

Kalamazoo River: Marshall to Morrow Pond
Calhoun and Kalamazoo Counties
A Fish and Habitat Survey of Sites Near the 2010 Enbridge Oil Spill

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Environment

The Kalamazoo River drains 2,020 square miles of land in southwest Michigan and has a length of 175 miles from its headwaters to Lake Michigan. It is a medium- to large-sized warmwater river with a sporadically confined channel as it meanders between moraine and man-made features from Marshall to Battle Creek, while it meanders freely in broad valleys from Battle Creek to Morrow Pond. Soils are primarily sand, silt, and clay loams and the watershed is dominated by agriculture (58%) and forest (25%). The average gradient of the mainstem of the Kalamazoo River is 3.0 ft/mi. This Report focuses on the downstream half of the upper section of the river. This section is characterized by higher gradient and habitat consists of predominantly run type habitat with few pools and riffles. Gradient ranges from 1.0 to 9.5 ft/mi with an average of 3.9 ft/mi. Detailed description of the Kalamazoo River and its watershed and tributaries can be found in the Kalamazoo River Assessment (Wesley 2005).

History

On July 26, 2010, a 30-inch diameter pipeline owned by Enbridge, Inc. ruptured discharging heavy crude oil into a wetland and subsequently into Talmadge Creek, a tributary to the Kalamazoo River. The amount of oil discharged was estimated to be at least 843,444 gallons (NTSB 2012). The oil flowed down 2.2 miles of Talmadge Creek, a small coolwater stream, before entering the Kalamazoo River. The oil migrated approximately 35 miles downstream to Morrow Pond where it was contained from further downstream movement by the dam.

During September 2010, staff of the Michigan Department of Natural Resources-Fisheries Division (DNR) with assistance from Entrix, Inc. (a consultant of Enbridge) and Michigan Department of Environmental Quality-Water Resources Division (DEQ) conducted fish community and habitat surveys on the Kalamazoo River and Talmadge Creek. The objective of these surveys was to assess the effects of the oil spill and associated cleanup activities on fish communities and habitat. Personnel from DEQ-Surface Water Assessment Section also collected macroinvertebrate and aquatic habitat data using their Procedure 51 protocol (MDEQ 2011). A study plan has been developed and additional surveys will be conducted in the future to monitor the long-term effects of the oil spill and associated cleanup activities on the fish and macroinvertebrate communities and aquatic habitat (Wesley and Walterhouse 2010).

Current Status

Sampling stations (Figure 1) were selected with emphasis on sites with historic (i.e., baseline) survey data that were collected prior to the oil spill (Wesley and Walterhouse 2010). Fisheries Division has a long-term Status and Trends Program monitoring site at 11 Mile Road on the Kalamazoo River. Surveys at this site follow standardized sampling procedures that allow for temporal comparisons as

well as comparisons to similar streams across the region and state (Wills et al. 2011). This Status and Trends protocol was used at all other sites for consistency. Wadeable electrofishing equipment and methods were used on the Kalamazoo River at the 17 Mile (reference), 15 Mile, 11 Mile, and Riverside sites. Boat electrofishing equipment and methods were used at the Custer Road site on the Kalamazoo River due to the site being too deep to wade. Catch per effort (CPE) was calculated as an indicator or relative abundance using the number of fish caught per 1,000 ft of shoreline sampled to standardize between sites where both banks were sampled and those where only one bank was sampled. Historic surveys at these sites used similar electrofishing equipment, except the 15 Mile Road and Custer Road sites had been conducted using a fish toxicant known as rotenone. During those historic surveys, rotenone was applied to the site and block nets were placed at the downstream end of the survey area (Townes 1984). In addition, subsamples of forage and small fish were collected with three fyke nets placed downstream of the block net. All fish were collected in the nets and identified, counted and measured. Catch rate comparisons between gears may not be appropriate, but species composition and growth rates can be examined through time. Habitat also was measured at all sites using the Status and Trends protocol. Water depth, flow, discharge, substrate composition, areal extent of woody structure, and composition of riffle/run/pools were measured at each site to examine changes due to the oil spill and cleanup activities. Definition of habitat types, designations, and assessment methods can be found in the Status and Trends manual (Wills et al. 2011).

Kalamazoo River - 17 Mile Road (Reference)

The 17 Mile Road location was upstream of the oil spill and had historical fish data from 2002 making it a good reference site for the Kalamazoo River. This site was relatively deep making some areas difficult to wade and electrofish. As a result, the section length was reduced from 1,000 ft to 800 ft during all surveys conducted except in 2002. Stream electrofishing gear was used to sample the left and right banks at 17 Mile Road. A total of 474 fish were collected in the 2002 survey and the most abundant species was Rock Bass ($n = 162$). Smallmouth Bass were the second most abundant species with a CPE of 54 fish of stream electrofished of which 76% were age-0 fish. A total of 23 species were collected resulting in a Simpson's diversity index of 6.1 and a Shannon diversity index of 2.3. In addition to the 2002 sampling, electrofishing targeting Smallmouth Bass was conducted in 2003 and 2004. Smallmouth Bass CPE was 67 fish in 2003 and 23 fish in 2004. Growth of Smallmouth Bass at 17 Mile was below state average prior to the oil spill with index scores of -0.8 in 2002, -1.9 in 2003, and -2.1 in 2004.

Electrofishing surveys were conducted annually during 2010 - 2015. A total of 3,278 fish were collected across all surveys, and CPE ranged from 95 to 1,267 fish (mean 535). The most common species caught across years were Common Shiner (CPE=174), Rock Bass (84), Bluntnose Minnow (71), and Smallmouth Bass (41). Northern Hog Sucker, Hornyhead Chub, and Rainbow Darters were other abundant species observed at this site. The lowest catch was observed in 2010 when very few minnows and shiners were collected. Peak CPE occurred in 2012 caused by a large recruitment year of Smallmouth Bass (129) and the highest CPE of Bluntnose Minnow (191), Common Shiner (559), and Rock Bass (147/1,000 ft). The number of species observed in surveys during 2010 - 2015 averaged 21 (range 16 to 25) with a Simpson's diversity score of 5.98 and a Shannon's diversity score of 2.15 (Table 1). Diversity scores fluctuated between surveys, but there was no trend through time, nor was diversity different than in the 2002 survey. Smallmouth Bass CPE averaged 82 in surveys following the oil spill. Average length for Smallmouth Bass was 5.3 inches and ranged from 1 to 19 inches. An

average of 7.5% of fish captured were of legal size (>14 inches), and most fish were age 1 or 2 with a few fish up to 9 years old being sampled. The size and age of Smallmouth Bass at 17 Mile Road did not vary through years with the exception of the large recruitment year in 2012 where most fish were age-0 (88%).

Habitat sampling was conducted before the oil spill on August 13, 2002 and August 16, 2004. In 2002, the average width was 100 ft with an average depth of 1.8 ft with a discharge of 182 cfs. Discharge was 191 cfs in 2004 with a mean depth of 1.8 ft. Habitat conditions were similar on the two sampling dates and were averaged to represent the pre-spill conditions. The water clarity was slightly turbid. Cover consisted of a moderate abundance of undercut banks, woody structure and overhanging vegetation with limited deep pools, aquatic plants, and boulders. Bottom type was predominantly gravel (55%), followed by sand (25%), cobble (7%), and silt (8%). The site was almost entirely run (96%) with small sections of riffle (3%). Bank stability ranged from good to poor with the predominant score of fair (25-50% of the bank = bare soil). Woody habitat was prevalent and there was an average of 64 logs per 1,000ft of river totaling 645 linear ft per 1,000 ft of river. In addition log jams, brush piles and stump clusters covered 5,360 square feet per 1,000 ft of river.

Habitat was sampled annually beginning in 2010. Habitat was very similar in assessments from 2010 to 2015. The mean depth and discharge on sampling dates varied due to fluctuations in seasonal precipitation and averaged 2.0 ft deep and 214 cfs. Substrate was still predominantly gravel (31%) followed by small cobble (23%), sand (18%), silt (12%), and large cobble (11%). The site was mostly run habitat (92%) with few areas of riffle (8%) and no pools in 2010 - 2012. Pools and riffles were more prevalent in 2013 due to the low discharge (153 cfs) resulting in more exposed riffles. Pools made up an average of 7.7% of the habitat after being low or absent in earlier samples. Riffles increased from an average of 7.5% from 2010 to 2012, to 23.1% in 2013. Woody cover was abundant with moderate levels of undercut banks, and aquatic plants, but sparse overhanging vegetation, deep pools, and boulders. Bank stability varied between good and fair with 0-50% of soil exposed on the bank. Woody habitat was consistent through time with a mean of 67 logs per 1,000 ft of river for a total of 752 linear feet per 1,000 ft of river. Log jams, brush piles, and stump clusters covered 7,515 square feet of woody habitat per 1,000 ft of river.

Kalamazoo River - 15 Mile Road

A rotenone survey was conducted at 15 Mile Road on August 29, 1982 (Towns 1984) which can serve as representation of the fishery at this site prior to the oil spill. Rotenone surveys were conducted 300 ft upstream to 300 ft downstream of the 15 Mile Bridge for a total of 600 ft of river sampled. No habitat data were collected as part of the 1982 sampling effort. A total of 942 fish and 27 different species were collected. The most common fish were Bluntnose Minnow (CPE = 270), Northern Hog Sucker (197), Common Shiner (185), Blackside Darter (135), White Sucker (125), Smallmouth Bass (120), and Rock Bass (92). Northern Pike also were collected with a CPE of 23/1,000 ft of rotenone application.

Following the oil spill, surveys were conducted annually at the 15 Mile Road site from 500 ft below the Squaw Creek mouth to 500 ft upstream for a total station length of 1,000 ft. This section is downstream from the 1982 rotenone survey which was conducted right at the 15 Mile Road Bridge.

The sampling station was moved for a more wadeable section and to move away from a busy response access site. A total of 6,894 fish were collected during 2010-2015. Total CPE was higher at 15 Mile Road than the other sites in the Kalamazoo River (mean = 1,100). Species richness ranged from 19 to 27 with a mean of 23.8 species. Species diversity was similar to the 1982 sample in 2010 and 2011 immediately after the oil spill, but declined in 2012. Simpson diversity scores were 10.3 in 2010 and 12.4 in 2011 which was comparable to the score of 11.1 in 1982. In 2012, Simpson diversity scores dropped to 5.8 and remained low from 2012 through 2015 (mean 8.0). The total CPE for all fish species at 15 Mile Road increased during 2012-2014 due to high mean CPE of Common Shiner (294), Bluntnose Minnow (428), and Rock Bass (198). This resulted in lower diversity scores as catch was dominated by a few abundant species. Rainbow Darter populations declined from a CPE of 139 in 2010 to a mean CPE of 51 from 2011 to 2013. Mean CPE for Rainbow Darters increased in 2014 and 2015 (mean CPE 162) indicating that quality riffle habitat was present at this site and rainbow darter populations were beginning to rebound. Smallmouth Bass numbers peaked in 2012 (CPE = 147) due to high production of young-of-year fish. Shortly after 2012, Smallmouth Bass catch rates declined each year to a low of 6 fish per 1,000 ft in 2015. Smallmouth Bass growth rates were average in surveys where an adequate number of fish were collected to estimate growth. The average length of Smallmouth Bass captured in surveys from 2010 - 2015 was 6.3 inches and was similar to the average size observed in the 1982 rotenone survey (6.9 inches). Smallmouth Bass ranged from 2 - 20 inches with an average of 6.4% of fish being legal size. No changes in the size of Smallmouth Bass were observed over the time period examined. Despite being observed in the rotenone sampling, only one Northern Pike was observed in electrofishing surveys from 2010 - 2015. Largemouth Bass CPE was higher at the 15 Mile Road site (12) compared to other sites.

Habitat was not assessed at 15 Mile Road prior to the oil spill, but surveys were conducted annually from 2010 through 2015. The habitat station begins approximately 500 ft downstream of where Squaw Lake Drain enters the river and continues upstream 1,000 feet. Similar conditions were observed in habitat surveys from 2010 through 2015. The average width of the river was 156.1 ft with an average depth of 1.5 ft. Mean discharge at 15 Mile Road was 257 cfs and ranged from 304 cfs in 2010 to 227 cfs in 2014. Boulders and aquatic vegetation were moderately abundant and undercut banks, overhanging vegetation, deep pools, and logs/woody cover were sparse. Substrate did not change through the sampling period and consisted primarily of small cobble (37%) and gravel (38%), with smaller prevalence of sand (12%), large cobble (6%), silt (5%), and boulder (1%). The site was made up primarily of run habitat (62%) followed by riffles (37%) and pools (1.3%). Less woody habitat was available at 15 Mile Road when compared to other sites. Mean estimates were 17 logs per 1,000 ft of river making up 149 linear feet and 1,781 square feet of log jams. Woody habitat decreased through time. In 2010, there were 28 logs per 1,000 ft measuring 252 linear feet which dropped to only 7 logs/1,000 ft totaling 72 linear feet in 2011. Log jams covered an average of 2,400 square feet in 2010 and 2011 then dropped to a mean of 1,471 square feet from 2012 to 2014. This decrease in woody habitat is due to the removal of oil-contaminated wood from the river by cleanup crews and represents a decrease in available habitat throughout the sampling period.

Kalamazoo River - 11 Mile Road

The 11 Mile Road site was a Status and Trends fixed site for Smallmouth Bass that has been surveyed annually since 2008. Only Smallmouth Bass were collected in 2008 while all species of fish were

collected in 2009 through 2015. The site extends 1,000 ft downstream of 11 Mile Road and is permanently marked to ensure consistent effort from year to year. The entire site was wadeable and sampling was conducted using a barge electrofisher. A total of 4,390 fish were collected from 2008 through 2015. The most common fish species were Common Shiner (CPE = 97), Rock Bass (73), Smallmouth Bass (64), Creek Chub (56) and Bluntnose Minnow (40). CPE peaked for Smallmouth Bass in 2012 (213/1,000 ft) due to a high recruitment year, similar to what was observed at the other sites. Following 2012, Smallmouth Bass CPE declined each year to 41 in 2013 and 21 in 2014 and 2015. These catch rates are lower than those observed prior to the oil spill (mean CPE = 69 in 2008 and 2009). The size of Smallmouth Bass observed decreased in 2011 through 2014. Mean length of fish in 2010 surveys (10.0 inches) was similar to that of 2008 and 2009 surveys (average of 9.2 inches) as was the percentage of fish of legal size (18.8 in 2010; 24.6 in 2008 - 2009). Mean size decreased in 2011 through 2014 with an average length of 5.1 inches and 3.5% of fish being of legal size. The large number of small fish in the 2012 survey did reduce these averages, but this trend was evident in other years as well. In 2015, mean length of Smallmouth Bass began to increase (9.7 inches; 28% legal size) and was similar to pre oil spill conditions. The 11 Mile Road site had sufficient numbers of Smallmouth Bass to allow calculation of growth rates from 2008 - 2014 (Table 1). Growth rates varied around the state average prior to the oil spill with a growth index score of +1 in 2008 and -1 in 2009. Mean growth indices from 2010 - 2014 did not differ from the state average with a mean of -0.5 although they were below average in 2014 with an index score of -1.2. Growth rates may be decreasing at 11 Mile Road, but more likely this is due to variation within surveys. This site will be sampled in the future and will be monitored to determine if growth rates are declining.

Darters were found at the site in low abundance in 2009 prior to the oil spill. Rainbow Darters were the most abundant (31/1,000 ft) followed by Johnny Darters (9/1,000 ft). The number of darters decreased in 2010 and 2011 (mean CPE: Rainbow Darter 12/1,000 ft; Johnny Darter 2/1,000 ft), but began to rebound in 2012 and 2013 (mean CPE: Rainbow Darter 48/1,000 ft; Johnny Darter 11/1,000 ft). In addition, Greenside Darters were captured in 2012 (3/1,000 ft) for the first time since sampling initiated in 2008. Despite initial increases, darter numbers declined in 2014. Rainbow Darter CPE dropped to 6/1,000 ft and Johnny Darters and Greenside Darters were not observed. This decrease in catch rate coincided with the increased sand and silt deposits associated with the removal of the Ceresco Dam in the fall of 2013. In 2015, CPE of darters began to increase again to levels similar to 2008 prior to the oil spill and dam removal. CPE in 2015 was the highest observed for Rainbow Darters (53/1,000 ft), Johnny Darters (22/1,000 ft), and Greenside Darters (10/1,000 ft) despite an increase in sand sediment deposition (see habitat data below). These species are recovering despite reduced habitat quality. Species richness averaged 23 and varied little through time with a range from 20 in 2010, 2011, and 2014 to 27 in 2015. Simpson's diversity index score was 9.32 in 2009 prior to the oil spill and declined in 2010 to 4.73. Diversity increased each year from 2010 to 2013 where it peaked at 11.06. Diversity decreased again in 2014 potentially because of the impact of increased sediment due to the Ceresco Dam removal. Diversity score rebounded to pre-oil spill numbers in 2015 with a score of 9.31. Fish populations at 11 Mile Road appear to have recovered to levels similar to those observed prior to the oil spill.

The habitat station began 1,000 ft downstream of the 11 Mile Road bridge and continued to the downstream side of the bridge. The site had a mean width of 143.4 ft and a mean depth of 1.2 ft from 2008 through 2015. Discharge varied from a high of 320 cfs in 2010 to a low of 187 cfs in 2012, with an average of 252 cfs. Boulders and aquatics plants were moderately abundant, and undercut banks,

overhanging vegetation, deep pools, and logs/woody cover were sparse. Habitat classifications remained the same each year except in 2015 when aquatic plants were sparse or absent. The site was split between riffle (56%) and run (44%) habitat with no pools present at the site. Reduction in the size of the island was noted. The vegetation on the island had been removed, and there was evidence of bank erosion. Woody habitat also decreased through time at this site. The highest abundance of logs was observed in 2008 before the oil spill with 66 logs per 1,000 ft present for 726 linear feet. The abundance of logs was similar in 2010 (53 logs per km and 540 linear ft) but dropped in 2011 (8 logs per km and 90 linear feet) and remained low from 2012 - 2015 (25 logs per km and 255 linear feet). The area of the river comprised of log jams did not change through time and averaged 1,597 square feet and peaked in 2013 with 2,688 square feet. Substrate at this site changed over the course of the sampling period. From 2008 through 2013, the site was dominated by small cobble (37%), gravel (31%), and large cobble (13%) with a small amount of sand (5%) and silt (4%). In 2014, we observed an increase in the proportion of sand (11.3%) and silt (11.3%) and a decrease in small cobble (16%) as well as increased turbidity. In 2015, this trend continued with an increase in prevalence of sand (47%) and a decrease in gravel (12.8%) and small cobble (17.5%). Vegetation was noted as being covered by sand and silt. The substrate changes were probably due to the removal of the Ceresco Dam at 12 Mile Road just upstream of the 11 Mile site. Sediment transport has increased due to the scouring of the new channel through the old impoundment resulting in an increased sand load. As the channel settles, we expect the sand to continue to move downstream and gravel and small cobble to become more available at this site in the future.

Kalamazoo River - Custer Road

This site began approximately 1,320 ft downstream of Custer Road and continued downstream 4,224 feet. Historic survey data for this site were available from sampling conducted in 1982 and 2005. On August 2, 1982, rotenone was applied to a 540 ft stream reach starting at 2,640 ft downstream of Custer Road (i.e., a subset of the 2010-2015 sampling area) using the same methods as the 15 Mile Road site (Towns 1984). In addition, an electrofishing survey was conducted in 2005 at a site downstream of Custer Road in Fort Custer Recreation Area. The survey is included as a non wadeable site comparison to the Custer Road site prior to the oil spill. Electrofishing surveys were conducted annually from 2010 - 2015. This section of river was not wadeable and required all sampling to be conducted from an electrofishing boat. The left descending bank was electrofished in a downstream direction as part of a non-wadeable protocol (Wills et al. 2011). CPE for all sites were calculated as the number of fish per 1,000 ft of shoreline electrofished.

In general, CPE for several species at Custer Road was lower than at other sites on the Kalamazoo River. A total of 655 fish were captured at the Custer Road site in the 1982 Rotenone survey, 80 fish were captured in 2005 electrofishing surveys, and an average of 227 fish were captured in surveys from 2010 - 2015. Rotenone surveys had higher CPE (1,213/1,000 ft) and captured more species (26) than electrofishing surveys (mean of 63/1,000 ft and 12 species respectively). The most common fish species caught in the 1982 rotenone survey were Striped Shiner (272/ 1,000 ft), Common Shiner (165/1,000 ft), Hornyhead Chub (106/1,000 ft), and Golden Redhorse (94/1,000 ft). The electrofishing survey in 2005 resulted in a CPE of 16.7/1,000 ft and a total of eight species. The most common species captured were Golden Redhorse (9.0/1,000ft), Common Carp (3.1/1,000 ft), and Smallmouth Bass (2.5/1,000 ft). CPE was higher in electrofishing surveys following the oil spill (2010 to 2015)

than in 2005 with a mean total CPE of 70.0. Similar to 2005, the most common species captured in electrofishing surveys from 2010 to 2015 were Golden Redhorse (CPE = 27.3), Northern Hogsucker (11.5), Common Carp (3.6), and Smallmouth Bass (2.5). Low numbers of other fish were captured. CPE for these species did not fluctuate throughout the 2010 - 2015 sampling period and Smallmouth Bass CPE did not increase in 2012 as it did at other sites. Smallmouth Bass were larger in Custer Road surveys than at other sites with a mean length of 10.2 inches and 27.1% being of legal size. This is most likely due larger Smallmouth Bass being more susceptible to boat electrofishing gear than smaller individuals. Growth rates for Smallmouth Bass were only available for 2013 and were below the state average with an index score of -1.3. No changes in fish community were observed at this site as a result of the oil spill. Many fish species that are sensitive to impacts on habitat quality (e.g. darter species) were not sampled adequately by boat electrofishing gear, limiting our ability to detect impacts.

There were differences in the species observed in the rotenone surveys compared to the electrofishing surveys with higher CPE of smaller bodied fishes and greater diversity in the rotenone surveys. These differences were observed prior to the oil spill in the 2005 electrofishing survey as well, suggesting differences were due to gear type, rather than habitat changes in the river. Total mean CPE was also lower in electrofishing surveys from 2005 through 2015 than those reported for 17 Mile, 15 Mile, and 11 Mile Roads most likely due to the differences in gear. Boat electrofishing gear utilized in the surveys from 2005 - 2015 was missing or underrepresenting a number of smaller fish species (e.g. darters, shiners, etc.) and is not comparable to data from other sites.

Habitat was assessed at Custer Road from 2010 through 2015 using the Status and Trends non-wadeable stream habitat assessment protocol (Wills et al. 2011). The site changed very little over the course of the surveys. The mean stream width was 142 feet and the water was deeper than at other sites with an average depth of 3.7 feet. The site was entirely run habitat with only one transect in 2012 being categorized as riffle. The site had moderate abundance of logs and woody debris and sparse overhanging vegetation. Aquatic plants and boulders were not observed at this site. On average, log jams and brush piles covered 3,331 square feet per 1,000 linear feet of river, and woody cover did not fluctuate from 2011 to 2015. The substrate was predominantly gravel (38.9%) and sand (33.0%) with some silt (7.8%) and detritus (6.8%). We did not observe changes in habitat throughout the survey period from 2010 - 2015. We do not have habitat assessment data prior to the oil spill which limits our ability to determine if habitat has changed from pre oil spill conditions. We did observe changes in woody structure and substrate at other sites that we did not observe at Custer Road which may indicate that habitat was not heavily impacted at this site. Custer Road is the furthest downstream site and may have been affected the least by the oil spill and cleanup efforts.

Kalamazoo River - River's Edge

The River's Edge site was sampled one time on August 12, 2010 following the oil spill to assess the fish species present. Electrofishing sampling was conducted using a barge electrofishing unit and sampling occurred on both banks following the Status and Trends protocol utilized at other sites. The station begins at the downstream side of 6 1/2 Mile Road Bridge and continues downstream 700 feet. A total of 185 fish and 21 different species were captured in the 2010 survey. The most common fish species were Bluntnose Minnow (CPE = 30), Common Shiner (19), and Sand Shiner (19). Total CPE of all species (132) and Smallmouth Bass CPE (10) were lower at River's Edge than 17 Mile, 15 Mile,

and 11 Mile Roads, but higher than Custer Road. Johnny Darters and Blackside Darters were present at this site and are species that may have a higher susceptibility to be impacted by the oil spill. We could not assess the potential impacts of the oil spill at this site as there were no pre-spill data or catch rates through time for comparison.

Analysis and Discussion

We observed fluctuations in the relative abundance of fish and species diversity throughout the study period (Appendix A and Table 2). Many observed changes through time did not coincide with the timing of the oil spill or were also reflected in the control site. When comparing changes in mean CPE from pre surveys to that of 2010 to 2015, we observed an increase for 69% of species at the control sites (17 Mile Rd) resulting in an increase in CPE of 101. Sites downstream of the oil spill location experienced an increase in only 39% of species at 15 Mile and 45% at 11 Mile resulting in changes in CPE of -470 and -32.1 respectively. The Custer Road site showed an increase in 89% of species most likely due to differences in gear between pre and post surveys. We also observed CPE of Johnny Darters and Rainbow Darters decrease following pre and 2010 surveys (Figure 4). These decreases were short lived and CPE for darter species returned to similar levels to CPE prior to or initially following the oil spill by 2015. CPE of Rainbow and Johnny Darters increased beyond to levels higher than reference conditions after 2012 most likely due to the benefits of the removal of the Ceresco Dam. We did not observe a decrease in species diversity across sites following the oils spill (Figure 5), despite some site specific decreases. With the exception of Custer Road, all sites had similar fish diversity as the reference site at 17 Mile Road in 2015 indicating no long term reduction in diversity following the oil spill. Differences in gear type most likely caused the lower diversity score at Custer Road rather than impacts from the oil spill.

By 2015, the fish communities at most sites had returned to conditions similar to those recorded prior to the oil spill. However, Smallmouth Bass numbers are still somewhat depressed in the 11 Mile and 15 Mile Road sites. Changes in fish habitat were also observed at some sites as a result of the oil spill and associated oil removal activities. Smallmouth Bass was the primary sport fish species in the Kalamazoo River at all sample sites. Smallmouth Bass catch rates declined in 2010 (i.e., immediately after the oil spill) in all sites except Custer Road (Figure 2). Catch rates also declined in the reference site at 17 Mile Road. Smallmouth Bass catch rates at 11 Mile and 15 Mile Roads experienced a greater decline than the reference site indicating a potential impact of the oil spill. Despite initial declines, there was an increase in catch rate in 2012 primarily caused by a large recruitment class. Most Smallmouth Bass captured in 2012 were age-0 fish ranging from 2 to 4 inches. Following 2012, CPE dropped again to levels similar to those following the oil spill and the 2012 year class did not result in an increased number of older fish in subsequent years. CPE in 2014 and 2015 were very low across all sites. In particular, CPE has declined at 15 Mile road since 2012 and has decreased to levels lower than pre oil spill conditions and lower than CPE at the reference site.

Average size of Smallmouth Bass caught was 7.2 inches, but fish as large as 18 to 20 inches were observed at all sites. Most Smallmouth Bass captured were age 1 and age 2 except in 2012 where a majority of fish captured were age 0. Growth rates were not calculated for all samples due to the low number of fish caught. It is difficult to assess how the oil spill affected growth as growth rates could not be calculated consistently through time. Growth index scores were generally considered average (-1 to 1) with below average growth in a few surveys at Custer Road, 11 Mile Road, 17 Mile Road, and

Riverside (Table 1). Size at age 1 was used to assess potential impacts of Smallmouth Bass growth as they were commonly captured in most surveys and could be compared across sites and through time (Figure 3). Mean length at age 1 fluctuated from 5.2 inches to 7.9 inches across sites. Growth rates were generally lowest at the 17 Mile reference site and no decrease in mean size of age-1 Smallmouth Bass was observed following the oil spill. Mean size declined in all sites in 2013 most likely due to the high recruitment year in 2012 resulting in limited resources and reduced growth of individuals due to density dependent mechanisms. Surveys in 2014 and 2015 indicated that mean size at age 1 for sites impacted by the oil spill was greater than that of the reference site (17 Mile) and within the range of growth rates observed through time. Despite observed decreases in density, Smallmouth Bass size structure did not show any long term impacts from the oil spill and in 2015 surveys was similar to pre oil spill conditions at all sites.

Northern Pike and Largemouth Bass were observed in low numbers at all sites. Due to low CPE, we could not evaluate the status of their populations, but relative abundance did not decline following the oil spill. In addition, small Bluegills were captured in relatively low numbers at all sites and Yellow Perch and Black Crappie occasionally were collected.

After the oil spill, there was a reduction in woody structure and over-hanging brush at the 15 and 11 Mile Road sites. Bank erosion was observed around the island at 11 Mile Road. There was a decrease in woody habitat in 2011 - 2013 associated with the cleanup effort which removed wood from the river that had oil contamination. Most sites still had reduced woody habitat in 2015, but densities were increasing. Wood additions were conducted in 2016 and should increase the availability of woody habitat throughout the impacted reach. Sedimentation was evident in sites downstream of the Ceresco Dam following removal in 2013. Increased sand and silt was measured at the 11 Mile Road site and was associated with some changes in the fish community, primarily the abundance of darters. Sediment load increased in 2015 as sand became more prevalent resulting from removal of the Ceresco Dam upstream. We expect that sediment should shift back to gravel and larger substrate types as the channel is established in the area that was impounded by the dam. Long-term benefits of the dam removal (including fish passage and improved downstream transport of large woody structure and nutrients) should outweigh the short-term effects at these sites.

Management Direction

Despite some species and site specific decreases in fish densities, species diversity, and habitat quality shortly after the oil spill occurred, we observed no consistent or long term impacts throughout the study period. By 2015, the fish communities at most sites had returned to conditions similar to those recorded prior to the oil spill. Smallmouth Bass numbers are still somewhat depressed in the 11 Mile and 15 Mile Road sites. The largest remaining limitation is the reduced availability of woody habitat due to the cleanup efforts. Wood additions were completed in 2016. These efforts should benefit Smallmouth Bass and other fish species at sites downstream of the oil spill. Monitoring of the 11 Mile Road Status and Trends site will continue following Status and Trends fixed site protocols (Wills et al. 2011) and will facilitate assessments of long term effects of the oil spill and the Ceresco Dam removal on the fishery. If Smallmouth Bass numbers or growth rates decline, future management actions may be required.

References

MDEQ. 2011. A biological survey of sites on the Kalamazoo River and Talmadge Creek near the Enbridge oil spill in Marshall, Calhoun County, Michigan, September 2010. Michigan Department of Environmental Quality, Water Resources Division, MI/DEQ/WRD-11/010.

National Transportation Safety Board (NTSB). 2012. Enbridge Incorporated Hazardous Liquid Pipeline Rupture and Release. Pipeline Accident Report. NTSB/PAR-12-01, PB2012-916502.

Towns. G.L. 1984. A fisheries survey of the Kalamazoo River, July and August 1982. Michigan Department of Natural Resources, Fisheries Division, Technical Report 84-7.

Wesley, J.K. 2005. Kalamazoo River assessment. Michigan Department of Natural Resources, Fisheries Division, Special Report 35, Ann Arbor.

Wesley, J.K., and M. Walterhouse. 2010. Workplan for macroinvertebrate, fish, and habitat sampling on the Kalamazoo River and Talmadge Creek to evaluate aquatic ecosystem effects of oil exposure and cleanup procedures. Michigan Department of Natural Resources and Environment, Fisheries Division and Water Resources Division, September 2, 2010.

Wills, T.C., T.G. Zorn, A.J. Nuhfer, and D.M. Infante. 2011 Draft. Stream status and trends program sampling protocols. Chapter 26 in Manual of Fisheries Survey Methods. Michigan Department of Natural Resources, Fisheries Internal Document, Ann Arbor.

Table 1. Growth index scores for Smallmouth Bass from electrofishing surveys pre oil spill (2002-2009) and after the oil spill (2010 – 2015). Blanks indicate that no survey was conducted and dashes indicate not enough fish were captured to calculate growth index scores.

Year	Custer Rd	11 Mile	15 Mile	17 Mile	Riverside
2002				-0.8	
2003				-1.9	
2004				-2.1	
2008		+1			
2009		-1			
2010	-	-0.3	-		-2.8
2011	-	-0.9	-	-0.8	
2012	-	-0.4	0.3	-0.7	
2013	-1.3	-0.5	-0.5	-1.5	
2014	-	-1.2	-	-	

Table 2. Species Richness (number of species observed) and two diversity index scores (Simpson's D and Shannon's H) for sites sampled in the Kalamazoo River prior to (PRE) and following the Enbridge oil spill in Talmadge Creek.

SITE	DATE	Year	Species Richness	Simpson	Shannon
11 Mile	09/14/2009	PRE	24	9.32	2.55
	09/08/2010	2010	20	4.73	2.05
	08/30/2011	2011	20	8.62	2.39
	09/05/2012	2012	24	9.15	2.48
	08/27/2013	2013	26	11.06	2.68
	08/27/2014	2014	20	6.60	2.39
	08/25/2015	2015	27	9.31	2.60
15 Mile	07/29/1982*	PRE	27	11.05	2.66
	09/14/2010	2010	25	10.29	2.57
	08/30/2011	2011	24	12.39	2.69
	09/06/2012	2012	23	5.80	2.16
	09/05/2013	2013	19	5.09	2.02
	08/26/2014	2014	25	6.07	2.18
	08/24/2015	2015	27	8.37	2.42
17 Mile	08/13/2002	PRE	23	6.09	2.31
	08/10/2010	2010	16	4.57	2.07
	09/08/2010	2010	25	8.03	2.46
	08/30/2011	2011	21	8.89	2.51
	08/29/2012	2012	24	4.01	1.85
	08/26/2013	2013	20	3.83	1.85
	08/25/2014	2014	23	5.04	1.99
	08/26/2015	2015	20	7.52	2.33
Custer Road	08/02/1982*	PRE	26	10.16	2.70
	07/29/2005	PRE	8	2.84	1.36
	08/11/2010	2010	20	6.77	2.21
	09/14/2010	2010	18	3.39	1.76
	09/01/2011	2011	9	2.43	1.27
	09/06/2012	2012	7	2.30	1.01
	09/23/2013	2013	13	2.67	1.34
	09/03/2014	2014	13	4.19	1.76
	09/09/2015	2015	7	1.72	0.87
Rivers Edge	08/11/2010	2010	21	8.46	2.44

*Data from Rotenone Sampling

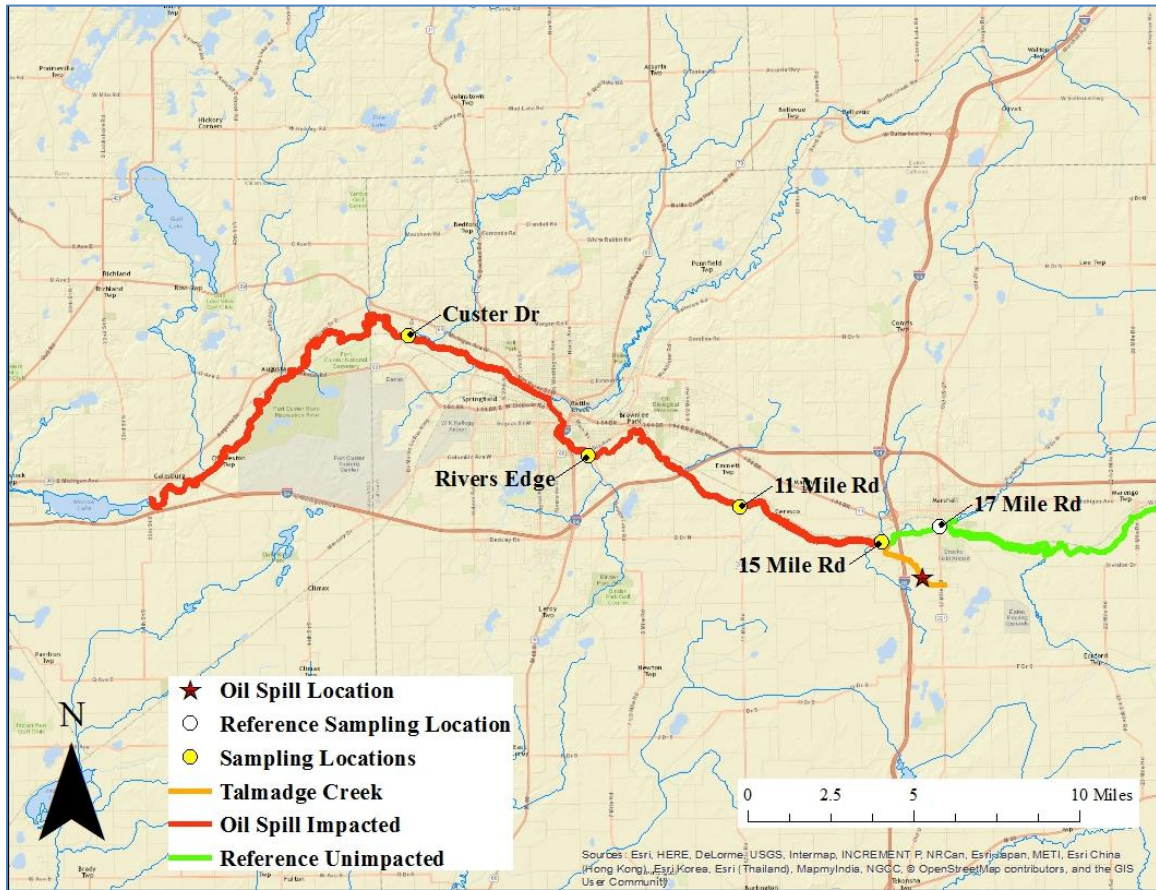


Figure 1. Fish sampling locations on the Kalamazoo River.

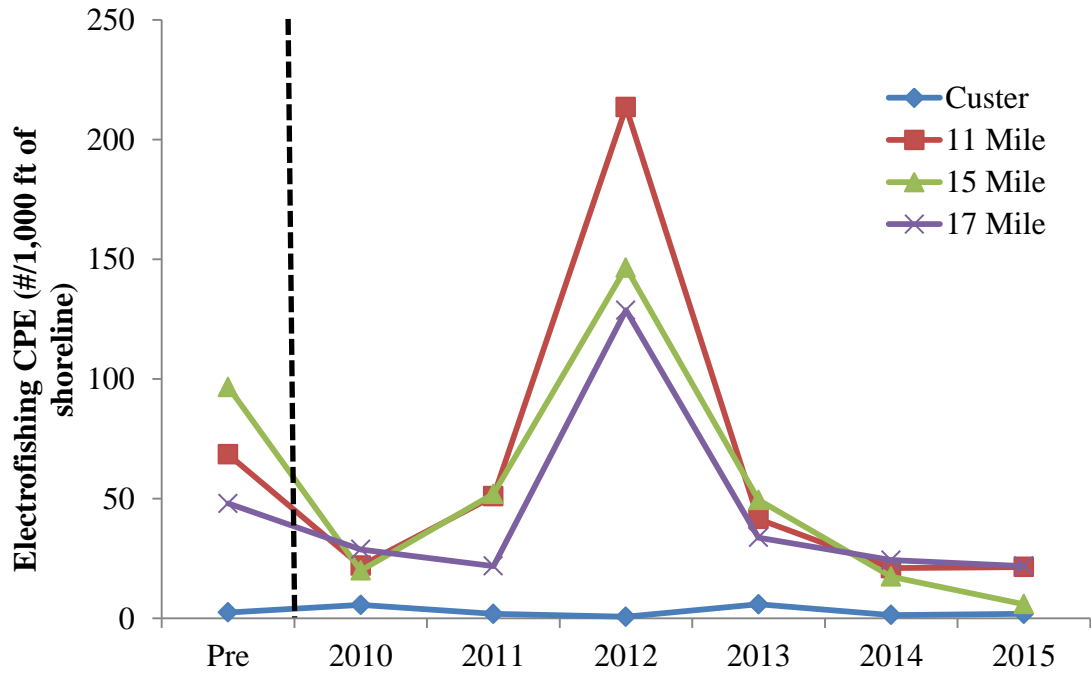


Figure 2. Catch rates for Smallmouth Bass in electrofishing surveys pre oil spill (1982-2009) and after the oil spill (2010 – 2015). The dotted line represents when the oil spill occurred in 2010. The 15 Mile site was sampled in the Pre time period using rotenone rather than electrofishing.

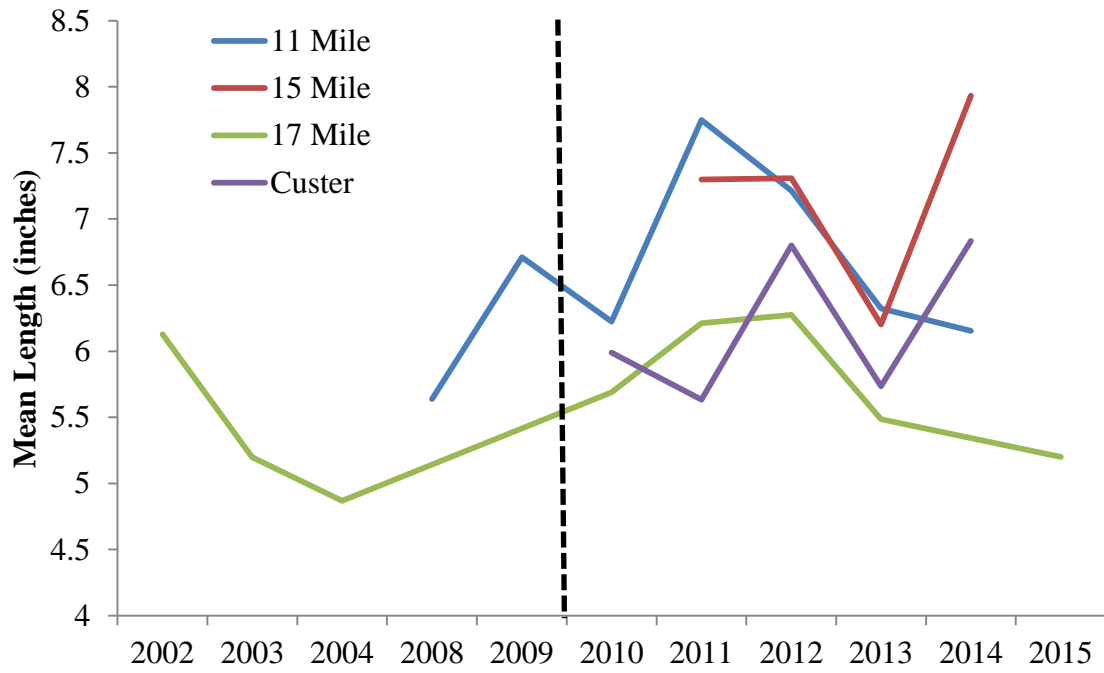


Figure 3. Mean length of age-1 Smallmouth Bass captured in electrofishing samples from 2002 through 2015 at four sites on the Kalamazoo River. The dotted line represents when the oil spill occurred in 2010.

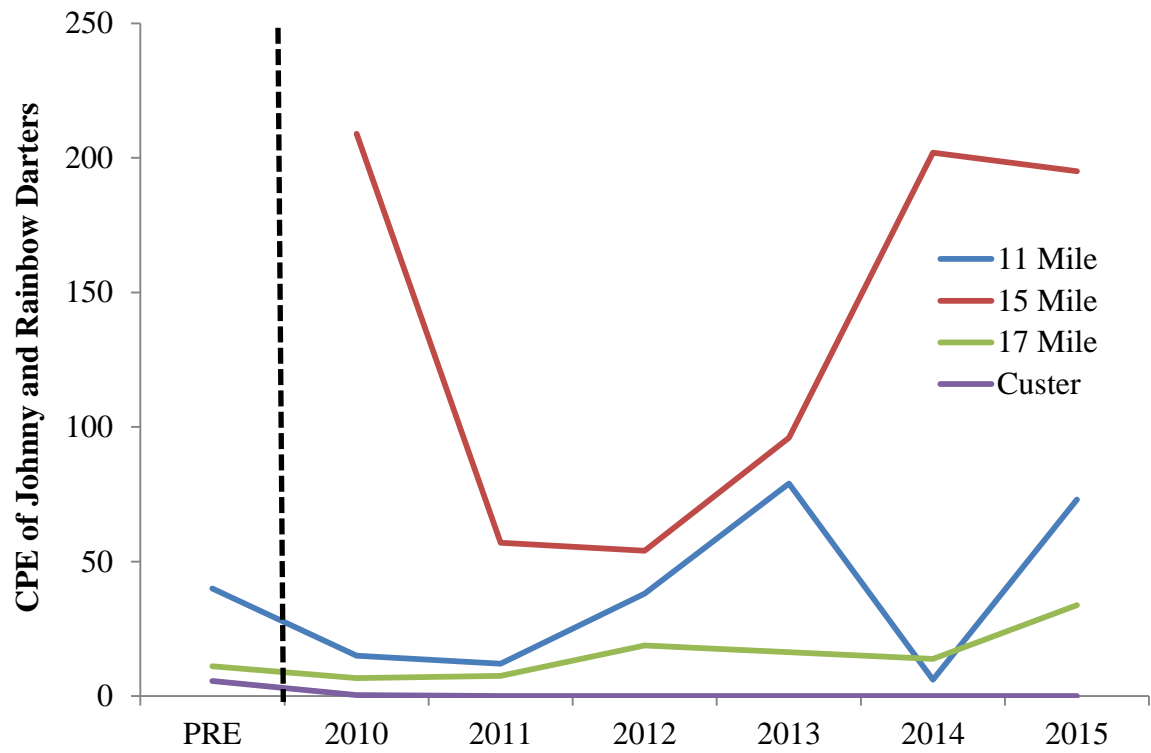


Figure 4: CPE of Johnny Darters and Rainbow Darters combined for 4 sites on the Kalamazoo River surveyed prior to (PRE) and following an oil spill in 2010. The dotted line represents when the oil spill occurred in 2010.

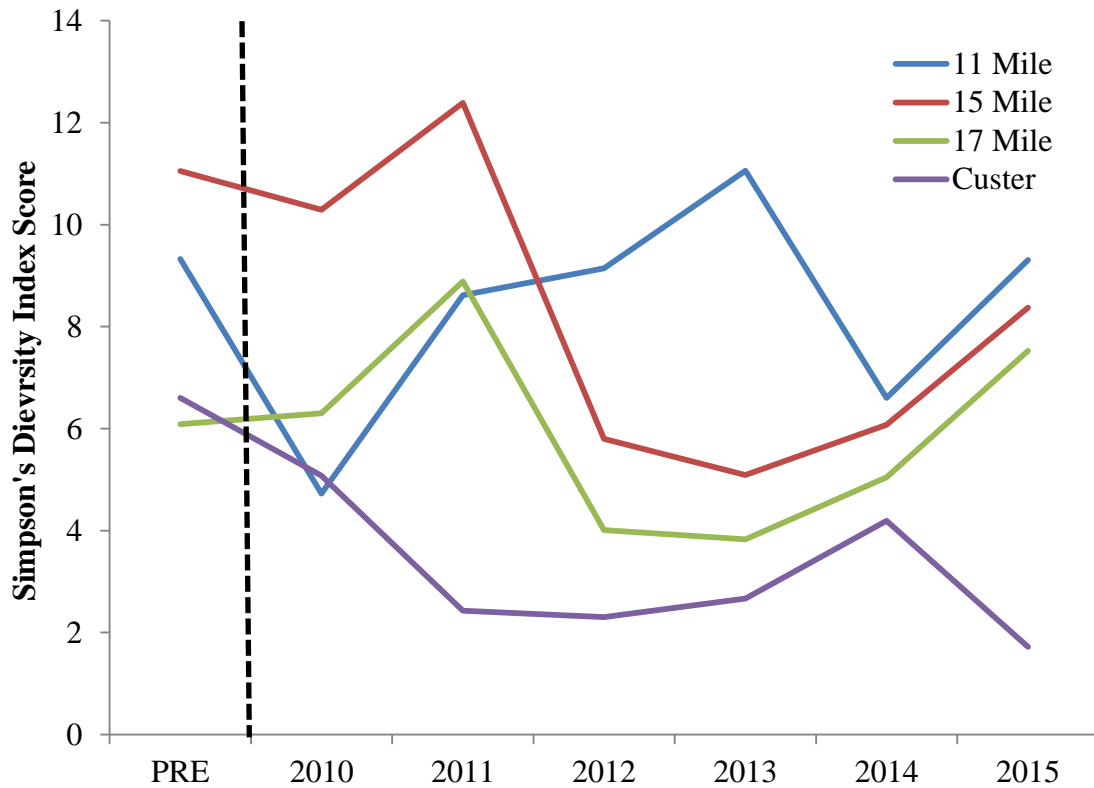


Figure 5. Simpson's diversity index score for four sites in the Kalamazoo River prior to the oil spill in 2010 (PRE) and in the years following the oil spill. The dotted line represents when the oil spill occurred in 2010.

Appendix A. Catch per unit effort (# of fish per 1,000 ft of river) from 5 sites in the Kalamazoo River before and after an oil spill in 2010. PRE samples at 15 Mile Rd were from rotenone surveys.

Species	17 Mile		15 Mile		11 Mile		Custer Road		River's Edge
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	2010
Am. Brook Lamprey	0.0	0.0	0.0	0.0	1.0	0.0	0.0	0.0	0.0
Black Crappie	0.0	0.4	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Bluegill	17.0	9.1	1.7	8.3	0.0	2.2	0.0	0.6	2.0
Blacknose Dace	0.0	0.0	0.0	1.0	4.0	0.0	0.0	0.0	0.0
Bluntnose Minnow	16.0	71.0	270.0	246.5	28.0	42.0	0.2	0.3	42.0
Blacknose Shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Bowfin	0.0	0.6	0.0	0.0	0.0	0.0	0.2	0.1	0.0
Brown Bullhead	0.0	0.5	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Blackside Darter	17.0	10.5	135.0	27.8	0.0	11.5	0.0	0.6	1.0
Brook Silverside	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.1	0.0
Common Carp	7.0	0.9	33.3	1.2	0.0	0.2	3.1	5.3	0.0
Channel Catfish	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.3	0.0
Chestnut Lamprey	0.0	2.0	0.0	1.5	0.0	0.8	0.0	0.1	1.0
Creek Chub	6.0	6.1	1.7	79.5	73.0	52.8	0.0	0.1	3.0
Common Shiner	35.0	174.0	185.0	157.2	115.0	94.3	0.0	1.9	27.0
Central Stoneroller	0.0	1.3	0.0	42.2	24.0	6.5	0.0	0.0	0.0
White Sucker	36.0	7.0	125.0	52.5	13.0	19.7	1.0	0.2	3.0
Freshwater Drum	0.0	0.0	0.0	0.0	0.0	0.3	0.0	0.0	0.0
Golden Redhorse	3.0	3.3	35.0	3.5	5.0	4.0	9.0	28.1	8.0
Golden Shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Grass Pickerel	0.0	0.9	6.7	1.8	5.0	1.2	0.0	0.0	0.0
Greater Redhorse	0.0	0.0	13.3	0.0	0.0	0.0	0.0	1.0	0.0
Green Sunfish	5.0	10.2	61.7	26.5	10.0	32.8	0.0	0.0	0.0
Greenside Darter	0.0	0.0	0.0	0.0	0.0	2.2	0.0	0.0	0.0

Appendix A. Continued

Species	17 Mile		15 Mile		11 Mile		Custer Road		River's Edge
	PRE	POST	PRE	POST	PRE	POST	PRE	POST	2010
Hornyhead Chub	9.0	37.8	1.7	19.8	27.0	25.5	0.0	0.0	3.0
Hybrid Sunfish	2.0	0.4	0.0	0.0	0.0	2.5	0.0	0.0	0.0
Johnny Darter	2.0	7.0	23.3	32.5	9.0	7.5	0.0	0.0	1.0
Largemouth Bass	1.0	8.5	13.3	11.7	1.0	0.7	0.0	0.0	2.0
Logperch	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Mimic Shiner	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	0.0
Mottled Sculpin	0.0	0.0	1.7	0.7	0.0	0.0	0.0	0.0	0.0
Central Mudminnow	0.0	0.4	20.0	3.0	1.0	0.8	0.0	0.0	0.0
Northern Hog Sucker	13.0	27.3	196.7	46.8	23.0	36.8	0.4	11.5	12.0
Northern Pike	0.0	0.8	25.0	0.2	2.0	0.2	0.0	0.4	1.0
Pumpkinseed	62.0	0.2	1.7	0.7	1.0	2.0	0.0	0.0	1.0
Map Turtle	0.0	0.0	0.0	0.0	0.0	0.2	0.0	0.0	2.0
Rainbow Darter	9.0	7.8	16.7	103.0	31.0	29.7	0.0	0.1	0.0
River Chub	1.0	7.1	0.0	8.5	0.0	4.0	0.0	0.1	0.0
Rock Bass	162.0	83.9	91.7	131.8	89.0	70.7	0.2	0.5	13.0
Rosyface Shiner	1.0	4.5	6.7	30.7	17.0	16.0	0.0	1.6	8.0
Redear Sunfish	0.0	0.2	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Sand Shiner	0.0	0.6	90.0	7.3	0.0	3.0	0.0	6.1	26.0
Spotfin Shiner	6.0	2.5	0.0	0.2	30.0	9.5	0.0	6.9	14.0
Shorthead Redhorse	0.0	0.1	55.0	0.0	0.0	0.0	0.0	0.0	0.0
Smallmouth Bass	54.0	81.5	120.0	48.6	68.5	61.8	2.5	3.1	10.0
Striped Shiner	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0
Stonecat	5.0	3.0	30.0	2.2	4.0	5.8	0.0	0.0	1.0
Walleye	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.2	0.0
Yellow Perch	0.0	0.2	0.0	0.2	0.0	0.0	0.0	0.0	0.0
Yellow Bullhead	5.0	3.8	8.3	3.2	5.0	6.7	0.0	0.0	0.0