

Appendix I: Mussel Shell Survey Report

**Mussel Shell Survey Report:
Kalamazoo River Unionid Mussel Shell
Survey in the Marshall and
Battle Creek Area
October 2010**

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1. Introduction

On July 26, 2010, an oil release from Enbridge Energy Partners, L.P. (Enbridge) line 6B was discovered. The line, located in Marshall, Calhoun County, Michigan, is a 30-inch, 283,000-barrels per day line that transports light synthetics and heavy and medium crude oil. The release occurred in an undeveloped area on the outskirts of town with coordinates of approximately North ½ Section 2, T3S, R6W, Latitude: 42.2395273, Longitude: -84.9662018. Upon discovery of the release, the pipeline was shut down and isolation valves closed, stopping the flow of the oil. The exact amount of oil released prior to the shutdown is unknown. However, it is estimated that at least 1 million gallons of crude oil was released to nearby Talmadge Creek and to the Kalamazoo River (U.S. EPA, 2010; Enbridge Energy, 2011).

Soon after the spill, the Trustees for the Natural Resource Damage Assessment (NRDA), in coordination with Enbridge, began to collect ephemeral data on potentially injured natural resources in Talmadge Creek and the Kalamazoo River and their watersheds. The Trustees include the U.S. Department of the Interior, represented by the U.S. Fish and Wildlife Service and the Bureau of Indian Affairs; the State of Michigan, represented by the Michigan Department of Natural Resources (MDNR), the Michigan Department of Environmental Quality (MDEQ), and the Michigan Attorney General; the U.S. Department of Commerce, represented by the National Oceanic and Atmospheric Administration; the Nottawaseppi Huron Band of the Potawatomi; and the Match-E-Be-Nash-She-Wish Band of Potawatomi. As a part of the ephemeral data collection, a mussel shell survey was conducted in October 2010. The survey was conducted to document post-mortem mussel shells that, depending on their relative condition, may be indicative of injury to mussels as a result of exposure to contaminants released during the spill; physical injuries to mussels as a result of response activities, such as crushing by boat traffic, habitat alterations, and sedimentation; or factors unrelated to the incident.

This report describes the mussel shell survey, which was conducted in October 2010 on the Kalamazoo River from the Marshall Impoundment to the Town of Battle Creek, Michigan, and summarizes the survey findings. The Trustees and Enbridge collaboratively developed the study work plan and conducted the survey field work.

Survey results may be used in combination with other information to help identify and characterize potential injuries to mussel communities resulting from potential exposure to oil or from physical injury (i.e., damaged or crushed shells) caused by oil spill response activities, as well as to distinguish spill-related effects from mortality likely to be unrelated to this incident. Results may also be used to evaluate the need for additional studies to quantify impacts to mussels as a result of the spill and to aid in the development of such studies.

1.1 Background on Unionid Mussels

Freshwater unionid mussels belong to one of four bivalve families that live along the bottoms of creeks, rivers, and lakes in Michigan. Nationwide, unionid mussels are among the most endangered groups of animals. A 1993 review of the status of unionid species by the American Fisheries Society found that 97 of 292 species that occur in the United States are considered endangered (Williams et al., 1993). Mussel population declines have been attributed to habitat degradation from pollution, physical alterations such as dams, and pressure from exotic species [e.g., zebra mussels (*Dreissena polymorpha*)].

Michigan's rivers and streams support significant populations of mussels, including federal- and state-listed endangered species. There are 46 unionid mussel species that occur in Michigan, 19 of which are state-listed as threatened or endangered. A total of 28 unionid mussel species have been observed in the Kalamazoo River Watershed. These include three state endangered species, three state threatened species, and six species of special concern¹ (Badra, 2010). There are no known federally listed mussel species present in the watershed. Between Marshall and Battle Creek, the stretch of the river where this study took place, 13 unionid mussel species have been observed since 1929 (Table 1).

Unionid mussels are an important component of Michigan's natural history and play important ecological roles in stream ecosystems. Unionids can be important to stream foodwebs, often comprising the highest percentage of biomass relative to other benthic stream organisms (Strayer et al., 1994). They are a key component in the food chain, linking aquatic microorganisms to muskrats, crayfish, birds, and other predators. Unionids are also intricately linked to fish communities because they depend on fish to act as hosts in the completion of their life cycle and provide a mechanism for dispersal and gene flow (Kat, 1984; Watters, 1992, 1995). They can also play a role in water quality, as the action of their filter feeding can change the particulate content of river water (Pusch et al., 2001).

Mussels are also important because they can act as ecosystem and water quality indicators. Many unionid mussel species are long-lived, some with life spans of 50 years or more. Mature mussels are generally sessile, spending most of their lives within a particular location in a stream. Furthermore, unionids are sensitive to many contaminants and, because they are filter feeders, can bioaccumulate contaminants. Given these characteristics, mussels can provide long-term information about ecosystem health and can be valuable indicators of water quality and biological integrity (Strayer, 1999; Grabarkiewicz and Davis, 2008).

1. Unlike state-listed threatened or endangered mussel species, species of special concern are not protected by Part 365 of PA 451, 1994 Michigan Natural Resources and Environmental Protection Act, but have been identified by the state to be of concern because of declining populations (MNFI, 2010).

Table 1. Unionid mussel species observed in past surveys of the Kalamazoo River between Marshall, Michigan, and Battle Creek, Michigan. These data may include both shells and live individuals. Historical records were obtained from five separate locations surveyed in 1929 and 1934. In 2000, one location in Wattles Park, Emmett Township, Michigan, near Historic Bridge Park was surveyed.

Common name	Species	State status	Historical records (1929; 1934)	Wattle's Park area (2000)
Mucket	<i>Actinonaias ligamentina</i>			X
Elktoe	<i>Alasmidonta marginata</i>	Special concern	X	X
Spike	<i>Elliptio dilatata</i>		X	
Wabash pigtoe	<i>Fusconaia flava</i>		X	X
Plain pocketbook	<i>Lampsilis cardium</i>		X	
Fatmucket	<i>Lampsilis siliquoidea</i>		X	
White heelsplitter	<i>Lasmigona complanata</i>			X
Creek heelsplitter	<i>Lasmigona compressa</i>		X	X
Fluted-shell	<i>Lasmigona costata</i>		X	X
Round pigtoe	<i>Pleurobema sintoxia</i>	Special concern	X	
Strange floater	<i>Strophitus undulates</i>		X	X
Ellipse	<i>Venustaconcha ellipsiformis</i>	Special concern	X	
Rainbow	<i>Villosa iris</i>	Special concern	X	

Sources: University of Michigan Museum of Zoology's Mollusk Collection records; Mulcrone and Mehne (2001).

1.2 Characterization of Mussel Shells Post-Mortem

The degree of mussel shell weathering, location of shells within a river system, and physical condition of shells can provide qualitative estimates of when, where, and how mussel death may have occurred. Rough estimates of time post-mortem can be made by evaluating and scoring the physical weathering of shells. Table 2 describes post-mortem shell age categories and their associated physical characteristics; this scale was developed by the Michigan Natural Features Inventory (MNFI) and adapted for use in this study. This terminology is commonly used to describe the condition of shells (see e.g., Badra 2009, Myers-Kinzie et al 2001, and Hoke 2005), but the physical definitions and estimates of time post-mortem provided in Table 2 were developed specifically for this study based on professional judgment. Shell decay rates are governed by streamflow rates and water chemistry, as described in Strayer and Malcom 2007.

Table 2. Mussel shell weathering scale developed by MNFI

Scale	Category	Physical shell characteristics	Approximate time post-mortem
1	Fresh dead	Soft tissue intact	Less than several days
2	Recent dead	No soft tissue, aside from hinge ligament	Several days to a few (2–3) weeks
3	Moderately worn 1	Hinge intact, marl not covering lower portion, light algae on inside of shell	A few (2–3) weeks to a few (2–3) months
4	Moderately worn 2	Hinge intact or not intact, marl can be covering entire shell, heavy algae and/or marl on inside of shell, most of periostracum intact, shell has most of its original strength	Greater than 2–3 months
5	Heavily worn	Periostracum worn and peeling, shell at least somewhat chalky and fragile	Greater than 3 months

The presence of intact soft tissue and hinge ligament allows for a relatively narrow post-mortem dating of a shell, since tissue and ligament degrade relatively quickly post-mortem. However, beyond this point, it is only possible to match shell wear categories to relatively broad timescales. With increased time post-mortem, microhabitat factors play a larger role in determining the amount of shell wear. For example, a shell that is buried in soft sediments will wear more slowly than a shell that is exposed to stream current on the surface of a rocky substrate. The difference in shell wear between the two would be relatively small over a shorter time period (e.g., one month post-mortem) and relatively large over a longer time period (e.g., five months post-mortem). The approximate time post-mortem given in Table 2 reflects this increased variation in the rate of shell wear as time post-mortem increases.

In addition to the degree of weathering, observations of physical damage to shells (e.g., broken, chipped, or crushed shells) can provide information on impacts to mussels. Shells can be damaged as a result of numerous processes in a river system. The three most relevant processes to this study include physical wearing and breaking of shells as a result of normal (non-spill related) in-stream processes, chipping as a result of animal predation, and crushing as a result of anthropogenic activities. The nature of the damage to the shells resulting from these three processes is quite distinct, and it is often possible to ascertain how shells were damaged by examining the characteristics of the damage.

Shells that have been worn over a relatively long period of time through normal in-stream processes become fragile and are often found with pieces broken off. These shells can be distinguished by the general wearing characteristics and nature of the breakage. For example, these shells typically fall into the “heavily worn” category described in Table 2, as shells having worn and peeling periostraca that are chalky and fragile. Breakage typically initiates around the

edges where the shell is thinnest. For the purposes of this study, these shells are referred to as being “broken.”

Shells that have been damaged as a result of foraging by aquatic mammals also have many distinguishing features. Piles of foraged mussel shells, or middens, are often found along the banks of rivers that support freshwater mussels and mammals, such as the Kalamazoo River. Middens are easily identified in the field due to the large number of single shells in one area and unique markings on the shells. The shells are typically chipped along the thin edges (where the predator has worked to open the shell) and often have scratches or bite marks. Middens are also identifiable by their physical location. For example, they are typically found in areas with abundant cover and easy access to shallow water, such as logjams.

Shells may also be damaged as a result of being physically crushed when a mussel is still alive or still has most of its original strength (i.e., up to two to three months post-mortem). This type of damage is distinct in that the shells are split with a clean, sharp edge, often through the thickest part of the shell. The crushing of mussel shells requires a relatively heavy impact or force that is not reflective of normal in-stream weathering processes or predation. Following the oil spill prior to this study, anecdotal observations in the Kalamazoo River suggested that mussels were crushed during response activities, including by boats passing over shallow sections of the river where mussels were exposed and by response crews wading in the river and stepping on mussels. Based on previous experience conducting mussel surveys across the state, observations of crushed mussel shells are very unusual. For the purpose of this report, shells exhibiting the characteristics of physical crushing described above are referred to as being “crushed.”

This study classified damaged shells into the three categories described above: broken, chipped, or crushed, in order to characterize the type of damage occurring at sampling locations. Table 3 summarizes the definitions of these three categories.

Table 3. Mussel shell damage categories identified for this study by MNFI

Category	Physical characteristics of shell
Broken	Shell is worn and thin, with breakage due to natural river processes in thinnest parts of the shell
Chipped	Shell has scratches and bite marks near the thin edges caused by predation
Crushed	Shell still has most of its original strength, with a sharp-edged break through the thick part of the shell due to non-natural heavy impact

Figures 1 and 2 illustrate the difference between the two types of damage most relevant to this study: broken shells and crushed shells.



Figure 1. Photographs of shells that have been gradually worn to a fragile state over time to a point where they are easily broken, where broken is defined as damage caused by normal in-stream processes. Top: moderately worn 2 strange floater; bottom: heavily worn elktoe.

Photograph taken by J. Matousek on October 18, 2010, in segment MS-1.



Figure 2. Photographs of crushed shells, where crushed is defined as damage caused by a heavy impact. Top: recent spike; bottom: moderately worn 1 pocketbook.

Photograph taken by J. Matousek on October 19, 2010, in segment MS-2.

1.3 Objectives and Scope

Given the ecological importance of mussels and field observations of crushed mussel shells in the Kalamazoo River, the Trustees, in cooperation with Enbridge, designed and initiated this mussel shell survey to document the extent of recent dead mussels at the site that may be attributed to the oil spill and subsequent response actions.

Specifically, the objectives of this study were to:

- ▶ Within survey sites, document the proportion of mussel shells observed at each stage of weathering and by species
- ▶ Survey selected segments of the Kalamazoo River from the Marshall Impoundment to the Town of Battle Creek for mussel shells that were less than approximately three months post-mortem (i.e., the post-mortem age that could reflect mussel death associated with the spill; the survey was conducted in late October 2010, and the spill occurred three months earlier in late July 2010)
- ▶ Document species occurrences in sampling segments using observations of both live mussels and mussel shells
- ▶ Delineate the spatial extent of mussel shells that were less than approximately three months post-mortem within the selected river segments.

Information on the degree of weathering of mussel shells and the location of dead mussels is ephemeral and will largely be lost over time as shells deteriorate and are displaced. Thus, this survey was conducted in October 2010 to capture ephemeral, time-sensitive data on the occurrence and location of post-mortem mussel shells. Though the purpose of the study was to survey post-mortem mussel shells, observations of live mussels were also recorded when encountered in the field. In the fall, live mussels begin to burrow deeper into the sediment, where they spend winter months. Thus, observations of live mussels recorded during this survey are likely not representative of live mussel abundance and should not be interpreted as a live mussel population survey. However, information from the mussel shell survey may be used to design a more intensive and quantitative mussel community survey (i.e., a live mussel survey), if deemed necessary, for the late spring or summer.

2. Methods

The mussel shell survey was performed on October 18–21 and October 25, 2010, pursuant to the field work plan (Appendix A). The study was performed by MNFI, with assistance from Stratus

Consulting on behalf of the Trustees, in cooperation with Enbridge and their contractor (Cardno ENTRIX). Survey field work was completed on a daily basis by either six or seven staff (depending upon individual availability), representing MDEQ, MDNR, Stratus Consulting, Cardno ENTRIX, and MNFI. Staff included Pete Badra (MNFI), Michael Carney (Stratus Consulting), Ryan Grafton (Cardno ENTRIX), John Matousek (Cardno ENTRIX), Mike Wilson (MDNR), Matt Wesener (MDEQ), Bill Taft (MDEQ), and Mike Walterhouse (MDEQ). All decisions regarding fieldwork were made by consensus of the field team.

This section describes locations and survey field methods. Modifications from the field work plan, made based on conditions encountered in the field, are also described.

2.1 Segment Locations

Five sampling segments were identified on the Kalamazoo River between the Marshall Impoundment and the Mill Pond in the Town of Battle Creek [Mile Post (MP) 15.5] in the mussel shell survey work plan (see Appendix A). Note that river miles are reported in MPs, the reference system established by Enbridge. The MPs begin at the spill site on Talmadge Creek (MP 0.0), the confluence of Talmadge Creek with the Kalamazoo River is marked as MP 2.2, and MPs extend downriver on the Kalamazoo River to Morrow Lake (MP 37.75).

Prior to sampling each segment, segment start locations were finalized in the field, based on the location of access points and the conditions encountered in the river. As indicated in the work plan, shell surveys were conducted in an upriver direction from the segment start location to the end of the proposed segment or as far upriver as could be covered in a single field day. Table 4 describes each sampling segment. A map of segment locations is provided in Figure 3.

Most sampling segments were accessed on foot. A boat was used at segment MS-5 to transport the survey crew over stretches of habitat that were too deep to wade.

Sampling segment locations were selected according to proximity to the spill site, areas of known response activities, locations of boat launches (and hence elevated boat activity), un-impacted areas upstream of the spill site (e.g., reference locations), and based on locations where mussel shells had been observed during prior NRDA fieldwork.

The following sections of the report describe the methods that were used when conducting the mussel shell survey, specifically, how survey sites within a sampling segment were delineated (Section 2.2) and characterized (Section 2.3). Additional collected information is described in Section 2.4, and documentation procedures are described in Section 2.5. Finally, modifications to the original work plan (Appendix A) that were made during the survey as a result of conditions met in the field are provided (Section 2.6).

Table 4. Summary of segment locations and date sampled. River miles are in MPs downriver from the pipeline release, as reported by Enbridge (with the confluence of Talmadge Creek and the Kalamazoo River at MP 2.2). Segment start and end coordinates were taken at the middle of the down- and upriver extremities, respectively, of each sampling segment.

Segment ID	Segment description and access notes	Nearest MP	Latitude	Longitude	Survey date
MS-1	Reference area downriver of the Marshall Impoundment along River Walk Park to 17 Mile Road Bridge. Segment was accessed from the boardwalk that runs along the north bank of the river.	Start: ^a End: ^a	42.26480 42.26211	-84.96385 -84.95550	10/18/2010
MS-2	Talmadge Creek confluence area; segment located just downriver from 15 Mile Road Bridge, boat ramp C0.1. Segment was accessed from community park off of Squaw Creek Road.	Start: 3.0 End: 2.25	42.25925 42.25864	-85.01009 -84.99898	10/19/2010
MS-3	11 Mile Road Bridge/C1.5 boat ramp area. Segment was accessed from 11 Mile Road Bridge by walking downriver from the bridge along a trail on left bank to start location.	Start: 7.75 End: 7.25	42.27732 42.27443	-85.09117 -85.08154	10/20/2010
MS-4	C3.2 boat ramp area near Historic Bridge Park. Segment was accessed from boat ramp parking lot by walking downriver from the parking lot along a trail on right bank to start location.	Start: 10.25 End: 9.25	42.29591 42.29373	-85.12777 -85.12421	10/21/2010
MS-5	C5 boat ramp area near Rivers Edge Landscaping and Mill Pond. Segment was accessed from C5 boat ramp by traveling downriver by boat to start location.	Start: 15.5 End: 14.5	42.30768 42.30119	-85.18924 -85.18023	10/25/2010

a. River mile MP not available because sampling segment is upriver of the pipeline release. MS-1 was located approximately 2.5 miles upriver from the spill site.



Figure 3. Overview of fall 2010 sampling locations on the Kalamazoo River between Marshall Impoundment and Battle Creek, Michigan.

2.2 Delineation of Survey Sites

Once the sampling segment start location was identified and coordinates recorded, surveyors slowly waded in an upriver direction and inspected the substrate for mussel shells. The field crew used glass-bottom buckets and/or polarized eyeglasses to view the river bottom. Observations of live mussels and mussel shells were recorded in field notebooks. The physical condition of mussel shells was screened according to the shell weathering scale described in Table 2. When a fresh dead or recent dead shell was found (see Table 2), surveyors thoroughly inspected the immediate area for additional fresh dead or recent dead shells. If no additional shells were observed in close proximity [~3 meters (m)], the species, weathering category, and location were recorded in field notebooks, and the survey crew continued upriver in the segment. If more than one fresh dead or recent dead shell was observed, the approximate area in which the fresh dead or recent dead shells were observed was delineated into a survey site. The boundaries of the

delineated site encompassed the area in which fresh dead or recent dead shells were found and extended upriver and extended across the river width until shells were no longer observed, with one exception. Survey site 2010.10.21-4-2 was located within a very large area of crushed shells that was too large to fully characterize in one day. Thus, at this site, the crew delineated a smaller area within the large area of crushed shells. Survey site boundary designation rationale for each survey site is provided in the results section (Section 3). The dimensions, river orientation, and boundary coordinates of the survey site were recorded on dedicated field datasheets and are also provided in the results section.

2.3 Survey Site Characterization

All shells and live mussels within a delineated survey site were collected in buckets and mesh bags and brought ashore for examination and enumeration. Each live mussel and shell was identified to species, and the physical condition was scored according to the shell weathering scale (Table 2). Single half shells and connected hinged shells were counted as a single observation. After all mussels and shells from a delineated site were enumerated and scored, shells and live mussels were returned to the river. Habitat information, such as substrate classification and water depth, was also recorded for each survey site.

2.4 Additional Collected Information

In addition to the fresh dead and recent dead mussel shell survey methods described above, additional mussel community information was collected for each sampling segment. This included noting presence of live mussels, non-native dreissenid mussels (*Dreissena polymorpha* and *D. bugensis*), and Asian clams (*Corbicula fluminea*) at each site. Sampling segment-specific species lists were made using observations of shells or live mussels.

2.5 Documentation

Survey information was recorded onto dedicated datasheets and in field notebooks (see Appendices B and C, respectively). Additional information such as field personnel, start and stop times, coordinates, and photograph information was recorded on sampling segment datasheets or in field notebooks.

Each day, field datasheets were scanned to an electronic Portable Document Format (PDF) file and saved on a computer hard drive. Original hardcopy datasheets were retained by MNFI. Photographs were taken with a single camera and backed up to a hard drive at the end of each survey day. Geographic positioning system (GPS) waypoints and track log files were also saved to a hard drive.

2.6 Work Plan Modifications

Table 5 summarizes modifications from the survey work plan.

Table 5. Modifications from the survey work plan

Work plan section	Proposed method	Field modifications
Table 1	Mussel shell weathering scale categories included fresh dead, recent dead, moderately worn, and heavily worn	An additional category of shell weathering was created to better capture the wide range of moderately worn shell characteristics encountered in the field. Specifically, moderately worn was split into two categories, and descriptions for each category were developed (see Table 1 in work plan). All segment characterizations incorporated this change, and include “moderately worn 1” and “moderately worn 2” categories, with the exception of MS-2. Field datasheets were changed to include the additional shell weathering category.
Mussel shell survey protocol	The survey site is delineated and surveyed simultaneously in an upriver direction until fresh dead or recent dead shells are no longer encountered, at which point the site boundary is defined	Survey sites were delineated and then surveyed. Note that single fresh dead/recent dead shell observations were still recorded.
Table 1	Reference sampling segment numbered MS-5 and RM not identified	Location selected for reference survey segment and renumbered MS-1.
None	None	The reference segment was walked, but no survey site was initially delineated, because no fresh dead or recent dead shells were encountered (observation of fresh/recent dead is the trigger for delineation of a survey site within a segment). However, the crew decided to return to the reference segment and delineate a survey site so that there would be a survey site within the reference segment for comparative purposes.

3. Results

This section presents mussel shell survey results. Results are presented for the five survey segments, MS-1 through MS-5. General observations are provided for each segment, and data collected at delineated survey sites within segments are also summarized.

Six survey sites within the five segments were delineated during the survey. This included one survey site in the reference sampling segment (MS-1) and one site in segment MS-2. Two survey sites were delineated in segment MS-3, and two were delineated in MS-4. No sites were delineated in segment MS-5. The location of each survey site is given in Table 6. Completed field datasheets and field notebooks are provided in Appendices B and C, respectively. Photographs taken during the survey are available upon request or can be accessed via the ENTRIX hosted File Transfer Protocol (FTP) site.

Table 6. Mussel shell survey sites that were delineated within sampling segments

Survey site		Latitude (N)	Longitude (W)	Survey date	Segment	Survey site surface area (m ²)
2010.10.21-1-1	Start:	42.26305	-84.95710	10/21/2010	MS-1	133
	End:	42.26284	-84.95668			
2010.10.19-2-1	Start:	42.25979	-85.01019	10/19/2010	MS-2	288
	End:	42.25983	-85.00980			
2010.10.20-3-1	Start:	42.27737	-85.09080	10/20/2010	MS-3	113
	End:	42.27736	-85.09071			
2010.10.20-3-2	Start:	42.27657	-85.08723	10/20/2010	MS-3	248
	End:	42.27661	-85.08678			
2010.10.21-4-1	Start:	42.29591	-85.12740	10/21/2010	MS-4	190
	End:	42.29600	-85.12704			
2010.10.21-4-2	Start:	42.29390	-85.12488	10/21/2010	MS-4	216
	End:	42.29370	-85.12486			

3.1 Segment MS-1

Segment MS-1, a reference area upstream of the pipeline release, was located on the Kalamazoo River 2.5 miles upriver from the Talmadge Creek confluence. Approximately 0.6 miles of the 1-mile segment was surveyed, from the Kalamazoo Avenue Bridge to just downriver of the Marshall Impoundment (Figure 4). Rice Creek enters the Kalamazoo River at the approximate midpoint of this sampling segment. The August 2010 mussel tissue and sediment sampling site (SE-2) was also located in this segment. One survey site was delineated in this segment.



Figure 4. Sampling segment MS-1.

3.1.1 General conditions

During the survey, the weather was seasonably warm (~ 55°F) and cloudy. Turbidity was very low, and the river bottom was visible in all wadeable areas. Approximately 80% of this sampling segment was shallow enough to wade. Most of the area directly downriver of the Rice Creek confluence was too deep to wade. In the area downriver of the Rice Creek confluence, only the substrate in shallower water along the shoreline was surveyed.

The substrate was variable and ranged from sand in depositional areas to coarse gravel and cobble in swift-flowing areas. Encrusting and filamentous algae covered gravel and cobbles. No visible submerged oil or oil sheening was observed during the survey. Glass bottles, pieces of metal, and general refuse were observed throughout the site.

3.1.2 Segment MS-1 shell observations

Shells of 16 unionid mussel species were observed in segment MS-1 (Table 7). This included the state threatened slippershell (*Alasmidonta viridis*) and state endangered eastern pondmussel (*Ligumia nasuta*), which was represented by a single shell observation. As noted in Table 7, four species of special concern were also found in this sampling segment. In addition to finding shells, five species of live mussels were also observed. These included spike, pocketbook, creek heelsplitter, fluted-shell, and ellipse (a species of special concern). Non-native Asian clam shells and live individuals were also observed in this segment.

Table 7. Unionid mussel species^a observed in sampling segment MS-1. Includes both living and shell observations made throughout the waded 0.6 miles of the segment, including observations in the survey site (2010.10.21-1-1).

Common name	Species	State status	Species observed	
			Shell	Live
Mucket	<i>Actinonaias ligamentina</i>		X	
Elktoe	<i>Alasmidonta marginata</i>	Special concern	X	
Slippershell	<i>Alasmidonta viridis</i>	Threatened	X	
Cylindrical papershell	<i>Anodontoides ferussacianus</i>		X	
Spike	<i>Elliptio dilatata</i>		X	X
Wabash pigtoe	<i>Fusconaia flava</i>		X	
Fatmucket	<i>Lampsilis siliquoidea</i>		X	
Pocketbook	<i>Lampsilis cardium</i>		X	X
White heelsplitter	<i>Lasmigona complanata</i>			
Creek heelsplitter	<i>Lasmigona compressa</i>		X	X
Fluted-shell	<i>Lasmigona costata</i>		X	X
Eastern pondmussel	<i>Ligumia nasuta</i>	Endangered	X	
Round pigtoe	<i>Pleurobema sintoxia</i>	Special concern	X	
Giant floater	<i>Pyganodon grandis</i>		X	
Strange floater	<i>Strophitus undulates</i>		X	
Paper pondshell	<i>Utterbackia imbecillis</i>	Special concern		
Ellipse	<i>Venustaconcha ellipsiformis</i>	Special concern	X	X
Rainbow	<i>Villosa iris</i>	Special concern	X	
Total number of unionid species			16	5

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

Observed shells in segment MS-1 were mostly moderately to heavily worn shells. These shells were coated with a layer of encrusting marl and algae to an extent that they often had to be cleaned off with a knife to identify. One recent dead pocketbook mussel shell was observed in the 0.6-mile survey segment (Figure 4). This observation was made near the downriver boundary of the segment. A survey site was not delineated at the location of this shell, because only a single recent dead shell was found.

Damaged shells that were worn and broken were observed in MS-1. These shells all had heavily advanced weathering (i.e., fell within moderately worn 2 and heavily worn categories) indicating the breakage likely occurred as a result of natural in-stream weathering processes. No crushed shells were observed, nor were any middens or chipped shells.

3.1.3 MS-1 survey site 2010.10.21-1-1

One survey site was delineated in segment MS-1 (survey site 2010.10.21-1-1). Only one recent dead shell was observed within segment MS-1, and no fresh dead shells were found. Therefore, a survey site was not delineated during the initial visit to the segment on October 18, 2010. On October 21, 2010, the survey crew decided to return to segment MS-1 and delineate a reference survey site to enable comparison of a reference with downstream survey sites. The survey crew agreed upon an area with a relatively high number of shells at the head of a shallow riffle within the sampling segment to designate as a survey site. This location was chosen because it had a high number of shells and was representative of the general habitat within the segment.

The survey site consisted of a shallow, 0.3- to 0.7-m-deep area that was 19-m-long and 7-m-wide, with a total surface area of 133 square meters (m²). The survey site boundary delineation was not based on occurrence of fresh dead or recent dead shells. The boundaries were arbitrarily delineated to generate a survey site surface area similar to previously delineated survey sites in other sampling segments. The substrate within the site was a mix of pebble [64–16 millimeters (mm) diameter], gravel (16–2 mm), and sand (2–0.0625 mm).

Table 8 summarizes the mussel species observations and shell weathering characterization results for the MS-1 survey site. Shells from nine species were observed in the survey site. Pocketbook shells were most dominant, comprising 27% of all shells found, followed by fluted-shell (23%). Fatmucket and rainbow shells were least common, contributing less than 1% of the total number of shells observed. One live pocketbook mussel was observed in the survey site.

A total of 213 shells were found in the survey site, representing a density of 1.6 shells/m². No fresh dead, recent dead, or moderately worn 1 shells were observed in survey site 2010.10.21-1-1 (Table 8). All of the shells in this site were covered with heavy marl and encrusting algae (Figure 5).

Table 8. Segment MS-1 survey site 2010.10.21-1-1 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	–	–	–	–
Elktoe	–	–	–	5	2
Slippershell	–	–	–	–	–
Cylindrical papershell	–	–	–	–	–
Spike	–	–	–	28	8
Wabash pigtoe	–	–	–	25	16
Fatmucket	–	–	–	3	–
Pocketbook	–	–	–	46	11
White heelsplitter	–	–	–	–	–
Creek heelsplitter	–	–	–	–	–
Fluted-shell	–	–	–	30	19
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	–	–	7	4
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	6	–
Rainbow	–	–	–	2	1
Total number of shells	0	0	0	152	61
Percentage	0.0%	0.0%	0.0%	71%	29%

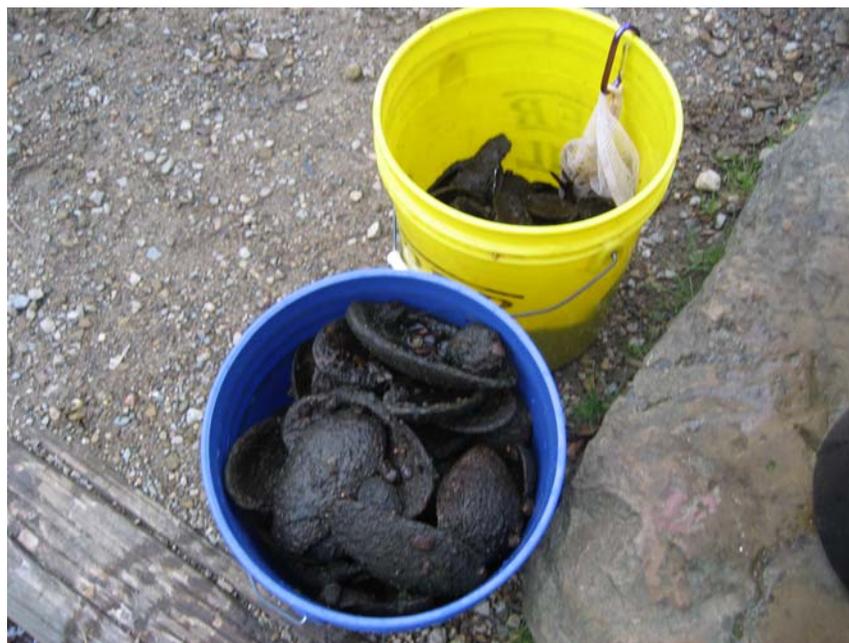
A total of 14 broken shells were observed within the survey site, mostly Wabash pigtoe. These shells were observed to be broken, rather than crushed.

3.2 Segment MS-2

Sampling segment MS-2 was located on the Kalamazoo River just downriver from the Talmadge Creek confluence. Approximately 0.8 miles of the 1-mile segment was surveyed, from MP 3.0 to 15 Mile Road Bridge (Figure 6). Squaw Creek enters the Kalamazoo River at the approximate midpoint of this sampling segment, and Bear Creek enters the river near the upriver boundary. Boat ramp C0.1 was located in this segment, which was closed at the time of the survey. One survey site was delineated in this segment.



(a)



(b)

Figure 5. Photographs of (a) an MS-1 shell with heavy marl and encrusting algae and (b) shells collected from survey site 2010.10.21-1-1.

Photograph taken by J. Matousek on (a) October 18, 2010, and (b) October 21, 2010.

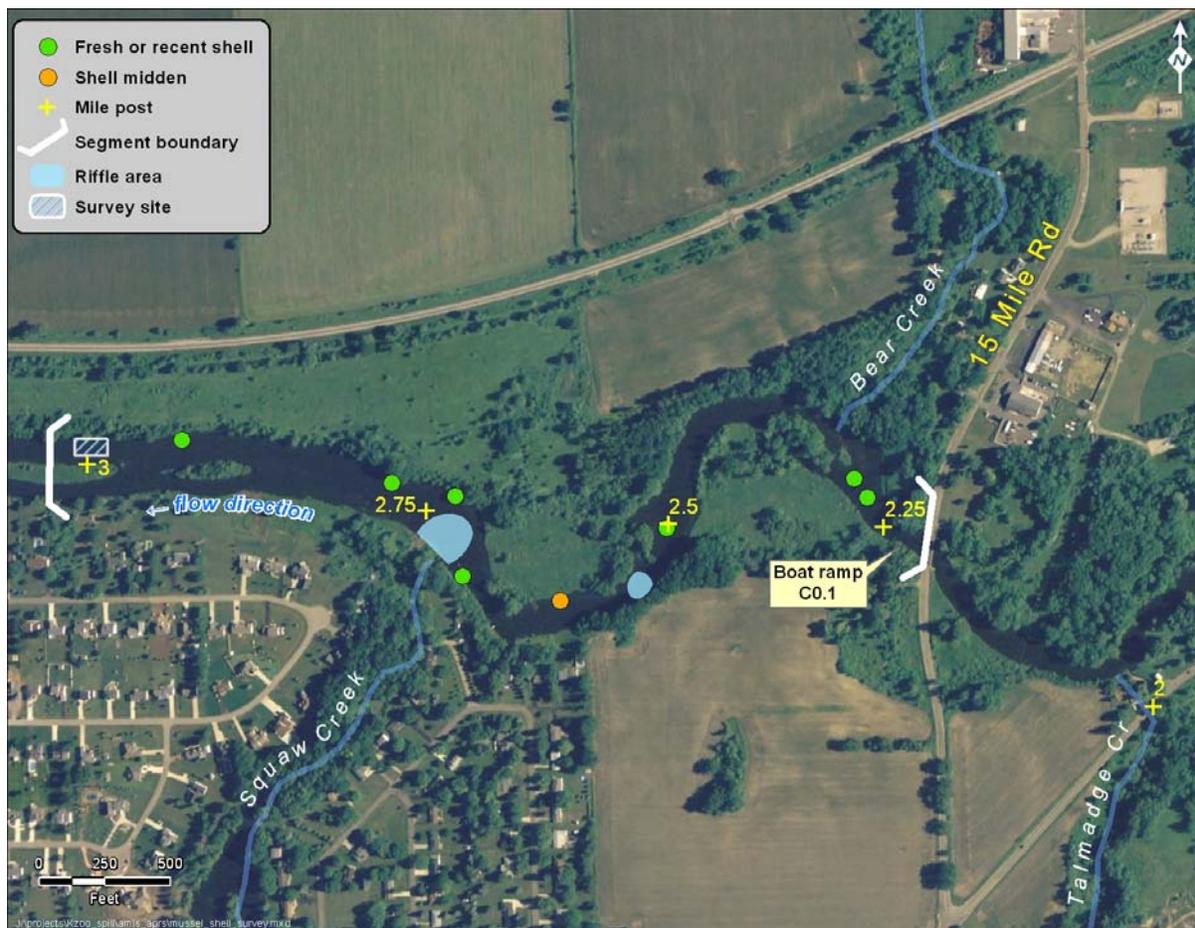


Figure 6. Sampling segment MS-2.

3.2.1 General conditions

During the survey, the weather was seasonably warm (~ 50°F) and cloudy. Turbidity was low, and the river bottom substrate was visible in all wadeable areas. The entire sampling segment was shallow enough to wade. Response/cleanup activities were occurring within this segment at the time of the survey. These activities were centered around islands where cleanup crews were replacing absorbent oil booms. A few air- and propeller-driven boats were also observed throughout the segment, but they did not noticeably affect turbidity.

Most of the river bottom within the segment consisted of shallow runs and riffles with relatively swift water. Coarse gravel and cobble were the dominant substrate types for most of the segment. Fine silty sediment was common in depositional areas, especially around the islands between booms and the shore. A large silt deposit was observed downriver of boat ramp C0.1, located on the right river bank, near 15 Mile Road Bridge (Figure 6). Oil sheens were observed on the water surface after wading through this silt deposit.

3.2.2 Segment MS-2 shell observations

Shells of 15 unionid mussel species were observed in segment MS-2 (Table 9). One state threatened species (slippershell) and four species of special concern were observed. Most live mussels were observed in a deep run just upriver of the Squaw Creek confluence and included spike, Wabash pigtoe, fatmucket, pocketbook, white heelsplitter, and creek heelsplitter species. Non-native Asian clams were also found in this segment.

In addition to the delineated site described below in Section 3.2.3, there were eight observations of fresh dead and recent dead shells made in this segment in areas that were not delineated (Table 10). These shells were recorded, but the observations did not initiate delineation of survey sites, as they were isolated shell occurrences. A single fresh dead pocketbook was found near the Squaw Creek confluence with soft tissue still intact (Figure 7).

Damaged shells were observed throughout this segment and included shells thought to be broken by natural in-stream weathering processes and predator activity and shells thought to be crushed as a result of anthropogenic activity. Heavily weathered and broken shells were observed in the segment. These shells were similar to broken shells observed in the MS-1 reference segment. A shell midden was observed near a shallow riffle, immediately upriver of the Squaw Creek confluence. A resident adjacent to this midden spoke to the survey crew and indicated that they had recently seen a mink near the shell deposit. Crushed shells were also observed, especially in a large shallow riffle just downriver of the Squaw Creek confluence. This riffle seemed to be an area that naturally accumulates mussel shells; most of these shells appeared to be mostly moderately to heavily weathered. Many of the accumulated shells were observed to have been crushed. Since shells were thought to be damaged post-mortem, a survey site was not delineated. This decision was supported by the fact that the same riffle was surveyed for live mussels during the August 2010 mussel tissue and sediment sampling event, at which time no live mussels were observed.

Table 9. Unionid mussel species^a observed in sampling segment MS-2. Includes both living and shell observations made throughout the waded 0.8 miles of the segment, including observations in the survey site (2010.10.19-2-1).

Common name	Species	State status	Species observed	
			Shells	Live
Mucket	<i>Actinonaias ligamentina</i>		X	
Elktoe	<i>Alasmidonta marginata</i>	Special concern	X	
Slippershell	<i>Alasmidonta viridis</i>	Threatened	X	
Cylindrical papershell	<i>Anodontoides ferussacianus</i>		X	
Spike	<i>Elliptio dilatata</i>		X	X
Wabash pigtoe	<i>Fusconaia flava</i>		X	X
Fatmucket	<i>Lampsilis siliquoidea</i>		X	X
Pocketbook	<i>Lampsilis cardium</i>		X	X
White heelsplitter	<i>Lasmigona complanata</i>		X	X
Creek heelsplitter	<i>Lasmigona compressa</i>		X	X
Fluted-shell	<i>Lasmigona costata</i>		X	
Eastern pondmussel	<i>Ligumia nasuta</i>	Endangered		
Round pigtoe	<i>Pleurobema sintoxia</i>	Special concern	X	
Giant floater	<i>Pyganodon grandis</i>			
Strange floater	<i>Strophitus undulates</i>		X	
Paper pondshell	<i>Utterbackia imbecillis</i>	Special concern		
Ellipse	<i>Venustaconcha ellipsiformis</i>	Special concern	X	
Rainbow	<i>Villosa iris</i>	Special concern	X	
Total number of unionid species			15	6

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

Table 10. Isolated observations of fresh dead, recent dead, and crushed shells made within sampling segment MS-2

Observation	Latitude	Longitude	Comments/details
Single recent dead rainbow shell	42.25968	-85.00858	Single shell occurrence
Single recent dead pocketbook shell	42.25954	-85.00601	Single shell occurrence
Two recent dead spike shells found together and two crushed pocketbook shells found	42.25940	-85.00508	Two shells observed in the same location were treated as a single shell occurrence
Single recent dead pocketbook shell	42.25848	-85.00513	Single shell occurrence
Single fresh dead pocketbook shell	42.25790	-85.00304	Single shell occurrence, with soft tissue intact
Single recent dead spike shell	42.25895	-84.99899	Single shell occurrence
Single recent dead pocketbook shell	42.25866	-84.99890	Single shell occurrence
Location of a few recent dead shells	42.25867	-85.00183	Site not delineated due to only finding a few shells, species not identified
Shell midden	42.25800	-85.00352	Pile of chipped shells
Area of crushed shells	42.25889	-85.00510	Mussels were likely not killed by being crushed, but shells crushed post-mortem
Area of crushed shells	42.25820	-85.00215	Mussels were likely not killed by being crushed, but shells crushed post-mortem
Crushed fluted shell, spike, and rainbow found; several live pocketbooks found	42.25825	-85.00249	Crushed shells occurred in shallow riffle areas
A few recent dead and crushed shells found	42.22579	-85.00167	



Figure 7. Photographs of a fresh dead pocketbook with soft tissue intact found in segment MS-2 just upriver from Squaw Creek confluence.

Photograph taken by J. Matousek on October 19, 2010.

3.2.3 MS-2 survey site 2010.10.19-2-1

The survey site delineated in segment MS-2, survey site 2010.10.19-2-1, was located near MP 3.0 at the downriver boundary of the sampling segment. The survey site consisted of a shallow, 0.4-m-deep area that was 32-m-long and 9-m-wide, with a total surface area of 288 m². The survey site was delineated after finding a scattered deposit of recent dead shells. The site upriver and river-width boundaries were extended until no further recent shell observations were made. Substrate within the site was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).

The observed shells within the site represented 11 species (Table 11). Spike shells were most dominant, comprising 31% of all shells found. Wabash pigtoe shells were also common (19%). Shells of mucket and the threatened slippershell were least common, contributing to less than 1% of the total number of shells observed. Four species of special concern, elktoe, round pigtoe, ellipse, and rainbow, were relatively common in the survey site. No live mussels were observed within the survey site.

Table 11 summarizes the mussel species observed and shell weathering characterization results for the MS-2 survey site. A total of 264 shells were collected (0.9 shells/m²), which included 6 recent dead shells. Damaged shells were observed within the survey site. These shells appeared to be older shells in which mortality would have occurred prior to the spill. No middens or recent dead/fresh dead crushed shells were observed in this sampling site.

3.3 Segment MS-3

Sampling segment MS-3 was located on the Kalamazoo River between Ceresco and Historic Bridge Park, just downriver from 11 Mile Road Bridge. Approximately 0.6 miles of the 1-mile segment was surveyed, from MP 7.75 to immediately downriver of the 11 Mile Road Bridge (Figure 8). Boat ramp C1.5 was located in this segment, which was closed at the time of the survey. A mussel tissue sample collection site from the mussel tissue and sediment sampling field work that was completed in late August 2010 was also located in this segment. Two survey sites were delineated in this segment.

3.3.1 General conditions

During the survey, the weather was sunny and windy, with an air temperature of ~ 50°F. Turbidity was moderate and gradually increased throughout the day. This limited the crew's ability to survey the full 1-mile segment. High turbidity may have been associated with dredging in the Ceresco Impoundment, which was occurring upgradient at the same time that this segment was being surveyed.

Table 11. Segment MS-2 survey site 2010.10.19-2-1 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1 and 2^a	Heavily worn
Mucket	–	–	1	–
Elktoe	–	–	4	7
Slippershell	–	–	2	1
Cylindrical papershell	–	–	–	–
Spike	–	2	63	17
Wabash pigtoe	–	1	44	6
Fatmucket	–	–	–	–
Pocketbook	–	1	25	10
White heelsplitter	–	–	–	–
Creek heelsplitter	–	–	–	–
Fluted-shell	–	1	6	5
Eastern pondmussel	–	–	–	–
Round pigtoe	–	–	7	2
Giant floater	–	–	–	–
Strange floater	–	1	18	13
Paper pondshell	–	–	–	–
Ellipse	–	–	14	1
Rainbow	–	–	10	2
Total number of shells	0	6	194	64
Percentage	0.0%	2.3%	74%	24%

a. MS-2 was surveyed prior to the development of “moderately worn 1” and “moderately worn 2” weathering categories. These two subcategories are included in all other segments.

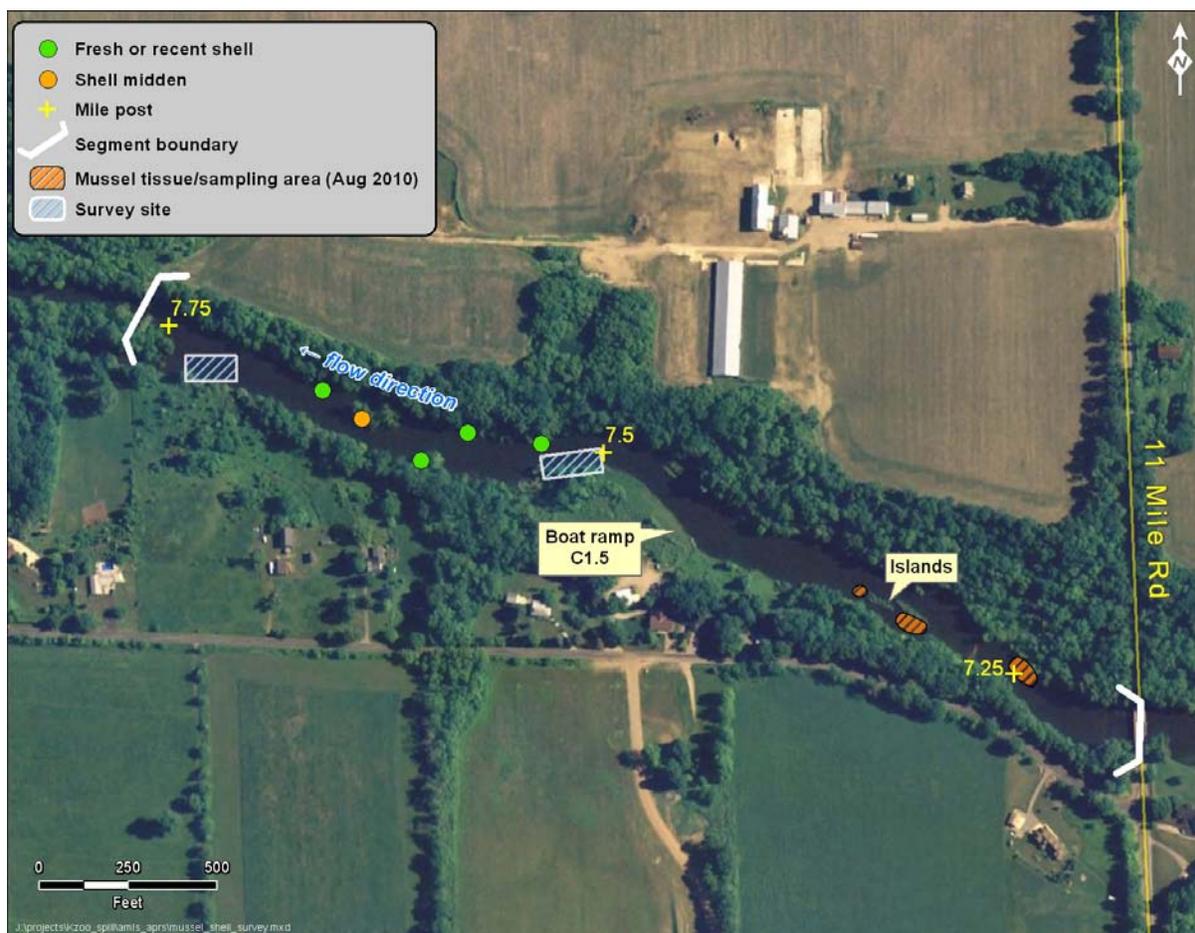


Figure 8. Sampling segment MS-3.

The substrate in segment MS-3 was highly variable. Shallow areas such as riffles with moderate flow were dominated by coarse sand and gravel. Substrates in slower, slightly deeper water and shallow areas near the river bank were covered with a surficial layer of fine silt. In these areas, mussel shells were blanketed with silt. Shell inspections often required picking these shells from the river bottom and washing off accumulated silt. Siltation was notably heavy at the downriver boundary of the segment, near boat ramp C1.5, and around two islands located approximately 0.1 mile downriver from 11 Mile Road Bridge. Larger cobble and bedrock were common between these two islands and 11 Mile Road Bridge. Oil sheening was observed near the two islands and near the boat ramp after wading through the soft, silty sediments. One dead frog was observed, and some oil was noted on the vegetation of one of the islands.

3.3.2 Segment MS-3 shell observations

Shells of 12 unionid mussel species were observed in segment MS-3 (Table 12). This included the state threatened slippershell and two species of special concern. Live mucket were common near the downriver segment boundary and in sediments between bedrock outcrops at the upriver segment boundary. Live spike, Wabash pigtoe, pocketbook, and white heelsplitter species were also observed. Non-native Asian clams were also found in this segment.

Table 12. Unionid mussel species^a observed in sampling segment MS-3. Includes both living and shell observations made throughout the waded 0.6 miles of the segment, including observations in the survey sites (2010.10.20-3-1; 2010.10.20-3-2).

Common name	Species	State status	Species observed	
			Shell	Live
Mucket	<i>Actinonaias ligamentina</i>		X	X
Elktoe	<i>Alasmidonta marginata</i>	Special concern	X	
Slippershell	<i>Alasmidonta viridis</i>	Threatened	X	
Cylindrical papershell	<i>Anodontoides ferussacianus</i>		X	
Spike	<i>Elliptio dilatata</i>		X	X
Wabash pigtoe	<i>Fusconaia flava</i>		X	X
Fatmucket	<i>Lampsilis siliquoidea</i>			
Pocketbook	<i>Lampsilis cardium</i>		X	X
White heelsplitter	<i>Lasmigona complanata</i>		X	X
Creek heelsplitter	<i>Lasmigona compressa</i>		X	
Fluted-shell	<i>Lasmigona costata</i>		X	
Eastern pondmussel	<i>Ligumia nasuta</i>	Endangered		
Round pigtoe	<i>Pleurobema sintoxia</i>	Special concern		
Giant floater	<i>Pyganodon grandis</i>			
Strange floater	<i>Strophitus undulates</i>		X	
Paper pondshell	<i>Utterbackia imbecillis</i>	Special concern		
Ellipse	<i>Venustaconcha ellipsiformis</i>	Special concern		
Rainbow	<i>Villosa iris</i>	Special concern	X	
Total number of unionid species			12	5

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

This was the first segment in which shells were categorized into moderately worn 1 and 2 categories (see Section 2.6). Many moderately worn 1 shells were observed in this segment. Most of these shells were covered by a layer of silt that made classifying between recent and moderately worn 1 weathering categories difficult. For example, silt staining on the inside of a recent shell may have caused it to appear moderately worn. Conversely, silt may have covered a moderately worn 1 shell so that algae did not grow inside of the shell, creating an appearance more consistent with a recent dead shell.

There were multiple isolated observations of recent shells in this segment that were recorded but did not warrant survey site delineation. These observations occurred within four general areas located in the downriver portion of the segment, ending immediately downriver of boat ramp C1.5 (Table 13; Figure 8). The number of shells or species in these four areas was not recorded due to time constraints. However, a survey site was delineated at the upriver end of this area, where moderately worn 1 shell observations became more concentrated (site 2010.10.20-3-2; see Section 3.3.4).

Table 13. Isolated observations of recent dead and crushed shells made within sampling segment MS-3

Observation	Latitude	Longitude	Comments/details
A relatively large concentration of live mussels found along with crushed shells and a few recent dead shells.	42.27723	-85.08967	Species not identified; shells likely crushed post-mortem
A few recent dead shells found with crushed shells	42.27673	-85.08885	Species not identified; shells likely crushed by boats in this shallow area
A few recent dead shells found	42.27683	-85.08839	Species not identified
A few recent dead shells found with crushed shells	42.27670	-85.08770	Species not identified; shells likely crushed by boats in this shallow area
Large deposit of moderately weathered shells	42.27545	-85.08370	Found around the islands near upriver segment boundary; mostly moderately worn 2 but included some moderately worn 1 shells with ligaments attached
Shell midden	42.27710	-85.08945	Pile of chipped shells
Pile of recent dead shells, possible shell midden	42.27599	-85.08549	Uncertain if deposit was a midden or a pile made by someone gathering shells
A concentration of live mucklets found	42.27443	-85.08154	

A large deposit of moderately worn shells was observed around the islands immediately downriver of 11 Mile Road Bridge (Table 13; Figure 8). This area was not delineated into a survey site because most of the shells were moderately worn 2. In addition, it was nearing the end of the day and turbidity was increasing, which interfered with the crew's ability to scan the river bottom for shells. Another deposit of recent shells was discovered just upriver and next to boat ramp C1.5. These shells, which were buried in soft silt along the river bank, might have been associated with a midden that was covered with silt but did not show signs of chipping or scratch marks consistent with mussel predation damage. These shells could have been disposed of by someone gathering shells in the area. Although the origin of this shell deposit was not confirmed, it was concluded in the field that it was likely not associated with oil or response activities, thus a survey site was not delineated at this location.

Damaged shells were observed throughout this segment. Similar to segments MS-1 and MS-2, broken, fragile, and worn shells were observed. Chipped shells were also found. These observations were associated with a shell midden. Additionally, a large pile of chipped shells was observed at the tail end of an island downriver from boat ramp C1.5. Observations of crushed shells that were recent dead and moderately worn were made downriver of the boat ramp in shallow riffle areas (Table 13; Figures 8 and 9). Survey site 2010.10.20-3-2 was delineated at the upriver end of this area (see Section 3.3.4).

3.3.3 MS-3 survey site 2010.10.20-3-1

Survey site 2010.10.20-3-1 was located near MP 7.75 at the downriver boundary of the sampling segment. The survey site consisted of a shallow, 0.4-m-deep area that was 15-m-long and 7.5-m-wide, with a total surface area of 113 m². The survey site boundary delineation was based on finding a scattered deposit of shells that were characterized as recent/moderately worn 1. Boundaries were extended to the point at which recent dead shells were no longer observed. The substrate within this site was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).

Shells from eight species of mussels were found in the delineated site (Table 14), approximately 60% of which were mucket. Wabash pigtoe were also common, comprising 16% of the total number of shells. Elktoe (a species of special concern) and spike shells were least common. No state threatened or endangered species were observed in this site. A total of 14 live mussels were also observed, most of which were mucket.



Figure 9. Photographs of crushed shells found downriver of boat ramp C1.5.
Photograph taken by J. Matousek on October 20, 2010.

Table 14. Segment MS-3 survey site 2010.10.20-3-1 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	–	3	88	1
Elktoe	–	–	–	1	–
Slippershell	–	–	–	–	–
Cylindrical papershell	–	–	–	–	–
Spike	–	–	–	1	–
Wabash pigtoe	–	–	–	24	1
Fatmucket	–	–	–	–	–
Pocketbook	–	–	–	7	2
White heelsplitter	–	–	–	2	–
Creek heelsplitter	–	–	–	–	–
Fluted-shell	–	–	3	16	1
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	–	–	3	2
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	–	–
Rainbow	–	–	–	–	–
Total number of shells	0	0	6	142	7
Percentage	0.0%	0.0%	3.9%	92%	4.5%

A total of 155 shells were collected from survey site 2010.10.20-3-1, which equates to 1.4 shells/m². Although no fresh dead or recent dead shells were found, six moderately worn 1 shells (3.9% of all shells collected) were observed. As mentioned above, distinguishing between recent and moderately worn 1 weathering of shells was difficult due to heavy siltation in this segment and survey site. Only one damaged shell, a mucket, was identified in this survey site. The low occurrence of damaged shells at this site might be associated with its location in the river. This site was located in slow-moving water near the right river bank (Figure 8) in an area that may not have been impacted by boat or foot traffic.

3.3.4 MS-3 survey site 2010.10.20-3-2

Survey site 2010.10.20-3-2 was a river bar located near MP 7.5, downriver of boat ramp C1.5. The depth of this site was variable (0.3–0.7 m). Site dimensions were 31-m-long and 8-m-wide, with a total surface area of 248 m². The survey site boundary delineation was based on finding a scattered deposit of recent dead shells; boundaries were extended to the point at which recent shells were no longer found. The substrate was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).

Shells from 10 species were observed in this survey site (Table 15). Strange floater shells were most common (26% of all shells) followed by spike, elktoe, and mucket; all shells were found in similar proportions. Cylindrical papershell and creek heelsplitter shells were least common, represented by only one shell observation each. Five slippershell shells (state threatened) also were observed. Eight live mucket were found in this site.

Table 15. Segment MS-3 survey site 2010.10.20-3-2 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	–	2	17	1
Elktoe	–	–	–	11	10
Slippershell	–	–	–	–	5
Cylindrical papershell	–	–	–	1	–
Spike	–	4	4	12	2
Wabash pigtoe	–	–	2	7	1
Fatmucket	–	–	–	–	–
Pocketbook	–	–	–	–	–
White heelsplitter	–	–	–	–	–
Creek heelsplitter	–	–	–	1	–
Fluted-shell	–	–	–	5	2
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	2	1	23	8
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	–	–
Rainbow	–	–	–	3	5
Total number of shells	0	6	9	80	34
Percentage	0.0%	4.7%	7.0%	62%	26%

A total of 129 shells were collected from this survey site (0.5 shells/m²). Approximately 12% of the shells collected at this site were either recent dead (4.7%) or moderately worn 1 (7.0%), indicative of being less than three months post-mortem. Crushed elktoe, strange floater, and spike were also observed within this survey site. The total number of crushed shells was not recorded.

3.4 Segment MS-4

Sampling segment MS-4 was located on the Kalamazoo River just downriver from Historic Bridge Park. Approximately 0.5 miles of the 1-mile segment was surveyed, from MP 10.25 to MP 9.25 (Figure 10). Boat ramp C3.2 was located in this segment, which was in use at the time of the survey. The upriver boundary of the segment was approximately 1/5 of a mile downriver of where the August 2010 mussel tissue and sediment sampling occurred near boat ramp C3.2 at Historic Bridge Park. Two survey sites were delineated in this segment.

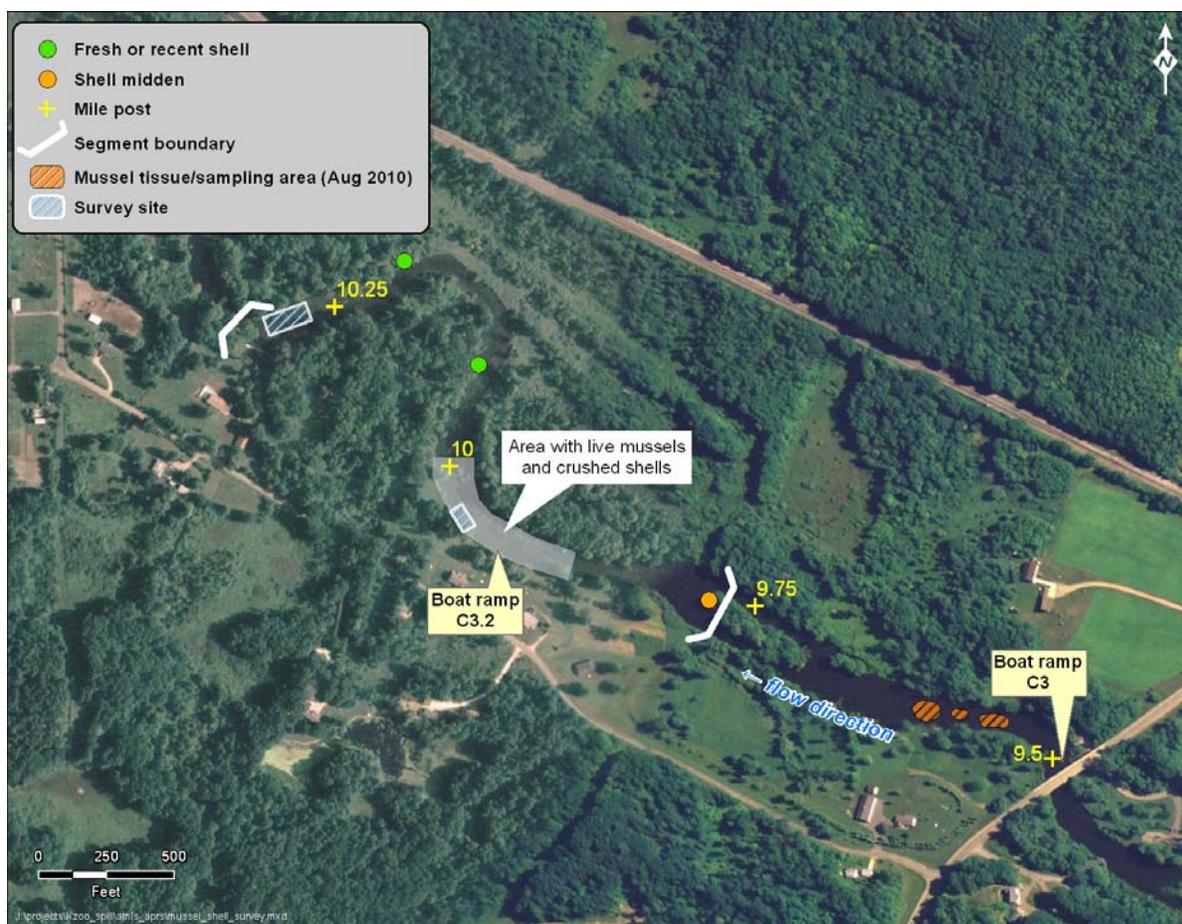


Figure 10. Sampling segment MS-4.

3.4.1 General conditions

At the start of the survey, the weather was sunny and cool (~ 45°F) but deteriorated to windy and cold with rain soon thereafter. Moderate turbidity was noted throughout the survey area, with periods of high turbidity when airboats ran through the segment. The survey was interrupted a number of times due to airboat passage. Interruptions generally lasted a few minutes in order to allow water to clear and enable viewing of the substrate. At times airboat traffic was so heavy that the survey crew exited the river due to safety concerns. Airboats were also observed hitting the bottom of the river when they powered up to get over shallow riffle areas.

Substrate was dominated by gravel and cobble, with areas of coarse sand and silt. Silt was common near boat ramp C3.2 and along the river banks. Most of the segment consisted of runs and riffles with shallow swift-flowing water. Shallow areas showed signs of being scoured by airboats and included lighter-colored sediments where the river bottom was disturbed. Oil sheening was observed near the toe of an island at the upriver boundary of this segment.

3.4.2 Segment MS-4 shell observations

Shells of 12 unionid mussel species were observed in segment MS-4 (Table 16). This included the state threatened slippershell and two species of special concern. Live mucket were common and live spike and Wabash pigtoe were also observed. A notable number of live mucket were observed downriver and in deeper water in undisturbed sediments directly across from boat ramp C3.2. Non-native Asian clams were found in this segment.

Shells representative of all weathering states were observed in segment MS-4. Two accumulations of recent shells were observed in the segment that were not delineated as survey sites in order to allow more time to survey the rest of the segment (Table 17). These accumulations included three recent mucket and two recent Wabash pigtoe mussel shells.

Damaged shells were observed throughout this segment. Similar to all other segments, fragile and worn shells were observed. Chipped shells were also found. These observations were associated with a shell midden observed at the tail end of an island located at the upriver segment boundary (Table 17). Crushed shells were observed in three shallow areas within this segment. The first was a shallow riffle at the downriver segment boundary. This area was delineated into survey site 2010.10.21-4-1. A second smaller area of crushed shells was noted just upriver from this site (Table 17). This second area was not delineated as a survey site because it was smaller and time did not allow further sampling. The third area of crushed mussels was located downriver of boat ramp C3.2. A survey site was delineated in this area (site 2010.10.21-4-2). However, due to the large extent of crushed mussels in this area and time constraints, the survey site represented only a small proportion of the total area of crushed shells. The approximate boundaries of this large area of crushed shells and survey site 2010.10.21-4-2 are shown in Figure 10.

Table 16. Total unionid mussel species^a observed in sampling segment MS-4. Includes shell observations made throughout the waded 0.5 miles of the segment, including observations in the survey sites (2010.10.21-4-1; 2010.10.21-4-2).

Common name	Species	State status	Species observed	
			Shell	Live
Mucket	<i>Actinonaias ligamentina</i>		X	X
Elktoe	<i>Alasmidonta marginata</i>	Special concern	X	
Slippershell	<i>Alasmidonta viridis</i>	Threatened	X	
Cylindrical papershell	<i>Anodontoides ferussacianus</i>		X	
Spike	<i>Elliptio dilatata</i>		X	X
Wabash pigtoe	<i>Fusconaia flava</i>		X	X
Fatmucket	<i>Lampsilis siliquoidea</i>			
Pocketbook	<i>Lampsilis cardium</i>		X	
White heelsplitter	<i>Lasmigona complanata</i>		X	
Creek heelsplitter	<i>Lasmigona compressa</i>		X	
Fluted-shell	<i>Lasmigona costata</i>		X	
Eastern pondmussel	<i>Ligumia nasuta</i>	Endangered		
Round pigtoe	<i>Pleurobema sintoxia</i>	Special concern		
Giant floater	<i>Pyganodon grandis</i>			
Strange floater	<i>Strophitus undulates</i>		X	
Paper pondshell	<i>Utterbackia imbecillis</i>	Special concern		
Ellipse	<i>Venustaconcha ellipsiformis</i>	Special concern		
Rainbow	<i>Villosa iris</i>	Special concern	X	
Total number of unionid species			12	3

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

Table 17. Isolated observations of recent dead and crushed shells made within sampling segment MS-4

Observation	Latitude	Longitude	Comments/details
A few crushed recent dead shells found	42.29617	-85.12585	Shells found in a 2–3 m ² area; included mucket and Wabash pigtoe shells
A few crushed moderately worn 1 and recent dead shells found	42.29573	-85.12447	Observed species included mucket and Wabash pigtoe
Notable number of live mussels, recent dead shells, and crushed shells observed	42.29464	-85.12506	Coordinates indicate the start point of observations; Figure 10 shows the full extent of the area A survey site was delineated within this area
Area with crushed shells	42.29608	-85.12664	Species not identified; shells likely crushed by boats in this shallow area
Midden	42.29300	-85.12127	Pile of chipped shells located at upriver segment boundary
A few crushed recent dead shells found in riffle	42.29581	-85.12732	
One heavily worn slippershell found	42.29624	-85.12480	Shell was encased in marl

Live mussels in this segment and in survey sites were observed lying on their sides in shallow water. This was not observed in any other segments and could have been caused by boats scraping along the river bottom. Some of these displaced mussels had deep scratches on their shells but were not cracked. Observations of crushed shells were also made in this area (Figure 11). This was particularly evident in the area where survey site 2010.10.21-4-2 was delineated.

3.4.3 MS-4 survey site 2010.10.21-4-1

Sampling site 2010.10.21-4-1 was located near MP 10.25 at the downriver boundary of the sampling segment. The survey site consisted of a shallow riffle, 0.4-m-deep area that was 19-m-long and 10-m-wide, with a total surface area of 190 m². This survey site boundary delineation was based on finding a deposit of recent shells; boundaries were extended to the extent of recent shell observations. The substrate was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).



Figure 11. Photograph of a crushed live mucket. This mussel was found approximately 10 m downriver from boat ramp C3.2.

Photograph taken by J. Matousek on October 21, 2010.

Shells from eight mussel species were found in this survey site (Table 18). Mucket shells were dominant, representing 72% of all shells that were found. Wabash pigtoe, the second most common species, only represented 11% of all shells. Slippershell (state threatened), creek heelsplitter, and strange floater shells were least common, with only a single shell found for each species. Shells from one species of special concern, elktoe, were also observed in low numbers. Three live mucket were also observed in this site.

A total of 74 shells were collected from this survey site (0.4 shells/m²). Nine recent dead shells (12% of all shells collected) and eight moderately worn 1 shells (11%) were also observed. Some of these recent dead shells were categorized as crushed. The survey crew observed an airboat scraping against the river bottom while surveys were underway in the delineated site. The crew walked over the riffle where the airboat had passed and observed crushed recent dead shells in this area.

Table 18. Segment MS-4 survey site 2010.10.21-4-1 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	7	4	41	1
Elktoe	–	–	–	1	1
Slippershell	–	–	–	1	–
Cylindrical papershell	–	–	–	–	–
Spike	–	–	–	3	1
Wabash pigtoe	–	1	3	4	–
Fatmucket	–	–	–	–	–
Pocketbook	–	–	–	–	–
White heelsplitter	–	–	–	–	–
Creek heelsplitter	–	–	1	–	–
Fluted-shell	–	–	–	4	–
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	1	–	–	–
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	–	–
Rainbow	–	–	–	–	–
Total number of shells	0	9	8	54	3
Percentage	0.0%	12%	11%	73%	4.1%

3.4.4 MS-4 survey site 2010.10.21-4-2

Site 2010.10.21-4-2 was located just downriver of boat ramp C3.2. Depth was 0.4 m and the dimensions were 18-m-long and 12-m-wide, with a surface area of 216 m². This survey site boundary delineation was based on finding a scattered deposit of recent dead shells, many of which were crushed. The extent of the recent dead shells was larger than the site boundaries (Figure 10), but the entire area was not included due to time constraints. Therefore, this survey site is only a subsample of the total area of recent dead and crushed shells. The substrate was a mix of pebble (64–16 mm diameter), gravel (16–2 mm), and sand (2–0.0625 mm).

Shells from eight species were observed in this site. Similar to the other MS-4 survey site (2010.10.21-4-1), mucket were the dominant species observed, comprising 85% of all shells. Elktoe (species of special concern) and Wabash pigtoe shells were also common (both 5% of the total shells). Cylindrical papershell, pocketbook, and rainbow (a species of special concern) shells were least common, comprising less than 1% of all shells observed at the site. No state threatened or endangered species shells were observed in this site. A total of 12 live mucket and two Wabash pigtoe shells were also observed in this site.

A total of 155 shells were collected from the survey site (0.7 shells/m²). Approximately 7% of the shells collected at this site were either recent dead (3.9%) or moderately worn 1 (3.2%). Twenty-one damaged shells were observed in this site. Nineteen of these shells were considered to be crushed (all mucket). One crushed live mucket and one Wabash pigtoe shell were also observed (Table 19).

Table 19. Segment MS-4 survey site 2010.10.21-4-2 shell weathering characterization results

Species	Fresh dead	Recent dead	Moderately worn 1	Moderately worn 2	Heavily worn
Mucket	–	3	4	124	–
Elktoe	–	–	1	4	3
Slippershell	–	–	–	–	–
Cylindrical papershell	–	–	–	1	–
Spike	–	–	–	1	2
Wabash pigtoe	–	3	–	5	–
Fatmucket	–	–	–	–	–
Pocketbook	–	–	–	1	–
White heelsplitter	–	–	–	–	–
Creek heelsplitter	–	–	–	–	–
Fluted-shell	–	–	–	2	–
Eastern pondmussel	–	–	–	–	–
Round pigtoe	–	–	–	–	–
Giant floater	–	–	–	–	–
Strange floater	–	–	–	–	–
Paper pondshell	–	–	–	–	–
Ellipse	–	–	–	–	–
Rainbow	–	–	–	–	1
Total number of shells	0	6	5	138	6
Percentage	0.0%	3.9%	3.2%	89%	3.9%

3.5 Segment MS-5

Sampling segment MS-5 was located just upriver from the Mill Pond in Battle Creek. This was the most downriver segment that was surveyed. Approximately 0.7 miles of the 1-mile segment was surveyed, from MP 15.25 to MP 14.5 (Figure 12). Boat ramp C5 was located in this segment, which was in use at the time of the survey. No survey sites were delineated in this segment.



Figure 12. Sampling segment MS-5.

3.5.1 General conditions

During the survey, the weather was partly cloudy and seasonably warm (~ 60°F). A boat was used to access this segment because the water was too deep to safely wade through. Approximately one-third of MS-5 was too deep to survey (> 1 m). In addition, this segment was partially impounded by the Mill Pond Dam, and slow current speed caused fine particles to settle out of the water column and cover the bottom. This heavy sedimentation also limited the amount of habitat that could be thoroughly surveyed and made inspecting the river bottom in some areas difficult. A sudden and noticeable increase in turbidity occurred just as the surveyors reached the upstream end of the sampling segment, which effectively ended survey activities.

3.5.2 Segment MS-5 shell observations

Despite high turbidity and sedimentation, 12 mussel species were observed in this segment (Table 20). This was the only segment that did not contain cylindrical papershell and creek heelsplitter and the only site in which paper pondshell, a species of special concern, was observed (Figure 13). Only two species, spike and Wabash pigtoe, were observed live. Asian clams were also observed in this segment.

Shells in this segment were mostly moderately worn 2. No fresh dead or recent dead shells were observed. Moderately worn 1 shells were observed, but a survey site was not delineated because these shells were associated with a shell midden. Two crushed mucket shells were observed, one near boat ramp C5 and one near MP 14.75 in shallow water. Heavy sedimentation of fine particles and turbidity obscured the view of shells on the bottom and may have reduced the surveyors' ability to find fresh dead or recent dead shells within this segment.

4. Summary

4.1 Species Observed

Shells from 18 unionid species were observed in the Kalamazoo River during this survey. This included one state endangered species, one state threatened species, and five species of special concern (Table 21). When compared to University of Michigan Museum of Zoology's Mollusk Collection records and Wattles Park (Historic Bridge Park) survey results reported by Mulcrone and Mehne (2001), five new mussel species were observed during this survey, including the state endangered eastern pondmussel and threatened slippershell. In addition, non-native Asian clam (*Corbicula fluminea*) were found in all of the sampling segments.

Table 20. Total unionid mussel species^a observed in sampling segment MS-5

Common name	Species	State status	Species observed
Mucket	<i>Actinonaias ligamentina</i>		X
Elktoe	<i>Alasmidonta marginata</i>	Special concern	X
Slippershell	<i>Alasmidonta viridis</i>	Threatened	X
Cylindrical papershell	<i>Anodontooides ferussacianus</i>		
Spike	<i>Elliptio dilatata</i>		X ^b
Wabash pigtoe	<i>Fusconaia flava</i>		X ^b
Fatmucket	<i>Lampsilis siliquoidea</i>		
Pocketbook	<i>Lampsilis cardium</i>		X
White heelsplitter	<i>Lasmigona complanata</i>		X
Creek heelsplitter	<i>Lasmigona compressa</i>		
Fluted-shell	<i>Lasmigona costata</i>		X
Eastern pondmussel	<i>Ligumia nasuta</i>	Endangered	
Round pigtoe	<i>Pleurobema sintoxia</i>	Special concern	X
Giant floater	<i>Pyganodon grandis</i>		
Strange floater	<i>Strophitus undulates</i>		X
Paper pondshell	<i>Utterbackia imbecillis</i>	Special concern	X
Ellipse	<i>Venustaconcha ellipsiformis</i>	Special concern	
Rainbow	<i>Villosa iris</i>	Special concern	X
Total number of unionid species			12

a. In addition to unionid mussels, live non-native Asian clam and shells were observed in the segment.

b. In addition to observing shells of this species, live individuals were also observed in the segment.

State status sources: MDNRE, 2010; MNFI, 2010.

The number of species and dominant species observed varied across segments (Table 22). The reference segment (MS-1) had the highest number of mussel species (16). Pocketbook shells were dominant in this segment, and shells of other species such as fluted-shell were also common. At MS-2, shells of 15 mussel species were observed. Spike shells were dominant in the MS-2 survey site, followed by Wabash pigtoe. In both the MS-3 and MS-4 segments, shells representative of 12 mussel species were identified, and mucket shells were dominant at all surveyed sites in these two segments. At MS-5, 12 species were observed. MS-5 was the only segment in which paper pondshell shells (species of special concern) were observed and cylindrical papershell and creek heelsplitter shells were not observed.



Figure 13. Photograph of a moderately worn 2 paper pondshell observed in segment MS-5.

Photograph taken by J. Matousek on October 25, 2010.

Table 21. Occurrences of state listed and special concern mussel species for each sampling segment

Species	State status	MS-1	MS-2	MS-3	MS-4	MS-5
Elktoe	Species of special concern	X	X	X	X	X
Slippershell	Threatened species	X	X	X	X	X
Eastern pondmussel	Endangered species	X				
Round pigtoe	Species of special concern	X	X			X
Paper pondshell	Species of special concern					X
Ellipse	Species of special concern	X	X			
Rainbow	Species of special concern	X	X	X	X	X

Sources: MDNRE, 2010; MNFI, 2010.

Table 22. Mussel shell species observed in each sampling segment

Species	MS-1	MS-2	MS-3	MS-4	MS-5
Mucket	X	X	X	X	X
Elktoe	X	X	X	X	X
Slippershell	X	X	X	X	X
Cylindrical papershell	X	X	X	X	
Spike	X	X	X	X	X
Wabash pigtoe	X	X	X	X	X
Fatmucket	X	X			
Pocketbook	X	X	X	X	X
White heelsplitter		X	X	X	X
Creek heelsplitter	X	X	X	X	
Fluted-shell	X	X	X	X	X
Eastern pondmussel	X				
Round pigtoe	X	X			X
Giant floater	X				
Strange floater	X	X	X	X	X
Paper pondshell					X
Ellipse	X	X			
Rainbow	X	X	X	X	X
Total number of unionid species	16	15	12	12	12

4.2 Shell Weathering

Table 23 provides shell weathering characterization results for the six survey sites. Fresh dead, recent dead, and moderately worn 1 shells were estimated to be less than three months post-mortem, as described in the agreed-upon work plan (Attachment A and Table 2 of this document), and these categories were combined in Table 23 for analysis purposes. The proportion of these shells within survey sites increases downriver from the spill, with the greatest percentage observed in segment MS-4 at site 2010.10.21-4-1 (23%). No fresh dead, recent dead, or moderately worn 1 shells were observed in the upstream reference segment, despite having the greatest density of shells. In summary, fresh dead, recent dead, and moderately worn 1 shells were more common in segments and survey sites downriver of the spill site compared to the reference site.

Table 23. Summary of delineated survey site shell weathering results. Percentage of shells < 3 months post-mortem was derived by dividing the total number of fresh dead, recent dead, and moderately worn 1 shells by the total number of shells observed in the site.

Segment/survey site	Shell density (shells/m ²)	Total number of shells	Number of fresh and recent dead shells	Number of moderately worn 1 shells	Shells < 3 months post-mortem (%)
MS-1					
2010.10.21-1-1	1.6	213	0	0	0%
MS-2					
2010.10.19-2-1	0.9	264	6	N/A	2.3%
MS-3					
2010.10.20-3-1	1.4	155	0	6	3.9%
2010.10.20-3-2	0.5	129	6	9	12%
MS-4					
2010.10.21-4-1	0.4	74	9	8	23%
2010.10.21-4-2	0.7	155	6	5	7.1%
MS-5 – no survey sites delineated within this segment					
N/A = MS-2 was surveyed prior to the development of “moderately worn 1” and “moderately worn 2” weathering categories; therefore, the number of moderately worn 1 shells is not available.					

4.3 Shell Damage

Damaged shells were observed in all five segments, but crushed shells were only found in the segments downriver of the spill site (Table 24). Broken shells that were in advanced stages of weathering were common in all segments, as would be expected as a result of natural in-stream weathering processes. Piles of chipped mussel shells were also common. These observations were associated with shell middens, which were observed in all but one of the segments. Crushed shells were observed in segments downriver of the spill site. No crushed shells were observed in the reference segment. The crushed shells included recent and moderately worn 1 shells, and crushed live mussels were also observed. Crushed shells were most often found in shallow water habitats downriver from boat ramps and in areas of high boat traffic. The largest area of crushed shells was found just downriver from boat ramp C3.2 in segment MS-4. The substrate in this area was discolored where boats had scraped along the river bottom. This area also contained a notable number of live mussels, some of which were lying exposed on their sides, with scratches on their shells. Others were crushed, including one individual that was still alive.

Table 24. Summary of damaged shells observed in each sampling segment. As categorized by the field team for the purposes of this study, broken shells are considered shells damaged due to advanced weathering, chipped shells are associated with predation, and crushed shells are defined as shells damaged by heavy impact (e.g., boat or foot traffic).

	Broken shells	Chipped shells	Crushed shells
MS-1	X		
MS-2	X	X	X
MS-3	X	X	X
MS-4	X	X	X
MS-5	X	X	X

4.4 Additional Observations

Additional observations of potential oil-spill-related impacts to mussel habitat were noted in sampling segments downriver from the spill site. Observations included oil sheens, elevated turbidity, and sedimentation/siltation:

- ▶ In segment MS-2, near boat ramp C1.5, oil sheens were observed in a heavily silted area near the location of two recent dead mussel shells. Moderate to high turbidity and siltation were observed in segments downriver from the spill site.
- ▶ Heavy siltation of river substrate and mussel shells were observed in segment MS-3. Fine silt covered the river substrate and mussel shells in areas with slow-moving water, and recent dead shells were often observed in these areas. Siltation may be the result of high turbidity from upriver dredging, eroding banks (observed near boat ramp C1.5), and/or boat traffic.
- ▶ Turbidity increased in segment MS-4, especially when boats passed through the survey site.
- ▶ Turbidity was greatest at the most downriver segment (MS-5), where it adversely affected the ability to conduct the survey. Despite conducting the survey of segment MS-5 under conditions of high turbidity and heavy sedimentation, crushed mussel shells were observed in this segment. This included two crushed mucket shells, one near boat ramp C5 and one near MP 14.75 in shallow water.
- ▶ A relatively large number of young live spike and mucket shells was found at MS-5. Based on a count of visible annular rings, these individuals were as young as three years old. This is notable because unionid mussels this young are not often observed during surveys, indicating that successful reproduction has occurred for these species in the recent past.

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A. Mussel Shell Survey Work Plan

October 16, 2010

Unionid mussel shell survey in the Kalamazoo River watershed, in the Marshall and Battle Creek, MI area

Introduction

On July 26, 2010, Enbridge Energy, Limited Partnership discovered a release of heavy crude oil (Cold Lake Blend) from line 6B just west of milepost 608 in the vicinity of its pump station located in Marshall, Calhoun County, Michigan. Line 6B is a 30-inch, 190,000 barrels per day (bpd) line transporting light synthetics, heavy and medium crude oil from Griffith, IN, to Sarnia, Ontario. The location of the release from Line 6B is located in an undeveloped area in the outskirts of town with coordinates of approximately North ½ Section 2, T3S, R6W, Latitude: 42.2395273 Longitude: -84.9662018. Upon discovery of the release the pipeline was shut down and isolation valves closed, stopping the source of the oil; however, initial estimates are that approximately 1 million gallons of crude oil may have been released to Talmadge Creek (approximately 1.5 miles) and to the Kalamazoo River.

Unionid mussels are an important biological resource in the state of Michigan and component of the state's natural heritage. Of the 46 unionid species that occur in Michigan, 19 are threatened or endangered in the state. One state endangered, three state threatened, and six special concern species have been documented in the Kalamazoo River since 1989 (Peter Badra, MNFI, personal communication, 2010). Anecdotal observations of dead mussels, and "fresh" and recent dead mussel shells (see below for definition of "fresh" and "recent") in areas of response activities in the river are suggestive of mussel injuries, including physical injuries caused by the breaking of shells by boat and other transportation on the river, as well as potentially injuries due to exposure to released contaminants.

Scope

This work plan describes freshwater bivalve (mussel) shell survey activities on the Kalamazoo River from Marshall impoundment to the town of Battle Creek, MI. The proposed survey will be conducted by the Michigan Natural Features Inventory (MNFI) and Stratus Consulting on behalf of the natural resource trustees (Trustees) in cooperation with Enbridge. Results may be used to identify and characterize potential injury to mussel communities resulting from toxicity due to exposure to hazardous substances, and physical injury (e.g., crushed shells) as a result of response activities, associated with the release of oil into Talmadge Creek and Kalamazoo River. Some of these data are ephemeral. Information on the location of dead mussels and the "freshness" of mussel shells will largely be lost over time and during spring high water events, if

not observed and recorded this fall. Additionally, survey information can be used to design a more intensive mussel community survey to be conducted next year.

The survey will focus on locating “fresh” or “recent” dead mussel shells. Interpretation of the age of mussel shells post-mortem can be made based on the condition of the shells according to the scale and physical characteristics described in Table 1. Classification of the age of shells post-mortem using this scale is qualitative and somewhat approximate. However, the scale is sufficiently precise for the purposes of this survey, which is to identify shells of dead mussels associated with the spill event and response activities. In other words, shells that fall into the first two categories in Table 1.

Table 1. Mussel shell scale

Scale	Category	Physical characteristics	Approximate post-mortem shell age
1	Fresh dead	Soft tissue intact	Several days
2	Recent dead	No soft tissue, aside from hinge ligament	Couple of weeks up to ~3 months
3	Moderately worn	Most of periostracum intact, shell has most of its original strength	3 months to one year
4	Heavily worn	periostracum worn and peeling, shell at least somewhat chalky and fragile	Greater than one year

Note that this survey is focused on mussel shells, and it is not intended as a mussel population survey. Occurrence and abundance of live mussels will be documented, if they are encountered during the shell survey. However, the survey is being conducted in the fall, the time of year when live mussels burrow into the sediment, where they spend winter months. Therefore, estimates on live mussel abundance made during this survey may not reflect the actual of live mussel abundance at surveyed sites.

The survey will be conducted in October 2010. It is anticipated that the survey will take approximately five days in the field, with five crew members, and may require a boat and supplies, to be arranged by MNFI.

Objectives

The objectives of this study are as follows:

- ▶ Survey selected segments of the Kalamazoo River from Marshall impoundment to the town of Battle Creek for fresh and recent dead mussel shells.

- ▶ Delineate the spatial extent of fresh and recent dead mussel shells within the selected segments. Delineated spatial areas of fresh and recent dead mussel shells will define survey sites.
- ▶ Within survey sites, document mussel shells observed, including species and condition (state of shell weathering; 1 through 4). Observed live mussels will also be recorded.

Preliminary Sampling Locations

Five discrete sampling segments have been identified on the Kalamazoo River between Marshall Impoundment and the Mill Pond at the Town of Battle Creek (approximate river mile 15.5). Sampling segments have been selected according to proximity to the spill site, areas of known response activities, locations of boat launches (and hence elevated boat activity), and prior mussel tissue and sediment sampling locations. The mussel shell survey protocol will be conducted at each of the sampling segment as time permits. Note that the locations may be subject to change, depending upon conditions encountered when in the field. The segments consist of one reference and four locations downstream of the release. An additional reference segment may be added, based on need, as judged by the crew while in the field.

Each sampling segment represents approximately one mile of river. One sampling segment will be sampled each day as described in Table 2. The crew will cover as much of the mile identified at each site as they can in one day, and then progress to the next site the following day. Though the crew may be successful at covering the full mile at each site, this is somewhat uncertain, and will depend upon field conditions encountered. The crews will move to a new segment each day even if the previous segment was not fully surveyed to ensure adequate coverage of the impacted length of the river. The segments will only be surveyed in habitat that is practically accessible. (i.e., not too deep or swift to wade, or contain complex habitat that limits observation of the river bottom).

Table 2. Mussel shell survey sampling segments and schedule. River miles area as reported by Enbridge.

Sampling day	Sampling segment (river miles; RM)	Attributes	Map figure number
1	MS-1: Down river of Marshall Impoundment (RM not available)	Reference area, contains a past survey location	Figure 1
2	MS-2: Talmadge Creek confluence area (RM 2.25 to 3.25)	Exposure area, contains a boat ramp and near a past survey location	Figure 2
3	MS-3: Boat ramp near 11 Mile Road Bridge (RM 7.00 to 8.00)	Exposure area, contains a boat ramp and past survey location	Figure 3
4	MS-4: Boat ramp near Historic Bridge Park (RM 9.25 to 10.25)	Exposure area, contains two boat ramps and past survey location	Figure 4
5	MS-5: Boat ramp at Rivers Edge Landscaping (RM 14.5 to 15.5)	Exposure area, contains a boat ramp and near sediment sparging/removal locations	Figure 5



Figure 1. Sampling segment downriver of Marshall Impoundment (MS-1).



Figure 2. Talmadge Creek confluence area sampling segment (MS-2).

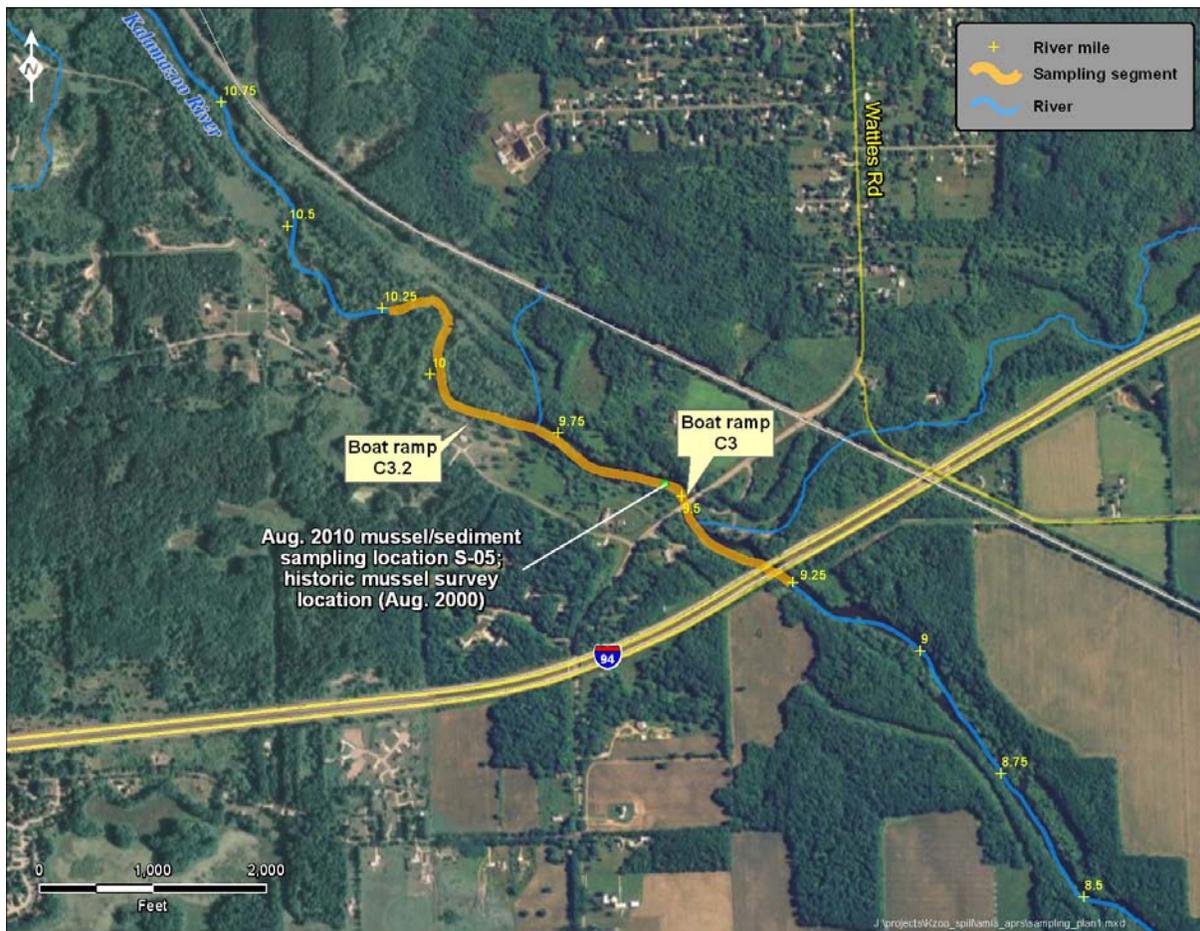


Figure 4. Sampling segment near Historic Bridge Park (MS-4). Historic mussel survey conducted by (Mulcrone and Mehne, 2001) in the summer of 2000.

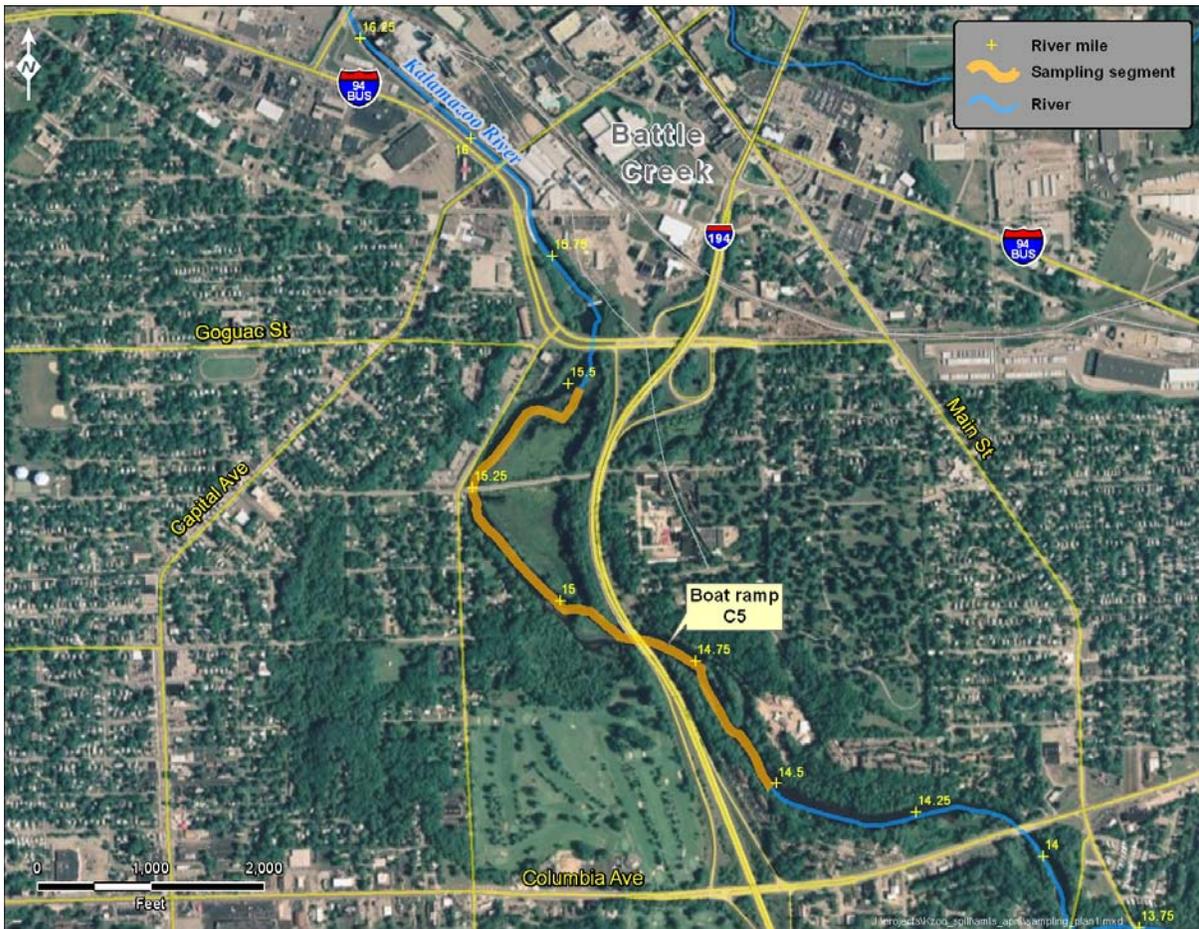


Figure 5. Sampling segment near Rivers Edge Landscaping in Battle Creek, MI (MS-5).

Survey Methods

The mussel shell survey will be led by MNFI and Stratus Consulting on behalf of the Trustees, in cooperation with Enbridge representatives. There will be a total of four to five crew members. Surveys will follow the mussel shell survey protocol (provided below). These methods may be modified to suit conditions encountered in the field as necessary. Any changes to the method made in the field will be recorded and shared with all parties involved. This survey will focus on identifying fresh and recent dead native mussel species shells. However, presence of older shells (category 3 and 4), and live mussels and non-native dreissenid mussels (*Dreissena polymorpha* and *Dreissena bugensis*) and Asian clams (*Corbicula fluminea*) will be noted in survey sites.

Survey information will be recorded onto a survey site-dedicated datasheet (Attachment 1). One datasheet will be used for each survey site. Additional information such as field personnel, start and stop times and coordinates, and photograph information will be recorded on a sampling segment datasheet. Only one sampling segment datasheet will be completed each day.

Note, that the survey will not be possible if river conditions, such as high flow and turbidity, limit observation of mussel shells. If it is determined that the substrate and mussel shell observations can not be made in wadable river reaches (depths ~1 meter) the survey will not be conducted until conditions improve.

Mussel Shell Survey Protocol

- ▶ Travel upriver through the sampling segment by wading.
- ▶ The crew will wade the river in a parallel line, inspecting the substrate with a stream bottom viewer and/or polarized glasses. Encountered objects may need to be picked up to enable identification of shells, and their categorization according to the shell scale (see Table 1).
- ▶ When fresh dead or recent dead mussel shells are encountered, this defines the downriver boundary of a survey site:
 - The survey site boundary GPS coordinates are taken and recorded in the datasheet (Attachment 1)
 - Survey sites will be named according to a predetermined naming convention:
 - Survey date (Year.Month.Day) – sampling segment ID – consecutive survey number conducted in the sampling segment
 - Example: 2010.10.26–2–004

- ▶ The survey site is delineated and surveyed simultaneously:
 - The crew continues to advance upriver (and across the wadable river-width), and all shells encountered are picked up and examined to identify the species and condition of the shell according to the shell scale (see Table 1 for shell scale).
 - Each observed shell, its species, and condition (1-4) are recorded in the field datasheet (Attachment 1).
 - Each observed live mussel is also identified and recorded in the datasheet.
 - Once crew members reach a point (upriver and across the wadable river width) where fresh/recent dead shells are no longer encountered, this defines a boundary of the survey site. At this boundary, the crew stops recording shell and live mussel observations.
 - Once the boundaries of the survey site have been identified, the dimensions of the survey site are then recorded in the datasheet, including survey site boundary lengths, a sketch of the survey site is drawn, and average water depth is recorded.

- ▶ An estimated proportion of substrate surface area covered with fresh/recent dead shells in the entire survey site (see datasheet for percentage categories) is then recorded on the datasheet.
 - Proportion estimates will be performed by at a minimum two crew members (and preferably with all crew members), and the agreed upon values will be recorded on one datasheet

- ▶ Notes regarding occurrence of shell piles, or other pertinent survey related information on the field datasheet in the spaces provided.

- ▶ Representative shell samples may be collected; samples will be place inside a labeled paper bag; shells will be stored at MNFI.
 - Sample labels will include the following information:
 - Collection date, time, and GPS coordinates (decimal degrees to five decimal places)
 - Name, affiliation, and phone number of collector
 - Species and condition represented by the sampled shell

- ▶ Pictures should be taken so that each species and shell condition is documented for the survey site. Pictures should also be taken of any other pertinent subjects while conducting the survey. The crew will work with a GPS unit and keep a tracklog running.
 - A common GPS unit and camera will be used and supplied by Entrix
 - The GPS unit will be reset, once, at the beginning of the survey

- Once a day, a picture of the GPS screen will be taken (the easiest way is to take it from a distance and do not zoom in) that shows the time on the GPS screen to the nearest second (see Attachment 2 for GPS tracklog and photo management protocol).
- ▶ Continue traveling upriver inspecting substrate, until fresh/recent dead shells are observed again. This defines the downriver boundary of the next survey site. Continue defining survey sites, and conducting surveys until the entire sampling segment has been inspected.
 - If the mile long sampling segment cannot be surveyed in the scheduled field day (Table 2), then estimated proportion of the sampling segment that had been sampled will be documented on the field datasheet
- ▶ At the end of each day field datasheets will be scanned into a pdf file. Scanned datasheets, pictures, and GPS tracklogs will be saved onto a backup device, such as a USB port or external drive. These data will then be uploaded to the Entrix and trustee's ftp sites. Trustees will retain the original datasheets and will provide copies to Entrix/Enbridge as requested.
 - Pdf datasheets and pictures files will be named according to a predetermined naming convention:
 - YearMonth.Day.Shell.Datasheet.sequential.series (example: 2010.Oct.25.Shell.Datasheet.015)
 - YearMonth.Day.Shell.Tracklog (example: 2010.Oct.25.Shell.Tracklog)
 - YearMonth.Day.Shell.Picture.sequential.series (example: 2010.Oct.25.Shell.Picture.005).

Reporting

The survey will be summarized in report format. The report will include a summary of survey methods and results. The report will include a map showing surveyed locations and brief description of relevant conditions at each location. For each survey site location, the report will include a description of the weathering condition of dead shells in the entire survey location for each native mussel species. Locations of live mussels and occurrence of non-native mussels will also be reported.

Reference

Mulcrone, R.S. and C. Mehne. 2001. Freshwater Mussels of the Kalamazoo River, Michigan, from Battle Creek to Saugatuck. Prepared for Lisa L. Williams U. S. Fish and Wildlife Service. October 1.

Attachment 1. Field Datasheets

Field Recorder:		Page ___/___	
Enbridge Oil Spill Mussel Shell Survey Field Datasheet			
Location Information			
Sampling Segment:			
Site Description/Landmarks/Access/Other Notes:			
GPS Coordinates (decimal degrees to 5 decimal places)			
Start location		End location	
Latitude:		Latitude:	
Longitude:		Longitude:	
Start Time:		End Time:	
Weather Conditions:			
Air Temperature:			
Personnel Present			
Name - Affiliation		Name - Affiliation	
Photograph Documentation			
Camera id/owner:		GPS unit id/owner:	
Photo #	Time	Photographer/Camera	Subject

Survey Site		(in consecutive order)		Page ___/___	
Surveyor(s):			Date:		
Enbridge Oil Spill Mussel Shell Survey – Mussel Survey Data					
Habitat Information					
Coordinates at downriver boundary:					
Survey Site Area Measurements					
Dimensions	Est. length (m)	Draw shape (label sides and flow direction)			
Side 1					
Side 2					
Side 3					
Side 4 (opt)					
Depth (1/10 meter)					
Proportion of substrate covered by shells					
Coverage (check one)					
>1%	1 to 5%	6 to 25%	26 to 50 %	51 – 75%	>75%
Shell piles: y/n					
Notes:					
Non-native species present (Y/N):					

Attachment 2. Entrix Protocol for Using a Digital Camera, GPS, and the Photolink Software

- ▶ GPS (these directions typically apply to Garmin handheld units)
 - Set GPS units to decimal degrees
 - Main menu/setup/units/hddd.ddddd
 - Set GPS track mode to on
 - Main Menu/tracks
 - It is best if the track log is cleared before you start
 - Intervals should be adjusted based on mode of transportation (i.e., increase interval if walking, decrease interval if boating)
 - Setup GPS track mode
 - Main menu/tracks/options/setup track log
 - Select local time for time display
 - Main menu/setup/time
 - Check to make sure that the GPS is “ready to navigate” when you are taking pictures
 - To save a waypoint
 - Main menu/mark/ok – saves the waypoint using the number in the flag as the ID number. The number automatically increases with each waypoint you save. You can rename the waypoint by editing the label in the flag.
 - To navigate to a waypoint
 - Main menu/find/waypoints

- ▶ Camera
 - Set camera time to GPS date and time to the nearest second.
 - After changing camera batteries, check to make sure time has not reset to some default.
 - Take a picture of the GPS screen (the easiest way is to take it from a distance and do not zoom in) that shows the time on the GPS screen to the nearest second. **This only needs to be done once per day.**

- ▶ Photolink
 - You must have the GPS with you and have the track-logs on in order to georeference your pictures.
 - The GPS photolink program automatically downloads your track log when you process your photos. Be aware that you can not use a track log saved on the GPS in photolink.

- You can save track logs to your computer using the Garmin Mapsource software if you do not have the photolink software. This is the only program I've found that saves the tracklog in a format that can be used by photolink. It comes with most Garmin map packages and is available as a stand alone program.

B. Field Datasheets

15 mile r

Field Recorder: J. Matanich Date: 10/19/10 Page 1/1
 Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information

Sampling Segment: Reference Location

Site Description/Landmarks/Access/Other Notes:

Start @ 17 mile Rd Bridge

GPS Coordinates (decimal degrees to 5 decimal places)

Start location	<u>17 mile start</u>	<u>17 mile end</u>	End location
Latitude:	<u>N 42.26480</u>	Latitude:	<u>N 42.26211</u>
Longitude:	<u>W 084.96385</u>	Longitude:	<u>W 084.95558</u>
Start Time:	<u>10:20 am</u>	End Time:	<u>15:33</u>

Weather Conditions: Cloudy, 55°F

Air Temperature: 55°F

Personnel Present

Name - Affiliation	Name - Affiliation
<u>John Matanich / ENTRIX</u>	
<u>Matt Wilson / DNRE</u>	
<u>Bill Toff / DNRE</u>	
<u>Mike Wilson / DNRE</u>	
<u>Pete Baska / MNFI</u>	
<u>Mike Koppitz / Stratco</u>	

Photograph Documentation

Camera id/owner:		GPS unit id/owner:	
Photo #	Time	Photographer/Camera	Subject
<u>1</u>			<u>Spill, recent dead</u>
<u>2</u>			<u>Eastern pond mussel, mod worn</u>
<u>3</u>			<u>Rainbow, mod worn</u>
<u>4</u>			<u>Spine, Live</u>
<u>5</u>			<u>Pocketbook, Live</u>
<u>6</u>			<u>Pocketbook, mod worn</u>
<u>7</u>			<u>Rainbow, mod worn</u>
<u>8</u>			<u>Elk toe, heavily worn</u>
<u>9</u>			<u>Cylindrical pearly shell, heavily worn</u>
<u>10</u>			<u>Viper shell, mod worn</u>
<u>11</u>			<u>Elk toe, Live</u>
<u>12</u>			<u>Giant floater, mod worn</u>
<u>13</u>			<u>Strap floater, mod worn</u>
<u>14</u>			<u>Creek Hail shell, heavily worn</u>
<u>15, 16, 17</u>			<u>Claw phyla</u>
<u>18, 19</u>			<u>Mucket, Mod. worn</u>
<u>20, 21</u>			<u>Round pig toe, Mod worn</u>

Field Recorder: J. Matonah Date: 19 Oct 2010 Page 13

Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information MS-21th MS-02

Sampling Segment:

Site Description/Landmarks/Access/Other Notes:

Start at River mile 3.0

GPS Coordinates (decimal degrees to 5 decimal places)

MS02 START Start location	Boat launch End location MS02 END
Latitude: <u>N 42.25925</u>	Latitude: <u>N 42.25864</u>
Longitude: <u>W 084.99898</u>	Longitude: <u>W 084.99898</u>
Start Time: <u>09:30</u>	End Time: <u>16:44</u>

Weather Conditions: Cloudy

Air Temperature: ~50°F

Personnel Present

Name - Affiliation	Name - Affiliation
<u>John Matonah - ENTRIX</u>	
<u>Mike Wilson - DNRE</u>	
<u>Matt Lehner - DNRE</u>	
<u>Bill Teft - DNRE</u>	
<u>Pete Bogra - MAIF</u>	
<u>Mike Cronig - Stratco</u>	

Photograph Documentation

Camera id/owner:		GPS unit id/owner:	
Photo #	Time	Photographer/Camera	Subject
<u>1,2</u>		<u>GPS time</u>	<u>GPS, time</u>
<u>3,4</u>			<u>Labiate pig toe - mod worn</u>
<u>5</u>			<u>Strange flatter - mod worn</u>
<u>6</u>			<u>Rainbow - mod worn</u>
<u>7</u>			<u>Asian clam - mod worn</u>
<u>8</u>			<u>Spike - recent dead</u>
<u>9</u>			<u>Pocketbook - Live</u>
<u>10</u>			<u>Ele toe - mod worn</u>
<u>11</u>			<u>Crack heel splitter, mod worn</u>
<u>12,13</u>			<u>fluted shell, mod worn</u>
<u>14</u>			<u>Labiate pig toe, mod worn</u>
<u>15</u>			<u>Flipse, mod worn</u>
<u>16</u>			<u>White heel splitter, Live</u>
<u>17</u>			<u>musket, mod shell</u>
<u>18</u>			<u>fluted shell, stain wide</u>

19 Ele toe, crushed top 25 - recent spike
20 Slipper shell 26 - Mod worn
21, 22, 23 Crew photos broken shell
24 Pocketbook, cracked, recent dead pocket book

Survey Site MS-02 Tronect 1		(in consecutive order)		Page 2/4	
Surveyor(s): Matousek, Taft, Badry, Weaner, Corney, Wilson				Date: 19 Oct 10	
Enbridge Oil Spill Mussel Shell Survey - Mussel Survey Data					
Habitat Information					
Coordinates at downriver boundary: N 42.25979 W 085.01019 to N 42.25983 W 085.01098					
Survey Site Area Measurements					
Dimensions	Est. length (m)	Draw shape (label sides and flow direction)			
Side 1	9m				
Side 2	32m				
Side 3	9m				
Side 4 (opt)	32m				
Depth (1/10 meter)	4/10m				
Proportion of substrate covered by shells					
Coverage (check one)					
<input checked="" type="checkbox"/> < 1%	<input type="checkbox"/> 1 to 5%	<input type="checkbox"/> 6 to 25%	<input type="checkbox"/> 26 to 50 %	<input type="checkbox"/> 51 - 75%	<input type="checkbox"/> >75%
Less than 1%					
Shell piles: y/n					
Notes: Asian Clams observed					
Non-native species present (Y/N) : (Y)					

Start ~5m from (L) bank, cover approx ^{9m} 10m of stream channel
 Wide and 32m long

Sampling Segment: MS-02 transect 1 (at Mile 3.0 sign)		Page 3/4					
Field Recorder: J. Markewich		Date: 19 Oct 10					
Shell and Mussel Observations (cont'd) waspt MS02 TRAN1 STR1							
		Shell Condition (check one)				N 42.25979 W 085.01019	
Species (G. species)	Live Mussel (check)	Fresh	Recent dead	Mod. worn	Heavily worn	Crushed shells (Y/N)	Notes/observations
Kibishi pig toe			/				moderate
Spike							
Spike			//				moderate
Spike							
Pocket beads			/				
Rainbow					//		
Fluted shell			/				
Mucket				/			
Elk toe							
Elipse					/		
Strange flatter			/				
Round pig toe					//		
Star-shell				//	/		

Asian Clams also observed

Endpoint MS02 TRAN END (12:15)

N 42.25983 W 085.00980

Field Recorder: <u>J. Matoušek</u>		Date: <u>20 Oct 2010</u>		Page <u>114</u>	
Enbridge Oil Spill Mussel Shell Survey Field Datasheet					
Location Information					
Sampling Segment: <u>MS-03</u>					
Site Description/Landmarks/Access/Other Notes: <u>Put in at the 11 mile road bridge crossing</u> <u>walked down to mile marker 775</u>					
GPS Coordinates (decimal degrees to 5 decimal places)					
time <u>10:13</u>		Start location <u>mile marker 775</u>		End location	
Latitude: <u>N 42.27732</u>		Latitude: <u>N 42.27443 W 085.08154</u>			
Longitude: <u>W 085.09117</u>		Longitude: <u>W 085.08154</u>			
Start Time: <u>10:13</u>		End Time: <u>11:30</u>			
Weather Conditions: <u>Sunny</u>					
Air Temperature: <u>50°F</u>					
Personnel Present					
Name - Affiliation			Name - Affiliation		
<u>Ryan Griffin - Cordco Entry</u>					
<u>John Matoušek - Cordco Entry</u>					
<u>Rita Babra - MNFI</u>					
<u>Matt Wagner - DNRE</u>					
<u>Mike Wilson - DNRE</u>					
<u>Mike Conroy - Stratco</u>					
Photograph Documentation					
Camera id/owner:			GPS unit id/owner:		
Photo #	Time	Photographer/Camera	Subject		
<u>1,2</u>		<u>Matoušek / #1</u>	<u>GPS time/date</u>		
<u>3</u>			<u>Muskrat / moderate 2</u>		
<u>4</u>			<u>Elk toe / moderate 2</u>		
<u>5</u>			<u>Spine / moderate 1</u>		
<u>6</u>			<u>Lubrite heel splitter / Live</u>		
<u>7</u>			<u>Whisker picture / moderate 2</u>		
<u>8</u>			<u>fluted shell / moderate 2</u>		
<u>9</u>			<u>Strange flatter / moderate 2</u>		
<u>10</u>			<u>Picket-book / moderate 2</u>		
<u>11,12,13</u>			<u>Crank pliers</u>		
<u>14,15</u>			<u>Moderate 1 exonside Muskrat</u>		
<u>16</u>			<u>Rainbow Moderate 2</u>		
<u>17</u>			<u>Muskrat with hole/damage</u>		
<u>18</u>			<u>Slipper - heavily worn</u>		
<u>19</u>			<u>Cylindrical paper shell mod 2</u>		
<u>20</u>			<u>Recent looking shells</u>		

Survey Site (in consecutive order) MS-3 Transect 1 Page 214

Surveyor(s): *Mattewick, Baden, Perry, Goffin, Wilson, Weaver* Date: 20 Oct 2010
 Enbridge Oil Spill Mussel Shell Survey - Mussel Survey Data

Habitat Information

Coordinates at downriver boundary: *N 42.27737 W 085.09080* *Upstream boundary N 42.27736 W 085.09071*

Survey Site Area Measurements

Dimensions	Est. length (m)	Draw shape (label sides and flow direction)
Side 1	7.5m	
Side 2	15m	
Side 3	7.5m	
Side 4 (opt)	15m	
Depth (1/10 meter)	4/10m	

Proportion of substrate covered by shells

Coverage (check one)					
>1%	1 to 5%	6 to 25%	26 to 50 %	51 - 75%	>75%
	<input checked="" type="checkbox"/>				

Shell piles: *y/n*

Notes: *Very encrusted shells. All/most shell with significant mud coating*

Non-native species present (Y/N):
Asian Clams

Bm x 31m

Sampling Segment: <u>MS-3 Transect 2</u>		Page <u>4/4</u>					
Field Recorder: <u>M. M. M.</u>		Date: <u>20 Oct 2010</u>					
Shell and Mussel Observations (cont'd)							
Species (G. species)	Live Mussel (check)	Shell Condition (check one)					Notes/observations
		Fresh	Recent dead	Mod. worn (1)	Heavily worn Mod (2)	Crushed shells (XAD) Heavy barn	
Musket	///			//	///	///	
					///		
Sliver shell						///	
Elk toe					///	///	broken shell on scene
Strange flatter			//	/	///	///	broken shells on scene
Spike			///	///	///	//	broken shell on scene
Webster pig toe				//	///	/	
Rainbow					///	///	
Fluted shell					///	//	
Cylindrical paprika					/		
Crack heel plate					/		

Asia Clam

Survey Site **MS-3 TRANSECT 2** (in consecutive order) Page 1

Surveyor(s): Matusch, Bodin, Lewis, Wilson, Conley, Griffin Date: 20 Oct 2010
 Enbridge Oil Spill Mussel Shell Survey - Mussel Survey Data

Habitat Information

Coordinates at downriver boundary: N42.27657 W085.08723 upriver boundary: N42.27661 W085.08678

Start

Survey Site Area Measurements

Dimensions	Est. length (m)	Draw shape (label sides and flow direction)
Side 1	8m	
Side 2	31m	
Side 3	8m	
Side 4 (opt)	31m	
Depth (1/10 meter)		

Proportion of substrate covered by shells

Coverage (check one)					
< 1%	1 to 5%	6 to 25%	26 to 50%	51 - 75%	>75%
<input checked="" type="checkbox"/>					

Shell piles: y/n
 Notes:

Non-native species present (Y/N):
Asian Clams

Field Recorder: J. Matonuk

Date: 21 Oct 2010

Page 1/8

Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information

Sampling Segment: M5-4

Site Description/Landmarks/Access/Other Notes:

Stationed below mile marker 10.25 below boat launch @ 3.2

GPS Coordinates (decimal degrees to 5 decimal places)

Start location	End location
Latitude: N42.29591	Latitude: N42.29373
Longitude: W085.12777	Longitude: W085.12421
Start Time: 09:30	End Time: 13:13

Weather Conditions: Sunny

Air Temperature: 245-55°F

Personnel Present

Name - Affiliation	Name - Affiliation
John Matonuk / Coastal Entry	
Ryan Crofton / Coastal Entry	
Dill Taff / DNRE	
Matt Wilcox / DNRE	
Mike Wilson / DNRE	
Mike Corney / Structural	

Photograph Documentation

Camera id/owner:		GPS unit id/owner:	
Photo #	Time	Photographer/Camera	Subject
1/2		Matonuk / #1	GPS data/time
3/4			Boat Launch
5			Stump fluster, Moderate 2
6			Mucket, Moderate 2
7			Elk toe, Heavy worn
8			Wabash pigtoe, Moderate 2
9			Becket boat, Heavy worn
10			Shells, Cracked
11			Spike / Moderate 1
12			White heelsplitter, Recent
13			Fluted shell / moderate 2
14			Crack heelsplitter / broken
15/16/17			Crow photos
18/19			Marlin crusted Shells
20			Cylindrical paper shell
21,22			Mucket, Cracked shell - Live

wide
19m x 10m

Survey Site MS-4 (in consecutive order) Transect 1 Page 2/8

Surveyor(s): Martinsch, Wisner, Tait, Corney, Sadra, Wilson, Brooker Date: 21 Oct 2010
Enbridge Oil Spill Mussel Shell Survey - Mussel Survey Data

Habitat Information

Coordinates at downriver boundary: MS4 TRNSTRT upstream boundary
N42.29591 W085.12740 N42.29600 W085.12704

Survey Site Area Measurements

Dimensions	Est. length (m)	Draw shape (label sides and flow direction)
Side 1	10m	
Side 2	19m	
Side 3	10m	
Side 4 (opt)	19m	
Depth (1/10 meter)		

Proportion of substrate covered by shells

Coverage (check one)					
< 1%	1 to 5%	6 to 25%	26 to 50 %	51 - 75%	>75%
<input checked="" type="checkbox"/>	<input type="checkbox"/>				

Shell piles: y/n

Notes:
Some cracked and recent dead found in this area

Non-native species present (Y/N):
Asian Clams

Survey Site (in consecutive order) Page 4/8
 MS-4 Target 2

Surveyor(s): *Matsush, Wase, Toff, Grafton, Conry, Wilson, Sadra* Date: *21-Oct-2010*
 Enbridge Oil Spill Mussel Shell Survey - Mussel Survey Data

Habitat Information

Coordinates at downriver boundary: *upstream boundary*
 N42.29390 W085.12488 *N42.29370 W085.12486*

Survey Site Area Measurements

Dimensions	Est. length (m)	Draw shape (label sides and flow direction)
Side 1	12m	
Side 2	18m	
Side 3	12m	
Side 4 (opt)	18m	
Depth (1/10 meter)		

Proportion of substrate covered by shells

Coverage (check one)					
>1%	1 to 5%	6 to 25%	26 to 50 %	51 - 75%	>75%
	<input checked="" type="checkbox"/>				

Shell piles: Y N

Notes:
 Many shell pieces, recent dead, and shell fragments - Heavy Boat traffic through this area.

Non-native species present (Y/N):
 Asian Clams

Survey Site MS1 Transect 1 (in consecutive order) Page 7/8

Surveyor(s): Taft, West, Metonich, Craig, Graham, Bodin, Wilson Date: 21 Oct 2018
 Enbridge Oil Spill Mussel Shell Survey - Mussel Survey Data

Habitat Information

Coordinates at downriver boundary: N 42 26 30 S W 084.9571 W upstream boundary N 42 26 28.4 W W 084.95668

Survey Site Area Measurements

Dimensions	Est. length (m)	Draw shape (label sides and flow direction)
Side 1	<u>7m</u>	
Side 2	<u>19m</u>	
Side 3	<u>7m</u>	
Side 4 (opt)	<u>19m</u>	
Depth (1/10 meter)		

Proportion of substrate covered by shells

Coverage (check one)					
>1%	1 to 5%	6 to 25%	26 to 50 %	51 - 75%	>75%

Shell piles: y/n

Notes:
Reference Area

Non-native species present (Y/N):
Asian Clams

19m x 7m

Sampling Segment: MS-1 Trinet 1		Page 8/8					
Field Recorder: Motouch		Date: Dec 2010					
Shell and Mussel Observations (cont'd)							
		Shell Condition (check one)					Notes/observations
Species (G. species)	Live Mussel (check)	Fresh	Recent dead	Mod. worn (1)	Heavily worn Mod (2)	Crushed shells (3)	
fluted shell							
Pocket bank	1						crushed shell
Spike							crushed shell
Webster pigtoe							crushed shell
Strong Feather							
Ranbow							
Elk toe							crushed shell
fat Mucket							
Eclipse							

Heavy mud and algae on all shells found

Field Recorder: Matousek Date: ^{10/25/10} ~~10/26/10~~ 10/25/10 Page 1/1
 Enbridge Oil Spill Mussel Shell Survey Field Datasheet

Location Information

Sampling Segment: MJ-5
 Site Description/Landmarks/Access/Other Notes:
Keweenaw + Fondak intersection Boat launch at Riverside
Riverside

GPS Coordinates (decimal degrees to 5 decimal places)

Start location	End location
Latitude: <u>N42.30768</u>	Latitude: <u>N42.30119</u>
Longitude: <u>W085.18924</u>	Longitude: <u>W085.18023</u>
Start Time: <u>10:00</u>	End Time: <u>12:30</u>
Weather Conditions: <u>~60° Partly Cloudy</u>	
Air Temperature: <u>~60°</u>	

Personnel Present

Name - Affiliation	Name - Affiliation
<u>Matt Weiner - DNRE</u>	
<u>Mike Walkowicz - DNRE</u>	
<u>Bill Taft - DNRE</u>	
<u>Mike Wilson - DNRE</u>	
<u>John Matousek - ENTRIX</u>	
<u>Pete Baska - MNFI</u>	

Photograph Documentation

Camera id/owner:		GPS unit id/owner:	
Photo #	Time	Photographer/Camera	Subject
<u>17³</u>			<u>GPS time date</u>
<u>5</u>			<u>Paper pond shell mod 2</u>
<u>6</u>			<u>White heels plitter mod 2</u>
<u>7</u>			<u>Jipper shell mod 2</u>
<u>8</u>			<u>Webast pigtoe mod 2</u>
<u>9</u>			<u>Meckets - mod 2</u>
<u>10</u>			<u>Fluted shell - mod 2</u>
<u>11</u>			<u>Pocketbook - mod 2</u>
<u>12</u>			<u>Spike - mod 2</u>
<u>13</u>			<u>Elk toe - mod 2</u>
<u>14</u>			<u>Rainbow - mod 2</u>
<u>15</u>			<u>Strange float - mod 2</u>
			<u>Round pigtoe</u>

No transect conducted at MJ-5 due to lack of recent Dead shells, High siltation, and water depth

C. Field Notebooks

MC / Oct. 18 2010 / Marshall Inp. <sup>River
front
park</sup>

- Arrived @ site around 9:00 am
for the group safety meeting
and go over the plan
- started @ bridge approx 1/4 of a
mile from the proposed downstream
end of the sampling segment
(water below bridge was fast and
deep) - also developed
potential permit property
issues if we would have had
to portage
- access river from the apartment parking
lot and worked upstream
- finished with site around 3:30
@ the park
- saw less live mussels than when
conducting the mussel ^{assess} survey

MC / Oct 18 2010 / Marshall, MI

- Site MS-2 Recon
- Boat ramp and decom
areas are closed and posted
as such
- no way to launch or launch there
might be hard to park
there as well
- Directing to community park
- 15 mile Rd ~~to~~ (R) on A Drive North
(R) on River Park Drive
(L) on Squaw Creek Rd
mediata (R) on De Gaulle Rd.
@ Light / Pump pole

MC / Oct 19, 2010 / Marshall MI

- Mussel survey site MS-02
Down Run of 15 Mile Rd Bridge
- good visibility / low turbidity
- some response / clean up work occurring around islands, replacing ~~at~~ about boom
- little boat traffic
- conducted survey for most of sampling segment
- ended @ 2:1 boat ramp
- seemed like there was a lot of siltation around boat ramp
- oil sheen obs. when walking through sediments around boat ramp
- live mussels observed in deeper runs in middle of sampling segment

MC / Oct 20, 2010 / Marshall MI

- Mussel survey site - MS-03
- walked along trail down run to start of sampling segment
- noticed that there were a lot of mussel shells in the same condition between ~~near~~ ^{recent} and moderate at start of segment
- lots of live mussels also obs. at start of survey segment
- turbidity was high throughout most of the day but could still see the bottom for most of the segment.
- obs. shell piles near areas with live mussels, obviously from an animal, live marks on edge of shells

MC / Oct 21 2010 / Waukegan Park MI

- Burst ramp C3 2, sampling site MS-04
- walked down river to start of sampling segment and decided to extend site down river another ~ 100 meters to include a shallow riffle
- cracked shells obs. in and around shallow riffle in areas w/ lighter substrate, lighter substrate looked like it was an artifact of boats bottoming out, actually saw a boat bottom out and pour through the riffle
- live mussels obs. on top of substrate in boat scraped substrate, some like mussels had scratched shells

MC / Oct 21 2010 / Site MS-04

- lots of boat traffic - almost to the point where it was unsafe to be in river, had to move out of the channel when we heard the boating.
- ~~high~~ high turbidity throughout the day especially when the boats would go by
- large shallow area just down river of boat much had a lot of crushed mussel shells, scratched live mussels and displaced live mussels
- up river of boat ramp there was lots of silt on substrate, ended survey just up river of boat ramp

10/18/10

Mussel shell survey @ Riverfront park
MNEI, ENTRIX, Stratus, DNRE

participating in survey at 9:30 start time
Safety paperwork completed for
ENTRIX and Enbridge

Walked downstream to put in @
17 mile bridge to walk upstream
to begin survey.

Asian Clams seen

Little mussel list between (17 mile start)

		Shell	Live
Picket book			
Picket book	III	✓	1 ✓
Wabash pig toe	III	✓	
Eastern pond mussel	1	✓	
fluted shell			1 ✓
Spite		✓	✓
Rainbow		✓	
Elk toe		✓	
Cylindrical paper shell		✓	
Slipper shell		✓	
Elyse			✓
Giant floater		✓	
Strong floater		✓	
Creek tree spliter		✓	✓

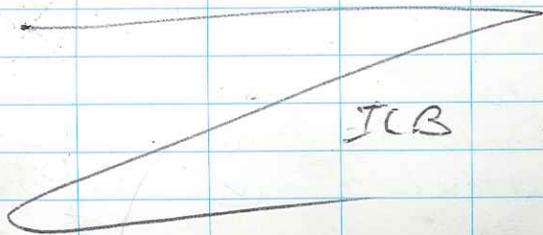
Stop for lunch 12:40
 Return to river @ 1:40 pm
 Same crew from morning, put back
 into river at same spot as took
 out. 5 people using seines or clear
 bottom buckets. J. Matowick taking
 notes and photos. A few deeper spots
 avoided due to depth of water.
 No more than 20 m of complete river avoided
 Left or right bank necessary to avoid due
 to water depth throughout entire reach.

	Live	Shell
Mucket		✓
Round pigtoe		✓

Pocketbook observed displaying lure

Gills with larvae.

Crew worked up to small island
 just downstream of impoundment
 End time 15:33



19 Oct 2010

Mussel Shell survey
 Location MS
 ENTREX, DNRE, MNFI, status
 participating in survey
 MS-02 str

N 42 25 925 W 085.01009

Species List

	Live	Shell
String Feather		✓
Rainbow		✓
Asian Clam		✓
Spike	✓	✓
Pocketbook	✓	✓
Creek heelsplitter	✓	✓
Elk toe		✓
Fluted Shell		✓
Walash pigtoe	✓	✓
Round pigtoe (?)		✓
Flippe		✓
White heel splitter	✓	✓
Mucket		✓
Slipper Shell		✓
Tat Mucket	✓	✓
(cylindrical) paper shell		✓

"Rite in the Rain"

Some recent dead found near 3 mi marker. Some crushed shell as well but difficult to determine how old crushed top shells are. Looks like old shell that maybe got stepped on by clearing crew - may have broken due to older condition of shell.

A single recent dead Rainbow found at waypt. Recent rainbow
N 42.25968 W 085.00858

A single recent dead pocketbook found at waypt. Recent pocket
N 42.25954 W 085.00601
-photo taken

A single spike found at waypt. Recent spike
N 42.25940 W 085.00508 (Mile post 2.75)
-photo taken
-at same point, broken shell pocketbook found - photo taken

-another pocketbook w/ broken shell collected here - photo taken

-another recent dead spike here photo taken

A recent dead pocketbook w/ broken shell found at waypt. Recent pocketbook
N 42.25848 W 085.00513
-photo taken

Stopped for lunch break @ 13:40
Returned to River @ 14:40

Crew worked upstream from park searching for recent/fresh dead shells upstream travel fairly quick, scanning for shells

Deposit of recent dead shells found. Decision made that likely due to animal feeding and deposit of shells photo taken next to log that shells are near. Confirmed sighting of a mink by landowner - next to the shell deposit area.

Fresh dead pocketbook found at waypt. FRESH POCKET
N 42.25790 W 085.00304
no damage evident to shell
fish contained in shell pic taken

"Return to the River"

20 Oct 2010

MS-3

DNRE, (Status) MNFI, ENTRIX on
Crew. Parked at 1/2 mile road bridge
traveled downstream to begin survey
Decided to add category to the
moderately worn designation
moderate 1 moderate 2

- | | |
|--|--|
| • hinge intact | • hinge intact or not intact |
| • mat not covering lower portion | • mat can be covering entire shell |
| • light algae on on inside of shell | • heavy algae or sedimentation on inside |

Will be noted during a delineated section survey and on photos

Species List

	Live	Shell
Mucket	✓	✓
Elle toe		⊙
Spike		✓
White heel splitter	✓	✓
Wabarin pig toe	✓	✓
fluted shell		⊙
Strange floater		⊙

Some broken shells found at
Broken shells (w/ w/pt.)

N 42.25825 W 085.00249
fluted shell, spike, + Rainbow
pig. taken

Several live pocketbooks found
in this area

Scattered broken shells in this
area likely due to high foot/boat
traffic in this area. Concentrated
to shallow riffle areas
live mucket seen near bank

w/pt "Broken spikes"

N 42.22579 W 085.00167
pic taken just downstream of
mile marker 2.5

A few recent dead shells and cracked
shells found along site, but agreed
that many fewer than expected
were seen

Stopped survey @ boat launch at
1/2 mile road crossing

N 42.25864 W 084.99898

Recent dead pocketbook found at w/pt.

"Recent peak" N 42.25866 W 084.99890

Recent dead spike found at w/pt "Re spike"

N 42.25895 W 084.99899

"Rite in the Rain"

No Show

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21 Oct 2010

09:30

Start Point at boat launch at
3-2 @ N42-29296 W085-12425
Walked downstream to area below
mile marker 10.25 to riffle observed
to have shell available. Start
point of survey @ "MS4 STRT"
N 42-29591 W 085-12777

Species List

Live

Shell

Mudflat
Strange Hoater
~~Mudflat~~ Elk toe
Slipper shell
Aspen Clam
Spike
Wabash pigtoe
Pocketbook
White heel splitter
Plated shell
Cylindrical paper shell

✓

✓

✓

✓

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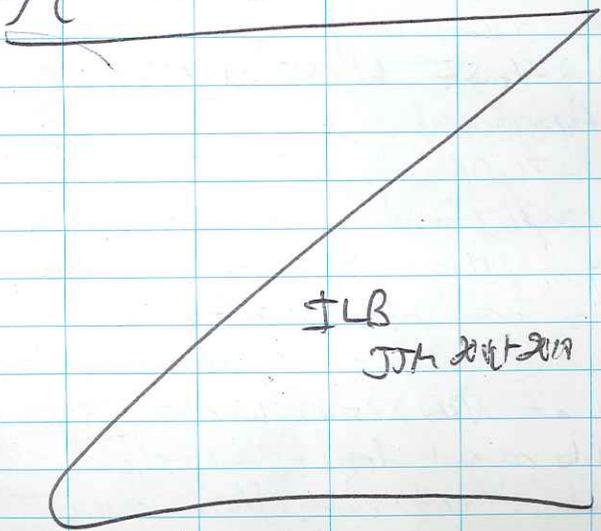
✓

✓

✓

sediment they were topped in. These
shells were likely uncovered by boat
traffic and wave action. Photo taken
No damage to shells evident, look to
be in good condition but were
buried in sediment. River visibility
much less than earlier mainly due
to turbidity increase.

Significant amount of live mussels
noted below bridge @ 11 mile
crossing @ N42-27443 W085-08154
Oil sheen noticed when walking
through soft sediment. Completed
Survey @ 11 mile bridge 16:30



SLB

JUN 2011 2010

Some recent and broken shells
 in riffle at N42.29581 W085.12732
 Started transect 1 @ MS4 TRNSTRT
 N42.29.591 W085.12740 (bittern)
 Area closer due to observation of
 recent dead shells and cracked shells at
 riffle location

MS4 TRNEND N42.29600 W085.12704
 19m x 10m transect

Some broken shells @ N42.29608 W085.12664

Recent dead found @ N42.29617 W085.12585
 Mucket, wabaw & pigtoe, found in a
 limited area ~ 2-3m²

Slipair still heavy cover @
 N42.29624 W085.1248
 Some moderate (1) / recent & dead
 found at

N42.29573 W085.12447
 Mucket (2), wabaw & pigtoe
 Also some broken shells observed
 Significant amount of live shells

at N42.29464 W085.12544
 from this pt. to the boat launch
 several recent dead, cracked, broken
 shell & pieces observed, more than through
 the rest of the reach

MS-4 transect 2 started just
 downstream of boat launch @ mile
 marker 10.0

Stop for lunch @ 12:30 returned
 to River @ 1:50

Completed count of transect 2
 mussels collected.

Good population of live mussels
 observed directly across from boat
 launch @ N42.29373 W085.12421
 Some animal shell deposits observed
 upstream of boat launch

Significant amount of turbidity due to
 boat traffic.

Decision made to survey up to mile
 marker 9.75 and terminate survey
 due to turbidity & reduced visibility
 Also high boat traffic a safety concern

Left MS-4 @ 15:15 to travel
 to reference area to complete a
 transect there

MS-1 Transect 1 completed @
 N42.26385 W084.95710 (start)
 N42.26284 W084.95660 (end)

End time ~ 17:00

"Rite in the Rain"

10/25/10 Site MS-5

Intersection of Kenosha & Fork
Boat launch at area we will
be using the MNFI Boat at this
location. ENTRIX, MNFI DNRE
pass + fee for this location. Status
unable to attend.

Launched boat @ 09:30. Traveled
downstream to begin survey just downstream
of Mile marker 15.25. Water too
deep to wade, looked for boat while
travelling upstream. Beams blocking
downstream travel past mile 15.25

Exited boat @ "MS-5 STR" -
N 42.30768 W 085.18924

Water temp 56°F

Species	Live	Shell
Paper pondshell		✓
White heelsplitter		✓
Snappershell		✓
Mucket	⊙	✓
Spike	⊙	✓
Water penny	⊙	✓
fluted shell		✓
Pocketbook		✓

Heavy fast siltation. Difficult to
see shells, likely buried in slower areas
Animal midden found at
N 42.30603 W 085.18854

Continued Species	Live	Shell
Elktoe		✓
Rainbow		✓
Stargazer		✓
Asian Clam		✓
Roundpigtoe		✓

Traveled by boat and walking through
lower 1/2 of reach. Several deep
areas that had to be avoided due
to water depth and limited visibility
Some air boat traffic causing some
turbidity issues

Large Animal deposit found all
around area N 42.30583 W 085.18172
Almost all Mucket with a few
water penny and spike. Most are
Moderately worn (2) with one average
mod. (1)

End of transect is at mile marker
14.05 @ N42.30119 W085.18023
Water became very turbid at
12:00 visibility very poor.

No recent dead shells found to
trigger conducting a transect. Also
deep water and siltation a factor
limiting success of a survey.

End time 12:30