Status of Native Freshwater Mussels, Including the Northern Riffleshell (*Epioblasma torulosa rangiana*) and Rayed Bean (*Villosa fabalis*), in Detroit River, Michigan.

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Background photo: Detroit River looking west from Stony Island. Photo by Brandon Armstrong. **Inset photos, left:** Female northern riffleshell (*Epioblasma torulosa rangiana*) valve from site SC3 in Lake St. Clair near Windmill Point, **right:** Male northern riffleshell valve from site SC5 in Lake St. Clair near Windmill Point. Photos by Peter Badra.

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Contents

Introduction 1
Methods 1
Results 2
Discussion 5
Acknowledgments 14
Literature Cited 15

Tables

Table 1. Latitude and longitude of sites surveyed in Lake St. Clair (2008) and Detroit River (2007). 3
Table 2. Mussel species found during surveys. 7
Table 3. Percent composition of each substrate size class estimated visually within transect at each site. 11
Table 4. Habitat and water chemistry measures for each site. 12
Table 5. Categories of shell wear. 13

Figures

Figure 1. Northern riffleshell (*Epioblasma torulosa rangiana*) valves from Windmill Point, Lake St. Clair. 4
Figure 2. Northern riffleshell (*Epioblasma torulosa rangiana*, male) valve from Windmill Point, Lake St. Clair 5
Figure 3. Shells of the state endangered fawnsfoot (*Truncilla donaciformis*), snuffbox (*Epioblasma triquetra*), three-horn wartyback (*Obliquaria reflexa*), from Windmill Point, Lake St. Clair.. 5
Figure 4. Shell of a state endangered black sandshell (*Ligumia recta*, female) from Windmill Point, Lake St. Clair. 6
Figure 5. Shell of a state threatened purple wartyback (*Cyclonaias tuberculata*) from Windmill Point, Lake St. Clair. . . .6
Figure 6. Shells of pocketbook (*Lampsilis ventricosa*), fat mucket (*Lampsilis siliquoidea*), and pink heelsplitter (*Potamilus alatus*) with zebra mussels (*Dreissena polymorpha*) attached, from Lake St. Clair. 10
Figure 7. Armored shoreline and chaotic wave action of Lake St. Clair near Windmill Point. 14

Introduction

This survey is part of a larger effort by Michigan Natural Features Inventory (MNFI) to ascertain an updated status of native mussels (Unionidae) in the Detroit River, and selected areas of Lake Erie and Lake St. Clair. Historically these water bodies have supported some the most species-rich unionid communities in Michigan, including globally significant populations of rare species (MNFI biotics database 2009). Of particular interest is the northern riffleshell (*Epioblasma torulosa rangiana*), a federally listed endangered species, and rayed bean (*Villosa fabalis*), a federal candidate species. MNFI performed surveys for unionid mussels at 21 sites in the Detroit River in the summer of 2007, and 10 sites in Lake St. Clair in the summer of 2008. This project adds to the 36 sites MNFI surveyed in the Detroit River International Wildlife Refuge in 2006 (Badra 2006a, Badra 2006b).

Unionid communities in these systems have experienced severe declines over the past 20+ years (Freitag 1984, van der Schalie 1986, Kovalak and Brusate 1990, Schloesser and Kovalak 1997, Schloesser *et al.* 1998, Sweet 1998). One of the main causes of this decline is the impact of the non-native zebra mussel (*Dreissena polymorpha*), which was introduced in the late 1980's, and the more recent introduction of the quagga mussel (*Dreissena bugensis*). Dreissenid mussels have had severe negative impacts on northern riffleshell in the Detroit River (Trdan and Hoeh 1993, Schloesser *et al.* 2006). The decline of the northern riffleshell over its range is cited in its USFWS Recovery Plan to be due to siltation, impoundment, in-stream sand and gravel mining, and pollutants. Recovery objectives for the northern riffleshell include maintaining and restoring viable populations in 10 separate drainages. The Detroit River is one of eight drainages that have been identified as necessary for achieving recovery (U.S. Fish and Wildlife Service 1994).

The northern riffleshell has not been found alive in the Detroit River since 1990 (MNFI biotics database 2009), however MNFI found several empty valves in 2005 and 2006, indicating the potential continued presence of this rare species in the Detroit River or adjacent waterbodies. For this project we focused our survey effort on Belle Isle, Stony Island, and Windmill Point in Lake St. Clair. There are eleven historic records of rare unionids at or near Belle Isle, including northern riffleshell and rayed bean. Stony Island is known to have supported northern riffleshell; snuffbox (*Epioblasma triquetra*) and round hickorynut (*Obovaria subrotunda*), both state listed endangered species; and wavy-rayed lampmussel (*Lampsilis fasciola*), and purple wartyback (*Cyclonaias tuberculata*), both state threatened species. Occurrence records for these species from the University of Michigan Museum of Zoology, are very dated (*ca.* 1930) and recent surveys of Stony Island are lacking. Historic records for northern riffleshell are also known for the southwest end of Lake St. Clair at Windmill Point.

The global range of northern riffleshell once included seven states and one Canadian province. It is now considered "critically imperiled" (S1) in five states and one province (including Michigan), "imperiled" in one state, and is not ranked/under review in the remaining state (NatureServe 2009). In addition to the Detroit River and Lake St. Clair, the northern riffleshell's historic range in Michigan includes the Black River (Sanilac and St. Clair Co.), River Raisin, Huron River, and Clinton River watersheds. This species has not been found in the Clinton River since 1935, the Huron River since 1931, and the River Raisin watershed since 1977 (MNFI biotics database 2009, University of Michigan Museum of Zoology 2009). A survey of the River Raisin watershed by Kopplin (2002) did not reveal any live northern riffleshell or shells. Portions of the Black River watershed were dredged and channelized in the late 1980's, before northern riffleshell was federally listed as endangered. A number of individuals (118) were relocated to the Detroit River, before the establishment of zebra mussels, to remove them from the area impacted by dredging. These survived for three years until zebra mussels invaded the area and colonized the unionids. The global range of rayed bean included eleven states and one Canandian province. It is now considered "presumed extirpated" (SX) in three states, "possibly extirpated" (SH) in one state, and "critically imperiled" (S1) throughout the rest of its range, including Michigan (NatureServe 2009).

Methods

Surveys were performed to determine the presence/absence, relative abundance, and status of native freshwater mussel species. The presence/absence of dreissenid mussels (*Dreissena polymorpha* and *Dreissena bugensis*), and Asian clams (*Corbicula fluminea*) was recorded. The colonization rate and intensity of dreissenid mussel colonization on unionids was determined when live unionids were found. Several habitat parameters were measured including water clarity, depth, dissolved oxygen, pH, conductivity, alkalinity, hardness, and temperature. A qualitative assessment of habitat suitability for the northern riffleshell, rayed bean, and other mussels was made.

Mussel survey methods follow a protocol developed by MNFI over the past several years for both deep and shallow river reaches. Generally, sites that are greater than approximately 70cm deep require SCUBA. Sites that are in less than 70cm of water were surveyed by wading with glass bottom buckets, although SCUBA was used at times at shallow sites when water clarity was very low. Areas for survey were targeted primarily by the presence of past occurrences of northern riffleshell. Sites were accessed by boat. Mussel habitat and signs of mussel beds, such as empty shells were identified from the boat or from shore and used as an aid for selecting survey sites within the identified areas. Handheld GPS units (Garmin 12XL) and topographic maps were used to document the position of survey sites. Latitude and longitude of each site were recorded.

The field crew for SCUBA sites consisted of two divers and a third person who records data, assists divers with gear, and tends the boat while divers are in the water. Once signs of a mussel bed are identified, the boat is anchored and transects are set. In some cases, sites are surveyed without prior evidence of shell or live individuals other than apparently suitable habitat or historic occurrence records. Transects are typically delineated using 10m lengths of 2.54cm nylon webbing with 4.5kg anchors tied to each end; however, due to very low mussel densities found in the survey area a single 40m transect was used. This setup also allows divers to be in closer proximity with each other and communicate easier at sites with very low visibility. When higher densities are found, shorter transects allow divers to return to the boat to process mussels found more frequently. A buoy was tied to one or both anchors to mark the endpoints of each transect. Divers on either side of the transect each searched a 1.6m wide, by 40m long area, passing the hands over and through the substrate to a depth of approximately 5cm. Total area searched at each site is 128m^2. Divers started searching the transect at the same time, moving in an upstream direction. Searching in an upstream direction minimizes a decrease in visibility due to disturbance of fine sediments. At sites where the current is very fast, transects were searched in the downstream direction.

Mussels buried up to approximately 5cm below the substrate surface are detected. At sites with low underwater visibility, mussels were located primarily by feel as divers pass their hands through the substrate adjacent to the transect lines. Relatively clear water makes visual detection of mussels possible in addition to locating by hand. Live unionids are placed in mesh bags, brought to the surface, and identified after completing each transect. Length measurements of all individuals were taken. The presence/absence of dreissenid mussels was recorded, and the number of dreissenid mussels attached to each live unionid was determined. The presence of shell or live Asian clams was recorded when detected. Empty unionid shell found during transect searches was either identified underwater or brought to the surface for identification. After processing, live unionids were planted back in the substrate, anterior end down, along transect lines in approximately the same density as they were found. The boat and outboard motor are either dried overnight or washed with a bleach solution to prevent the transportation of live dreissenid mussels between boat launch sites.

Substrate within each transect was characterized by estimating the percent composition by volume of each of the following six particle size classes (diameter); boulder (>256mm), cobble (256-64mm), pebble (64-16mm), gravel (16-2mm), sand (2-0.0625mm), silt/clay (<0.0625) (Hynes 1970). Water clarity was measured with a transparency tube. This devise is a 1.2m tall clear plastic tube, open at the top and closed at the bottom with a black and white pattern similar to a Secchi disk. The tube is filled with water then drained using a valve until the Secchi pattern becomes visible through the top of the water column. The height of the water in the tube was then recorded. Woody debris and aquatic vegetation were noted when observed within the transect. Dissolved oxygen and temperature were recorded with a YSI Model 55 handheld meter. Conductivity and pH were recorded with an Oakton handheld meter. Alkalinity was measured with a LaMotte kit (model DR-A) and hardness was measured with a Hach kit.

To maximize diver safety three factors in particular were addressed; water quality, current, and visibility. Bacteria counts in Lower Michigan rivers are often high enough that contact with river water should be avoided. Sediments in river substrates can also contain potentially hazardous substances. Reports of discharges into the river are monitored to avoid diving downstream from points of discharge for at least a week after an event. Drysuits with dry-hoods and full facemasks are used to minimize contact with river water and sediments. Traditional face masks were used in Lake St. Clair. Current speeds at some sites make it necessary for divers to wear a heavier weight belt than usual. Transect lines not only delineate the area to be searched, but are also used as a hand line to help divers stabilize themselves in the current. Broken glass, scrap metal, zebra and quagga mussel shell, and other sharp debris are frequently encountered during tactile searches. Neoprene gloves (3mm) with kevlar reinforcement are worn to minimize the chance of injury. Underwater visibility in the Detroit River and Lake St. Clair can vary from a few cm to greater than 3m. Transect lines are used to keep divers oriented to sampling areas during surveys.

Results

Twenty-one sites were surveyed in the Detroit River in the summer of 2007, including twelve at Belle Isle, eight at Stony Island, and one at Fox Island. Ten sites were surveyed in Lake St. Clair in the summer of 2008 (Table 1). In addition, a qualitative search was made of the shoreline

Table 1. Latitude and longitude of sites surveyed in Lake St. Clair (2008) and Detroit River (2007).

Site #	Waterbody	Area	Latitude	Longitude
SC1	Lake St. Clair	N.E. of Windmill Point	42.36088	-82.92361
SC2	Lake St. Clair	N.E. of Windmill Point	42.37120	-82.91944
SC3	Lake St. Clair	N.E. of Windmill Point	42.36506	-82.92193
SC4	Lake St. Clair	N.E. of Windmill Point	42.36594	-82.91651
SC5	Lake St. Clair	N.E. of Windmill Point	42.36758	-82.92074
SC6	Lake St. Clair	N.E. of Windmill Point	42.36011	-82.92525
SC7	Lake St. Clair	N.E. of Windmill Point	42.36248	-82.92345
SC8	Lake St. Clair	N.E. of Windmill Point	42.36782	-82.92155
SC9	Lake St. Clair	N.E. of Windmill Point	42.37264	-82.91770
SC10	Lake St. Clair	N.E. of Windmill Point	42.37509	-82.91604
4	Detroit River	Belle Isle	42.33968	-82.96219
5	Detroit River	Belle Isle	42.33912	-82.96642
6	Detroit River	Belle Isle	42.34202	-82.98661
14	Detroit River	Belle Isle	42.33924	-82.96386
15	Detroit River	Belle Isle	42.33908	-82.96717
16	Detroit River	Belle Isle	42.33827	-82.97044
17	Detroit River	Belle Isle	42.33907	-82.97283
18	Detroit River	Belle Isle	42.33449	-83.00374
19	Detroit River	Belle Isle	42.33749	-83.00051
20	Detroit River	Belle Isle	42.34114	-82.95886
21	Detroit River	Belle Isle	42.34065	-82.95930
22	Detroit River	Belle Isle	42.34258	-82.98459
23	Detroit River	Belle Isle	42.34285	-82.98333
1	Detroit River	Stony Island	42.12385	-83.13072
2	Detroit River	Stony Island	42.12499	-82.13413
3	Detroit River	Stony Island	42.12797	-83.13546
25	Detroit River	Stony Island	42.12217	-83.13357
26	Detroit River	Stony Island	42.12260	-83.13489
27	Detroit River	Stony Island	42.12430	-83.13679
28	Detroit River	Stony Island	42.12906	-83.13415
29	Detroit River	Stony Island	42.12684	-83.13665
30	Detroit River	Fox Island	42.10534	-83.14149

at site 5 on Belle Isle. SCUBA was used at all sites except two at Belle Isle (sites 4 and 6), and three at Stony Island (sites 1-3), where glass bottom buckets were used. A total of 23 unionid species were found, all represented by empty shell except for one live mucket (*Actinonaias ligamentina*) at site SC7, by Windmill Point in Lake St. Clair. Empty shells of northern riffleshell were found at six sites at Windmill Point (SC3, SC5-9) and one site at Belle Isle (21) (Figures 1 and 2). Two riffleshell valves were recognizable as being from males, and one from a female. No live individuals or empty shells of rayed bean were found. Shells of the state endangered snuffbox (*Epioblasma triquetra*), eastern pondmussel (*Ligumia nasuta*), black sandshell (*Ligumia recta*), three-horn wartyback (*Obliquaria reflexa*), hickorynut (*Obovaria olivaria*), and round hickorynut (*Obovaria subrotunda*) were found, as well as the state threatened purple wartyback (*Cyclonaias tuberculata*) and fawnsfoot (*Truncilla donaciformis*), and species of special concern kidney-shell (*Ptychobranchus fasciolaris*) and deertoe (*Truncilla truncata*) (Figures 3-5) (Table 2).

Live zebra and quagga mussels (*Dreissena polymorpha* and *Dreissena bugensis*) were observed at all of the sites at Windmill Point and were present in very high numbers. The number of live zebra mussels at Belle Isle varied from just a few found within the transect, to thousands. Live zebra mussels were found at only two of the eight

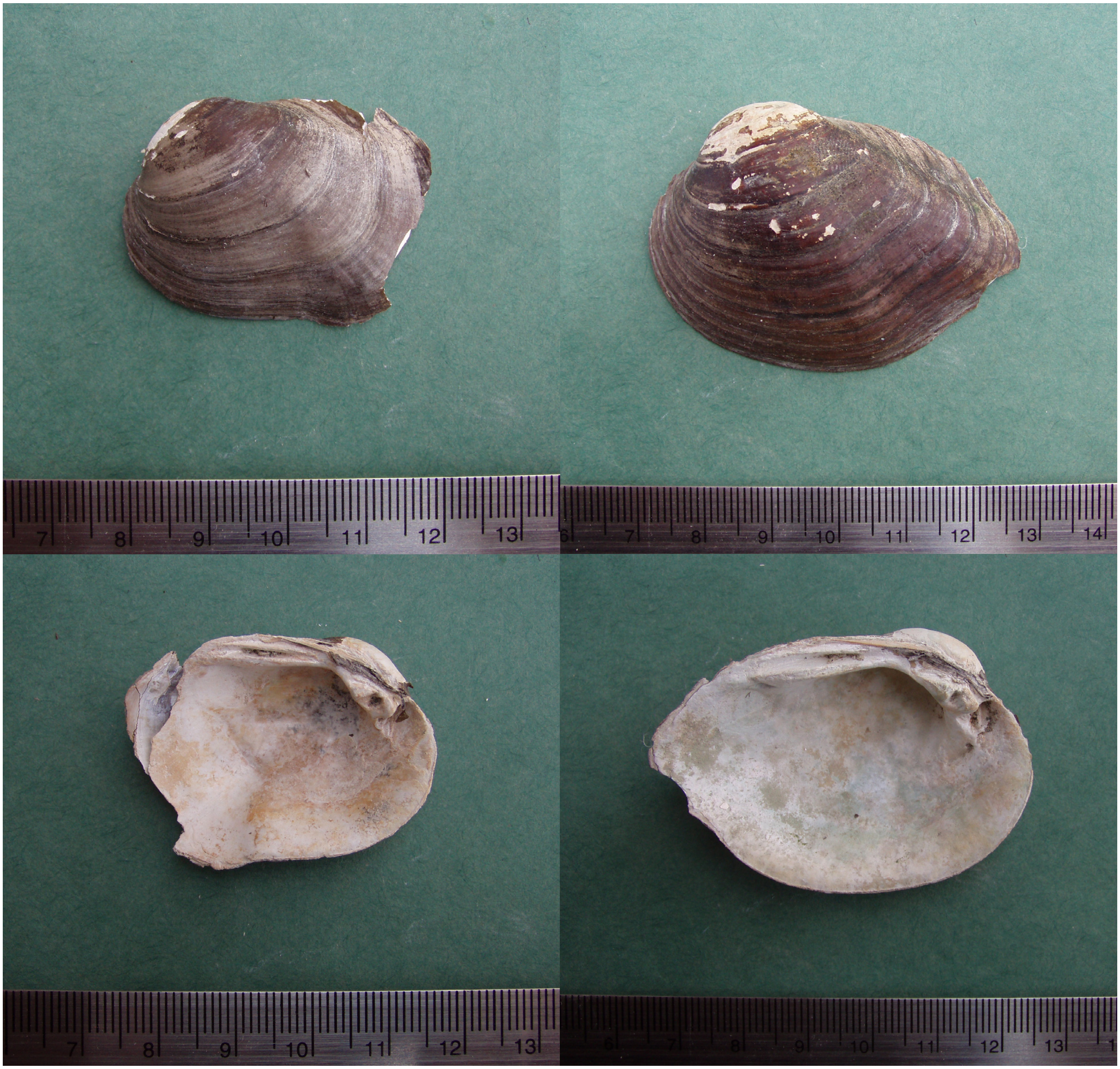

Figure 1. Northern riffleshell (*Epioblasma torulosa rangiana*) valves from Windmill Point, Lake St. Clair. Shell on the left is from a female and on the right is from a male. Scale is in centimeters. Photos by Peter Badra.

Figure 2. Northern riffleshell (*Epioblasma torulosa rangiana*, male) valve from Windmill Point, Lake St. Clair. Approximately actual size. Photo by April Wright.

Figure 3. Shells of the state endangered fawnsfoot (*Truncilla donaciformis*, top left), snuffbox (*Epioblasma triquetra*, bottom left and bottom right, both male), three-horn wartyback (*Obliquaria reflexa*, top right), from Windmill Point, Lake St. Clair. Scale is in centimeters. Photo by Peter Badra.

sites at Stony Island, and none were detected at the Fox Island site. Most unionid shells had empty dreissenid shells still attached with bysal threads (Figure 6). The one live unionid found had no zebra or quagga mussels attached.

Round gobies (*Neogobius melanostomus*) were very common at the Windmill Point sites. Tubenose gobies (*Proterorhinus marmoratus*) were also noted at sites SC3 and SC7 in Lake St. Clair. Crayfish (*Decapoda*), smallmouth bass (*Micropterus dolomieu*), and madtom (*Noturus* sp.) were also frequently encountered at the Windmill Point sites. A young mudpuppy (*Necturus maculosus*) was observed at Site 3 at Stony Island. This species is the primary host for the state endangered salamander mussel (*Simpsonaias ambigua*) (Howard 1951).

Substrate composition at eight of the ten sites near Windmill Point, six of the eight sites at Stony Island, and the one site at Fox Island appeared suitable for northern riffleshell. They had significant components of sand and gravel along with other substrate size classes. The other two sites at Windmill Point lacked a gravel component, and the other two Stony Island sites had a very high proportion of silt. Substrate at the Belle Isle sites had a larger component of sand and silt than Windmill Point and Stony Island. Silt was the dominant size class at five of these sites. Substrate at two Belle Isle sites appeared suitable for northern riffleshell (19 and 21) (Table 3).

Water clarity ranged from 68cm to greater than 120cm and seemed to vary based on wind conditions. Aquatic vegetation was present at most sites, whereas woody debris was entirely absent. Conductivity was consistently low at all sites. Water quality measures are given in Table 4. Measurements were not taken at four of the sites due to their close proximity to the previous sample site.

Discussion

Survey effort in 2008 was focused on Windmill Point due to the relatively large number of species represented by shells found at the first survey sites there, and the lack of unionid shell and live individuals found in the Detroit River in 2006 and 2007. The fact that the only live unionid mussel found was at Windmill Point also led us to believe that it would be more likely to find live riffleshell in this area than the Detroit River.

All of the sites where empty northern riffleshell valves were discovered had substrate compositions that appeared suitable for the species, i.e. significant components of sand and gravel along with smaller components of other substrate size classes. Silt was the dominant size class at 12 of the 31 sites surveyed, and the co-dominant size class at 11 of the 31 sites. Substrate at the Belle Isle sites

Figure 4. Shell of a state endangered black sandshell (*Ligumia recta*, female) from Windmill Point, Lake St. Clair. Scale is in centimeters. Photo by Peter Badra.

Figure 5. Shell of a state threatened purple wartyback (*Cyclonaias tuberculata*) from Windmill Point, Lake St. Clair. This shell is unusual in that it lacks bumps, or “warts”, on the outer surface of the shell typical of purple wartyback. Scale is in centimeters. Photos by Peter Badra.

Table 2. Mussel species found during surveys. Numbers of empty shells are reported unless otherwise noted. Area searched at each site was 128m^2 except at site 5 Belle Isle, where a qualitative search of the shoreline was made. (S=shells found-number of shells not reported, m=male, f=female)

		Lake St. Clair, N.E. of Windmill Point									
Species	Common Name	SC1	SC2	SC3	SC4	SC5	SC6	SC7	SC8	SC9	SC10
Actinonaias ligamentina	Mucket		3	7		9	18	12(+1 live)	9	13	1
Amblema plicata	Threeridge	1					1	1	1		
Cyclonaias tuberculata	Purple wartyback, T		3	2		5		2	1		
Elliptio dilatata	Spike	8	24	10	10	38	16	29		14	2
Epioblasma triquetra	Snuffbox, E		1f			2	1f	2m	2, 1m	1, 1f, 2m	2f, 1m
Epioblasma torulosa rangiana	Northern riffleshell, fed E			1f		1	4, 1m	2	1, 1m	5	
Fusconaia flava	Wabash pigtoe						1	4	2	1	1
Lampsilis siliquoidea	Fatmucket		9	3		5	7	11	15	18	6
Lampsilis ventricosa	Pocketbook	5	13	13	2	13	9	20	22	28	9
Lasmigona costata	Fluted shell		5	1		4	3	3	3	2	1
Leptodea fragilis	Fragile papershell	1	1			1	3	1	1		1
Ligumia nasuta	Eastern pondmussel, E			1							
Ligumia recta	Black sandshell, E	1m, 1f	7	4	2	7	6	4	18	4	1
Obliquaria reflexa	Three-horn wartyback, E	3	2	4	1	5	5	11	2	7	1
Obovaria olivaria	Hickorynut, E					1					
Obovaria subrotunda	Round hickorynut, E				2	1					
Pleurobema sintoxia	Round pigtoe, SC						3	1		2	
Potamilus alatus	Pink heelsplitter	3	23	20	1	36	21	27	35	60	23
Ptychobranchus fasciolaris	Kidneyshell, SC	1	10	10	2	37	5	45	44	21	6
Quadrula quadrula	Mapleleaf						1				
Truncilla donaciformis	Fawnsfoot, T	3	2	5	7	44	19	19	34	65	28
Truncilla truncata	Deertoe, SC	8	8	9	6	20	53	64	32	45	9
Villosa iris	Rainbow										
# species live								1			
# species live or shell		10	14	14	9	17	18	18	16	15	14
Corbicula fluminea	Asian clam										
Dreissena bugensis	quagga mussel	L	L	L	L	L	L	L	L	L	L
Dreissena polymorpha	zebra mussel	L	L	L	L	L	L	L	L	L	L

Table 2. (cont.)

Species	Belle Isle												
	4	5	6	14	15	16	17	18	19	20	21	22	23
Actinonaias ligamentina	S		S										
Amblema plicata											S		
Cyclonaias tuberculata													
Elliptio dilatata		S								S	S	S	
Epioblasma triquetra													
Epioblasma torulosa rangiana											1		
Fusconaia flava	S									S			
Lampsilis siliquoidea	S	S	S									S	S
Lampsilis ventricosa													
Lasmigona costata													
Leptodea fragilis													
Ligumia nasuta		S											S
Ligumia recta													
Obliquaria reflexa													
Obovaria olivaria													
Obovaria subrotunda													
Pleurobema sintoxia													
Potamilus alatus												S	
Ptychobranchus fasciolaris	S												
Quadrula quadrula													
Truncilla donaciformis													
Truncilla truncata													
Villosa iris		S											S
# species live													
# species live or shell	4	4	2							2	3	3	3
Corbicula fluminea													
Dreissena bugensis	S												L
Dreissena polymorpha	S	S	L	L	L	L	L		L	L	L	L	L

Table 2. (cont.)

	Stony Island								Fox Island
Species	1	2	3	25	26	27	28	29	30
Actinonaias ligamentina									
Amblema plicata									
Cyclonaias tuberculata									
Elliptio dilatata						S*	S	S	S*
Epioblasma triquetra									
Epioblasma torulosa rangiana									
Fusconaia flava									
Lampsilis siliquoidea									
Lampsilis ventricosa									
Lasmigona costata									
Leptodea fragilis									
Ligumia nasuta									
Ligumia recta									
Obliquaria reflexa									
Obovaria olivaria									
Obovaria subrotunda									
Pleurobema sintoxia									
Potamilus alatus									
Ptychobranchus fasciolaris									
Quadrula quadrula									
Truncilla donaciformis									
Truncilla truncata			S						
Villosa iris									
# species live									
# species live or shell			1			1	1	1	1
Corbicula fluminea									
Dreissena bugensis									
Dreissena polymorpha	S	S	L				S	L	

*shells found outside transect

Figure 6. Shells of pocketbook (*Lampsilis ventricosa*, top left), fat mucket (*Lampsilis siliquoidea*, bottom left), and pink heelsplitter (*Potamilus alatus*, right) with zebra mussels (*Dreissena polymorpha*) attached, from Windmill Point, Lake St. Clair. Scale is in centimeters. Photo by Peter Badra.

was less suited for northern riffleshell than expected, considering that this area used to support relatively high numbers of the species. There may have been an increase in the silt component over the past few decades due to land use practices within the watershed. Alternatively, riffleshell may have been tolerant of these levels of silt.

In addition to northern riffleshell, empty shells representing eight state listed unionid species were documented in this survey. (Michigan's list of threatened and endangered species was updated and made effective April 9, 2009.) Shells of the following three species were found in relatively high numbers at all the Windmill Point sites. Three-horn wartyback (*Obliquaria reflexa*) has declined throughout its range and has recently been listed as state endangered in Michigan. It has been found live at only two locations (Huron River) in recent years, and has possibly been extirpated from the Raisin River watershed, a large portion of its former range in the state. Black sandshell (*Ligumia recta*) is now state endangered. This species is found very infrequently in Michigan, and when it is present it tends to be in very low numbers of older individuals only. Black sandshell has also possibly been extirpated from the Raisin River watershed, a significant portion of its range in Michigan. The Menominee watershed in the Upper Peninsula may be the last stronghold for this species in Michigan. Fawnsfoot (*Truncilla donaciformis*) is now state threatened. No live individuals have been found in several years of surveys within its former range. Shells of the state threatened purple wartyback (*Cyclonaias tuberculata*), and state endangered snuffbox (*Epioblasma triquetra*), eastern pondmussel (*Ligumia nasuta*), hickorynut (*Obovaria olivaria*), and round hickorynut (*Obovaria subrotunda*) were found less frequently and in lower numbers but still represent significant occurrences. Only historic occurrences of hickorynut (*Obovaria olivaria*) are recorded for Lower Michigan. The only river in Michigan known to still support live hickorynut is the Menominee River (MNFI biotics database 2009, NatureServe 2009, UMMZ 2009).

The length of time since mortality is difficult to estimate with empty shells. There is a clear progression of shell deterioration from the time of death to complete disintegration, but the rate at which this occurs varies widely depending on a number of factors. Shells are predominately made of calcium carbonate ($CaCO_3$) and organic material such as the periostracum, a covering on the outside of the shell made of protein, and the hinge ligament. Wear occurs through mechanical means from

Table 3. Percent composition of each substrate size class estimated visually within transect at each site.

Site #	Area	Boulder	Cobble	Pebble	Gravel	Sand	Silt
SC1	N.E. of Windmill Point		15	15		35	35
SC2	N.E. of Windmill Point		10	10		40	40
SC3	N.E. of Windmill Point	2	3	5	30	30	30
SC4	N.E. of Windmill Point	5	10	10	10	33	32
SC5	N.E. of Windmill Point	5	10	15	30	20	20
SC6	N.E. of Windmill Point		5	15	15	15	50
SC7	N.E. of Windmill Point		20	15	15	20	30
SC8	N.E. of Windmill Point	5	10	10	15	30	30
SC9	N.E. of Windmill Point		10	5	15	30	40
SC10	N.E. of Windmill Point		5	5	10	60	20
4	Belle Isle					50	50
6	Belle Isle					50	50
14	Belle Isle					10	90
15	Belle Isle					80	20
16	Belle Isle			5		47	48
17	Belle Isle			30		35	35
18	Belle Isle				5	48	47
19	Belle Isle	15	15	15	15	20	20
20	Belle Isle		2	2		20	76
21	Belle Isle	4	10	10	10	33	33
22	Belle Isle			10		10	80
23	Belle Isle			10		10	80
1	Stony Island	5	15	20	15	20	25
2	Stony Island	5	20	20	10	15	30
3	Stony Island	30	30	20	10	5	5
25	Stony Island						100
26	Stony Island	5	5	5	5	5	75
27	Stony Island	20	20	10	10	20	20
28	Stony Island	40*	20	7	6	7	20
29	Stony Island	30	15	15	20	10	10
30	Fox Island		25	25	15	15	20

* Included 30% bedrock, 10% boulder

Table 4. Habitat and water chemistry measures for each site. Water chemistry measurements were not taken at sites SC2, SC7, SC9, and 26 due to their close proximity to the previous sample site.

Site #	Area	Depth (cm)	Water clarity (cm)	Aquatic vegetation?	Woody debris?	DO (mg/L)	pH	Conductivity (µS)	Alkalinity (mg/l as $CaCO_3$)	Hardness (mg/l as $CaCO_3$)	Water temperature (C)
SC1	N.E. of Windmill Point	180	99	y	n	8.600	8.87	205	100	100	24.2
SC2	N.E. of Windmill Point	150	75	n	n						
SC3	N.E. of Windmill Point	180	103	y	n	8.88	8.88	277	128	140	24.2
SC4	N.E. of Windmill Point	240	85	y	n	8.94	8.86	208	148	140	23.9
SC5	N.E. of Windmill Point	150	140	y	n	8.60	8.80	239	136	140	22.9
SC6	N.E. of Windmill Point	180	107	y	n	9.14	8.89	227	140	140	25.2
SC7	N.E. of Windmill Point	230	100	y	n						
SC8	N.E. of Windmill Point	135	-	y	n	8.78	8.87	249	144	140	25.4
SC9	N.E. of Windmill Point	100	120	n	n						
SC10	N.E. of Windmill Point	90	105	y	n	7.86	8.76	263	144	120	24.5
4	Belle Isle	47	87	n	n	10.65	8.38	240	135	120	18.0
6	Belle Isle	47	121	n	n	11.16	8.43	235	140	120	18.7
14	Belle Isle	113	>120	y	n	10.74	8.74	233	158	140	22.9
15	Belle Isle	63	92	y	n	10.85	8.80	235	138	120	24.2
16	Belle Isle	106	>120	y	n	10.05	8.70	235	140	100	23.5
17	Belle Isle	110	>120	y	n	10.13	8.64	235	136	80	23.1
18	Belle Isle	210	79	y	n	11.14	8.68	234	190	120	23.4
19	Belle Isle	130	68	n	n	10.61	8.64	233	150	120	23.5
20	Belle Isle	108	>120	y	n	10.37	8.61	229	150	60	22.4
21	Belle Isle	115	100	y	n	10.37	8.86	227	145	100	22.6
22	Belle Isle	110	108	y	n	11.03	8.78	225	150	120	22.8
23	Belle Isle	108	105	y	n	10.86	8.76	231	150	120	22.9
1	Stoney Island	70	>120	y	n	13.78	8.84	241	160	120	19.0
2	Stoney Island	45	118	y	n	15.46	9.18	233	140	120	20.0
3	Stoney Island	37	119	y	n	17.74	9.35	219	130	100	19.5
25	Stoney Island	101	70	y	n	12.33	8.90	232	140	120	22.7
26	Stoney Island	80	100	y	n						
27	Stoney Island	70	90	y	n	10.97	8.84	233	130	100	22.5
28	Stoney Island	75	>120	y	n	12.67	8.72	231	135	100	23.5
29	Stoney Island	72	95	y	n	11.04	8.81	233	140	120	22.9
30	Fox Island	120	95	y	n	14.12	9.21	229	150	140	24.6

abrasion with surrounding substrate, and chemically, through dissolution of calcium carbonate into the water. The rate of shell deterioration varies among different water bodies and substrate types. It also varies among species. Small thin shelled species will deteriorate faster than larger thicker shelled species. Differences in decay rates of freshwater bivalve shell relates to water chemistry, current, and size of the shell (Strayer and Malcom 2007).

Categories of shell wear can only provide a rough estimation of time since mortality. Using the scale in Table 5, the northern riffleshell valves found near Windmill Point ranged from moderately worn to heavily worn, and the one from Belle Isle was heavily worn. Given that the water of Lake St. Clair is fairly hard (100-140 mg/liter as $CaCo_3$) and current relatively low, aside from wave action, the length of time since mortality judged by shell condition could be on the order of several years.

The higher abundance of shells found at Windmill Point versus sites in the Detroit River may be attributed to three factors; different rates of shell deterioration, current, and collection of shells. Alkalinity and hardness (mg/liter as CaCo3) were similar between sites near Windmill Point and in the Detroit River, but the difference in current between the river and lake sites likely leads to faster shell deterioration rates in the Detroit River. The current at the river sites may have caused shells to drift downstream away from collection sites. Also, Belle Isle is a much smaller area than Windmill Point, it is accessible without a boat and scuba, and has been more thoroughly searched for shells over the past couple decades. More empty shells may have been collected by researchers and collectors from Belle Isle than Windmill Point.

All but three of the 18 unionid species found in a 1986 survey of Lake St. Clair (Nalepa and Gauvin 1988) were found in this survey. These were wavy-rayed lampmussel (*Lampsilis* fasciola), white heelsplitter (*Lasmigona complanata*), and giant floater (*Pyganodon grandis*). Seven species were found in this survey, which were not found in the 1986 survey, including northern riffleshell. Out of 29 sites sampled in 1986, which were fairly evenly distributed across the lake, the site closest to Windmill Point had the third highest abundance, and the site with the highest abundance was also in the south east corner of Lake St. Clair. The site closest to Windmill Point was approximately 3km from sites in our survey. The substrate at the site was reported to be "silt over gravel". Dissolved oxygen was higher at sites in the Detroit River than in Lake St. Clair. This is a typical difference between rivers and lakes due to the increased mixing of water in rivers. The Lake St. Clair shoreline around Windmill Point is armored by a steel wall. Instead of absorbing wave energy like a typical progressively shallow shoreline, the armoring reflects waves back. These combine with incoming waves to form a chaotic wave pattern and results in chop that is larger than the prevailing wind conditions would otherwise produce (Figure 7). No woody debris was found at any of the sites surveyed. This leads to the question of whether or not historically, before the shorelines and riparian zones of these systems and their tributaries were developed, there was more woody debris present that acted as habitat for fish hosts.

It was not possible to identify the species of madtoms observed while performing scuba surveys. A historic occurrence (1937) for the state listed endangered, northern madtom (*Noturus stigmosus*) and a recent occurrence (1999) for the species of special concern, brindled madtom (*Noturus miurus*) are recorded for Windmill Point (MNFI biotics database 2009). Surveys to determine which species of madtom are present at Windmill Point would provide useful information for the conservation of these species.

Mudpuppy (*Necturus maculosus*) is the primary host for the state endangered salamander mussel (*Simpsonaias ambigua*) (Howard 1951). The substrate at Site 3 near Stony Island was covered with many large flat rocks, a preferred habitat characteristic of both the mussel and mudpuppy. Salamander mussel occurrences at Belle Isle have been recorded over several decades, pre-1930, 1983, and 1998 (MNFI biotics database 2009). The presence of suitable habitat and its primary host make the Stony Island area a relatively high potential to support salamander mussel. Due to the small size and specialized microhabitat of this mussel, additional targeted surveys are recommended in order to get satisfactory detection confidence.

Table 5. Categories of shell wear.

Fresh dead with at least some soft tissue still intact
Fresh dead with no soft tissue, aside from the hinge ligament
Moderately worn - most of periostracum intact, shell with most of its original strength
Heavily worn - periostracum cracked and peeling, shell at least somewhat chalky and fragile
Fragments

A total of nine threatened and endangered unionid species were found, reflecting the significance of these areas to Michigan's aquatic biodiversity. The results of this survey add to the large body of evidence that highlights the importance of taking preventative measures to keep exotic and invasive species from being introduced into the Great Lakes. Once these species are established they are nearly impossible to remove from aquatic systems, and we are left to simply document the ecological and economic impacts they cause.

An empty northern riffleshell valve with some soft tissue still intact was found in the Black River (Sanilac and St. Clair Co.) in 1998, indicating some individuals survived the dredging that took place in the 1980's. A survey of 12 sites in 2003 did not reveal any empty northern riffleshell valves or live individuals, however a live salamander mussel, and shells of rayed bean and wavy-rayed lamp mussel were found (Badra 2004). Due to the abundance of Dreissenid mussels in the Detroit River and Lake St. Clair, the Black River watershed may be the most viable northern riffleshell and salamander mussel habitat left in Michigan. Additional dredging of the Black River watershed would further degrade habitat for this and other unionid species. Dr. G. Thomas Watters at Ohio State University is currently propagating and translocating northern riffleshell in Ohio. Success of translocations depends in part on habitat quality. The future viability of northern riffleshell and other rare unionids in Michigan, and globally, is very questionable unless changes are made in our management of key watersheds.

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Figure 7. Armored shoreline and chaotic wave action of Lake St. Clair near Windmill Point. Photo by April Wright.

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