., average IBI score  $\geq 36$ ), then fish monitoring should

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<sup>2</sup> Note that only the 2004 fish data were used to re-calibrate the IBI proposed by Uzarski *et al.* (2005). There was a significant correlation ( $r = 0.92$ ,  $P = 0.076$ ,  $n = 4$ ) between disturbance gradient and IBI score for 2004. Data collected from 2005 and 2006 provide evidence for relatively high precision of the IBI and that inter-annual variation is not strongly affecting IBI scores.

<sup>3</sup> The IBI score of 33 was arbitrarily defined based on visual interpretation of Figure 1.

<sup>4</sup> On average, 68% of observations should be within 1 standard deviation of the mean, assuming the population is normally distributed (Sokal and Rohlf 1995).

continue for an additional 3 years to determine whether the numerical target is achieved. This process should be repeated until the target is achieved. Additionally, fish sampling should continue in other drowned river mouth lakes (Figure 1), especially Pentwater and Kalamazoo, to provide an opportunity to determine whether temporal trends in IBI scores are specific to Muskegon Lake (and indicative of a “healthier” or “degraded” ecosystem) or associated with regional fluctuations in biotic and abiotic factors. For instance, if regional fluctuations, not associated with human-induced disturbance, caused multiple drowned river mouth lakes to experience declines in IBI scores, then the numerical target for Muskegon Lake should be reassessed to determine its scientific validity (i.e., the numerical target may need to be shifted). Thus, shifting the numerical delisting target may be necessary in the future but should only be done based on scientific evidence.

A concern about using the fish-based IBI to set delisting targets for fish habitat is whether sampling fish at sites with submerged aquatic vegetation (SAV; sampling methods are described below) will weaken the relationship between the IBI score and overall habitat quality in the lake. For instance, if there are only a few small habitat patches of SAV in a lake, then will sampling fishes from those habitat patches reflect the overall quality of habitat in the lake? We expect the fish-based IBI (Table 1) will provide an index of overall habitat quality in the littoral zones of drowned river mouth lakes because there is widespread support (in ecology) for a strong, positive association between species richness (i.e., number of species) and habitat area (Adler *et al.* 2005) and habitat loss is often associated with reduced species richness and trophic diversity (Dobson *et al.* 2006). Thus, the IBI should be sensitive to overall changes in water quality and littoral habitat. Moreover, there is abundant SAV habitat in Muskegon Lake.

#### Scope of Work for Restoration:

The only action proposed to delist the *loss of fish habitat* and *degradation of fish populations* BUIs is continued fish monitoring (both in Muskegon Lake and other drowned river mouth systems) to document whether the delisting target (i.e., IBI score) is met over a 3-year period. Thus, restoration actions focused on fish habitat are not considered necessary to meet the proposed delisting target.

Delisting the *loss of fish habitat* BUI does not mean that additional work is unnecessary to restore, protect, and improve the fishery in Muskegon Lake. Alterations to the natural shoreline of lakes—caused by human development—are a widespread problem in Michigan lakes (O’Neal and Soulliere 2006) but not a primary reason for designation of the *loss of fish habitat* BUI on Muskegon Lake. Modifications to the lakeshore can result in loss of fish habitat and reduction in fish populations (e.g., Sass *et al.* 2006), and cumulative effects of small modifications to aquatic habitat can substantially degrade fisheries (O’Neal and Soulliere 2006). The proposed habitat restoration to delist wildlife BUIs will create littoral and wetland habitats that were filled as part of human development on Muskegon Lake and provide more natural shoreline. These restoration activities should improve fish habitats and populations, which will help Muskegon Lake meet or exceed its fish-based delisting target.

AWRI can conduct the required fish monitoring in Muskegon Lake if funding is secured to cover costs. Three sites will be monitored in Muskegon Lake beginning in 2009. Monitoring

will consist of sampling fish with small-mesh fyke nets (Breen and Ruetz 2006) at three sites per lake in July of each year. Three fyke nets will be set at each site in shallow areas (<1 m) with SAV (Ruetz *et al.* 2007). Fyke nets will be fished for 24 hours. All fish captured will be identified, measured for total length, and released. Currently, AWRI conducts seasonal fish sampling in Muskegon Lake as part of a long-term monitoring project supported by the Community Foundation for Muskegon County (Steinman and Ogdahl 2004). Two of the long-term monitoring sites, located near Johnson's Point and Fisherman's Landing, will be used to gather data for calculating IBI scores. A third fish monitoring site will be located on the lake's south shoreline near a wildlife restoration site. Additionally, fish sampling will be conducted in the other drowned river mouth lakes to determine whether temporal trends in IBI scores are specific to Muskegon Lake or associated with regional fluctuations (see *Restoration Targets*). In the other lakes, we will sample the SAV sites reported in Cooper *et al.* (2007), which were used to calculate the IBI scores (Figure 1). Two additional sites will be selected at the time of sampling in each of those lakes. For all lakes, once sites are selected during the first year of sampling, they will be used in following years.

The estimated cost for AWRI to conduct the fish monitoring at the six lakes previously sampled (see Figure 1) is about \$16,000 per year (i.e., total for 3 years: \$48,000)<sup>5</sup>. However, costs for monitoring the six lakes could be shared between the Muskegon Lake and White Lake AOCs because data collected would be used for setting delisting targets in both AOCs. Potential sources of funding include the Michigan Department of Environmental Quality, EPA's Great Lakes National Program Office, and USFWS's Coastal Program – Great Lakes.

#### Project Reporting:

Both fisheries data and IBI scores that result from monitoring will be reported annually to the MDEQ, and fish sampling will meet MDEQ quality assurance plans.

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<sup>5</sup> This estimate includes costs for personnel to conduct sampling and calculate IBI scores, sample water chemistry (to calculate disturbance gradient in the event that the target needs to be shifted), travel to the study sites, and full indirect. The principal investigator's time would be used as in-kind match (not included in cost).

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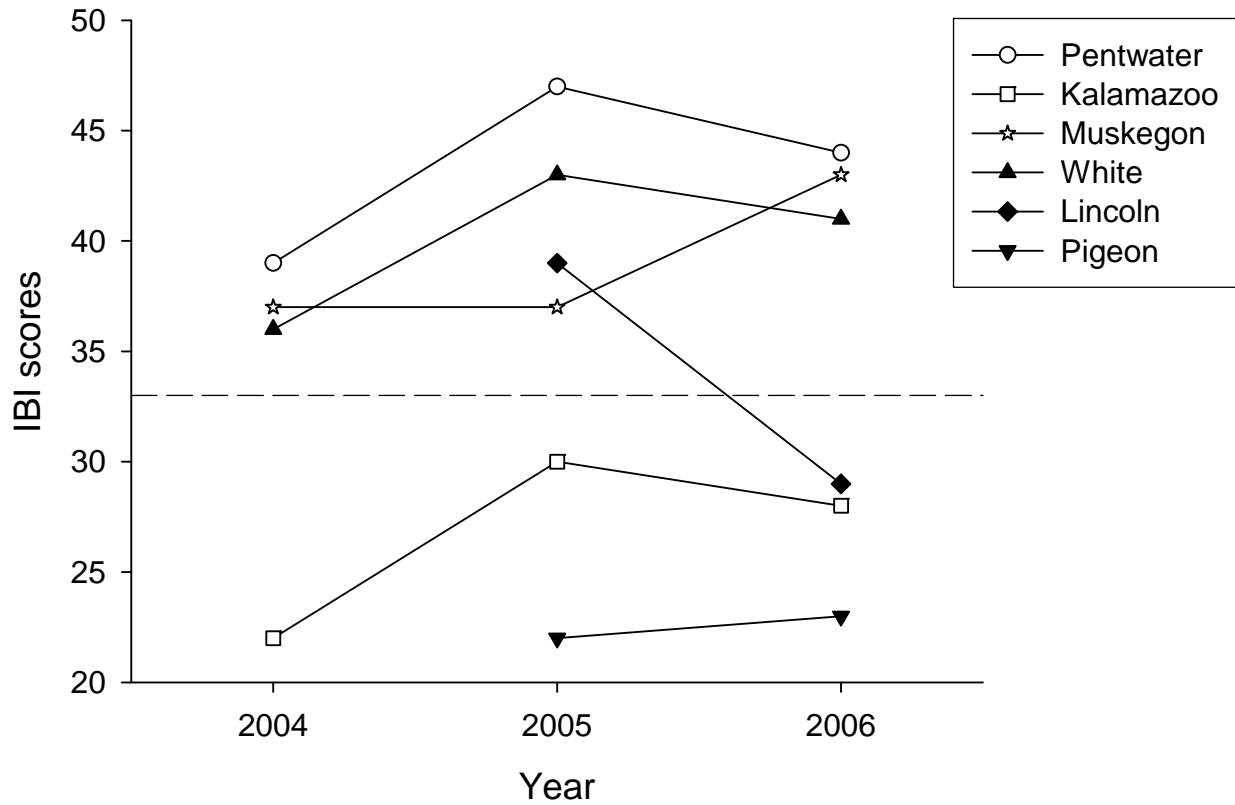
**Table 1.** Metrics for fish-based index of biotic integrity (IBI) for drowned river mouth lakes. The IBI is modified from Uzarski *et al.* (2005). Fish sampling should be conducted with fyke nets (Cooper *et al.* 2007) at shallow (depth  $\leq 1$  m) sites with submerged aquatic vegetation. At least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

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***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 ( <i>Micropterus dolomieu</i> ) 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 ( <i>Ambloplites rupestris</i> ) catch per net-night:	0 to 1 score = 0	>1 to 5 score = 3	>5 score = 5	
10. Bluegill ( <i>Lepomis macrochirus</i> ) abundance per net-night:	0 to 3 score = 0	>3 to 20 score = 3	>20 to 30 score = 5	>30 score = 7
11. <i>Lepomis</i> spp. catch per net-night:	>50 score = 0	>20 to 50 score = 3	>5 to 20 score = 5	0 to 5 score = 7

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**Figure 1.** Scores from fish-based index of biotic integrity (IBI) for six drowned river mouth lakes. Data from 2004 were used to build the IBI. The dashed line represents the break (at an IBI score of 33) between relatively “healthy” and “degraded” ecosystems among the six lakes studied. Metrics used in the IBI are described in Table 1. One site with submerged aquatic vegetation was sampled in each lake (see Cooper *et al.* [2007] for a description of sampling and site locations).