Unionid Mussel Surveys at Selected Sites in the Pine River and Manistee River - Manistee River Watershed, Michigan

Prepared by:
Peter J. Badra

Michigan Natural Features Inventory
P.O. Box 30444
Lansing, MI 48909-7944

For:
USDA Huron-Manistee National Forest

February 14, 2013

Report Number 2012-10

MICHIGAN STATE UNIVERSITY EXTENSION

Michigan Natural Features Inventory

Photos:
Top-left, A small spike (*Elliptio dilatata,* 4-5 years old) from Site 19 in the Manistee River;
Top-right, Site 14 in the Manistee River where shells of slippershell (*Alasmidonta viridis*) and elktoe (*Alasmidonta marginata*) were found;
Bottom-left, A pocketbook (*Lampsilis ventricosa*) with zebra mussels attached from Site 18 in the Manistee River;
Bottom-right, An overview of sites surveyed in the Pine and Manistee Rivers, Summer 2011.

Photos on cover and in body of report by Sarah Coury, Chris Riley, and Peter Badra.

Citation:
Badra, P. J. 2012. Unionid Mussel Surveys at Selected Sites in the Pine River and Manistee River - Manistee River Watershed, Michigan. Michigan Natural Features Inventory Report No. 2012-10. Report to Huron-Manistee National Forest, USDA Forest Service, Lansing, MI. 19pp.

Acknowledgments

Funding for this survey was provided by the USDA Huron-Manistee National Forest. Thank you to Chris Riley and Rich Corner whose efforts made this work possible. Sarah Coury provided essential assistance with fieldwork and data processing. Nancy Toben, Sue Ridge, and Brian Klatt provided administrative and logistical support.

Purpose

Michigan Natural Features Inventory (MNFI), in cooperation with Huron-Manistee National Forest staff, performed unionid mussel surveys at selected sites in the Pine River and Manistee River during the Summer of 2011. The aim of these surveys was to determine unionid mussel species presence/absence and composition at these sites.

Methods

Locations of survey sites were chosen with guidance from Huron-Manistee National Forest staff. Surveys took place in wadable habitats (less than approx. 70cm depth) and utilized visual and tactile methods of detection. The number of individuals, both live and shells, was determined for each unionid mussel species at each site.

A measured search area was used to standardize sampling effort among sites and allow mussel density estimates to be made. Typically 128m^2 provides a good compromise between the amount of search effort per site and the number of sites to be completed within the scope of the project. The size of this search area is also consistent with a number of mussel surveys in Michigan that have used 128m^2 as a standard search area. The search area was defined by dividing stream width into 128 to get a reach length that would give 128m^2. In some cases more or less area is searched based on amount of suitable habitat. When possible, sites were searched from bank to bank so that the full range of micro habitats was covered and the area equaled the stream width times the reach length.

A combination of visual and tactile means was used to locate live mussels and shells within the search area. Glass bottom buckets were used to facilitate visual searches. At sites where visual detection was difficult (e.g. pebble sized substrate with silt) hands were passed through the substrate throughout the entire search area. Occasional tactile searches through the substrate were made at sites where primarily visual detection was used to help ensure that buried mussels were not overlooked. Live individuals were identified to species and planted back in the substrate anterior end down. Shells were identified to species. The presence/absence of zebra mussels (*Dreissena polymorpha*), and Asian clams (*Corbicula fluminea*) was recorded.

Latitude and longitude of sites were recorded with handheld GPS units. The substrate within each transect was characterized by estimating the percent composition 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). Percent pool/riffle/run habitat within each survey area was estimated visually. The presence of aquatic vegetation and/or woody debris was noted, and a rough estimate of current speed was made for each survey site.

Results

Two species found in this survey were not previously documented in the Manistee Watershed. These are the state threatened slippershell (*Alasmidonta viridis*) and special concern elktoe (*Alasmidonta marginata*). Both species were represented by a single empty shell at Site 14 in the Manistee River.

A total of nineteen sites were surveyed, six in the Pine River and 13 in the Manistee River. A canoe and kayak were used to access sites in the Pine River, and a motor boat was used to access sites in the Manistee River. Locations of sites are given in Table 1 and Figures 1-3. A total of seven species were recorded in the 13 sites surveyed on the Manistee River (Table 2). Spike (*Elliptio dilatata*) was the most frequently encountered and the most abundant species, occurring at five out of 19 sites and a density of up to 3.18 individuals per square meter (at Site 11). Only one shell of one species (fatmucket, *Lampsilis siliquoidea*) was found in the six sites surveyed in the Pine River. No shells or live unionid mussels were seen during the qualitative visual search from Site 6 to Low Bridge in the Pine River.

A meander search consisting of approximately 0.5 person-hours was performed upstream of Site 12 in the Pine River. A qualitative visual search for mussel shells was performed by canoe and kayak from Site 6 downstream to Low Bridge. This was made possible by relatively shallow depth and clear water in this portion of the Pine River, resulting in very good visibility. Due to a combination of high unionid mussel density and large substrate particle size component (cobble and pebble) at Site 11, it took an especially long time to search through the substrate and detect all mussels present. A smaller area was searched at Site 11 because of this (Figures 4 and 5).

Live zebra mussels were found at nine of the 13 Manistee River sites. Zebra mussel shells were present at all 13 survey sites in the Manistee River, and were absent from all six sites in the Pine River. Live unionid mussels were colonized by zebra mussels at Sites 11, 13, 18, and 19. The frequency and intensity of zebra mussel colonization was especially high at Site 18, where all six individuals of native unionid mussels found at the site were colonized with an average of 15.0 zebra mussels per unionid. Colonization at Site 19 was also severe, with 95% of the 151 native mussels found colonized with an average of 9.91

zebra mussels per native mussel (Table 3). Native mussels were cleaned of any attached zebra mussels before placing them back in the substrate. Asian clams were not found at any of the survey sites.

Substrate composition at survey sites in the Pine and Manistee Rivers were generally similar, with a mix of 2-5 size classes per site of cobble, pebble, gravel, sand, and silt (Table 4). Gravel and sand were the most dominant size classes throughout the survey (Figures 6 and 7). In the Manistee River, empty zebra mussel shells were present in the substrate at several sites and actually comprised a substantial component of the substrate at Sites 14, 16, and 17. Surveys were located in runs at all sites except for Sites 2 and 5 in the Pine River where riffles were present. Aquatic vegetation was present at just over half of the survey sites. Woody debris was present at all Pine River sites and over half of the Manistee River sites (Table 5).

Discussion

Slippershell is a headwater species typically found in small streams in the upper reaches of watersheds. The shell found at Site 14 in the Manistee River may have been transported downstream with the river current from a tributary (Figure 8). This site is located less than one mile downstream of Tippy Dam, suggesting the shell came from a very small tributary nearby, or is an anomaly that was established in the main stem of the Manistee. Slippershell reaches a maximum length of about 6cm and maximum lifespan around 10 years (Watters et al. 2009)

Elktoe typically occur in small rivers and large creeks, in riffles and runs. They reach a maximum length of about 11cm and maximum lifespan around 12 years. Elktoe are bradytictic, meaning their larvae (glochidia) overwinter in the marsupial gills of the females (Watters et al 2009). The converse reproductive strategy, tachytictic, is exhibited by species who's fertilization, larval development, and attachment to host all occur within the same calendar year. It is not known whether slippershell is bracytictic or tachytictic.

Known host fish species for slippershell are mottled sculpin (*Cottus bairdi*), banded sculpin (*Cottus carolinae*), and Johnny darter (*Etheostoma nigrum*). Mottled sculpin and Johnny darter are known to occur in the Manistee River, but banded sculpin is not (Rozich 1998). Host suitability studies are generally performed in a laboratory setting with a limited number of fish speices. Species utilized as hosts in natural systems may differ, and/or include species not tested in the lab.

Known host fish species for elktoe are rock bass (*Ambloplites rupestris*), white sucker (*Catostomus commersoni*), northern hogsucker (*Hypentelium nigricans*), warmouth (*Lepomis gulosus*), and shorthead redhorse (*Moxostoma macrolepidotum*). These host species were determined by identifying natural infestations without evidence of metamorphosis, and are questionable (host fish information compiled in Watters et al. 2009). All of these species have been documented in the Manistee River except warmouth (Rozich 1998).

Six of the 13 mussel species now know to occur in the Manistee River were found in this survey (Table 6). Recent surveys and historic records from the University of Michigan Museum of Zoology Mollusk Collection document one state endangered mussel species, one state threatened species, and two species of special concern (Badra 2010). There are many potential reasons why almost no sign of unionid mussels were found in the Pine River, including lack of fish hosts, insufficient fish host density, lack of food resources, unknown past impact, unsuitable water chemistry, etc.. Also, smaller watersheds tend to have fewer mussel species than larger systems (Strayer 1983, Watters 1992). The substrate appeared to be favorable for unionid mussels, with a mix of different particle size classes including sand, gravel, and pebble without excessive amount of silt or solid clay slab. Zebra mussels were absent and stream current was sufficient.

Live zebra mussels co-occurred with slippershell and elktoe shells at Site 14 and are presumably having negative impacts on any live individuals of those species that occur adjacent to the site. The site with the highest abundance and species richness (Site 19) was found to be undergoing severe colonization by zebra mussels (Figure 9). The three sites with the greatest amount of empty zebra mussel shell (Sites 14, 16, and 17) had no live unionid mussels present. This suggests the possibility that zebra mussels may have caused the extirpation of any native unionind mussels that may have occurred at these sites.

Site 18 was visited twice in previous MNFI mussel surveys, which took place in 2002 and 2005 (Figure 10) (Badra and Goforth 2003, Badra 2005). In those surveys, this location was identified as Site M6. Although a statistically rigorous sampling design was not employed, a decrease in native mussel density and species richness is evident in each repeat visit. Native mussel density decreased from 0.20 indvs./m^2 (2002), to 0.07 indvs./m^2 (2005), to 0.02 indvs./m^2 (2011). Number of species found per m^2 area searched decreased from 0.055 spp./m^2 (2002), to 0.023 spp./m^2 (2005), to 0.007 spp./m^2 (2011) (Table 7). Both the frequency and intensity of zebra mussel infestation of native mussels increased from 2002 to 2005. In 2011, the intensity was slightly lower than in 2005 (15.0 zebra mussels per unionid vs. 19.2) but the frequency of

infestation remained 100%, as it was in 2005 (Table 8) (Figure 11).

The state endangered black sandshell (*Ligumia recta*) was found at Site 18 in 2002 but not in 2005 or 2011. The substrate at this site was sand and silt. The only stable, hard surfaces suitable for zebra mussel attachment were native mussels protruding from the bottom. Zebra mussels covered any surface of the native mussels exposed above the stream substrate (Figures 12 and 13). Site 17 was also previously visited in 2005, and was identified as Site M9. Many native mussels at Sites 18 and 19 were covered with so many zebra mussels that they appeared unable to open their shells. Empty shells of strange floater (*Strophitus undulatus*) were found in 2005 at Site 17, along with live zebra mussels. Many of the Zebra mussels are a clear threat to the continued presence of native mussels in the Manistee River

The lack of zebra mussels in the Pine River and abundance of them in the Manistee River is likely due to the relatively high amount of boat traffic and presence of impoundments in the Manistee River. MNFI has performed unionid mussel surveys in most of the major watersheds in Michigan, and documented the presence/absence of zebra mussels at each survey site. One pattern in the distribution of zebra mussels that is clear is their association with large impoundments and lakes commonly used for boating. Zebra mussels tend to be absent from rivers without impoundments (e.g. Belle and Looking Glass Rivers) and present in rivers with large impoundments (e.g. Manistee, Huron, and Muskegon Rivers). This observation matches patterns seen in Wisconsin that impoundments have facilitated the invasion of zebra mussel and other aquatic invasive species (Johnson et al. 2008).

Zebra mussels have free swimming larvae, called veligers. Unlike unionid mussels, which have larvae that attach to host fish, zebra mussels are poorly suited to maintaining populations in flowing river habitat. Free swimming larvae drift downstream with the river current. Unionid mussel larvae (glochidia) are transported to new habitats, including upstream habitats, while they are attached to host fish. Inadvertent transport of zebra mussel larvae (on boats, trailers, live wells, etc.) facilitates the establishment and maintenance of zebra mussel populations. The Pine River is largely zebra mussel free, most likely due to the fact that the Pine see's relatively little boat traffic compared to the main stem of the Manistee, where zebra mussels are plentiful. Similarly, no zebra mussels were found in surveys of the upper portion of the White River Watershed in 2012 (Badra 2012a) or in Pine Creek and Hinton Creek in 2011 (Badra 20012b), though live zebra mussels were found at five out of five sites surveyed in White Lake in 2004 (Badra 2004).

One potential method of reducing the impact of zebra mussels on native mussels is to manually remove them from individuals of high priority native mussel populations. Certain populations of native mussels could be selected based on abundance, species richness, and/or the presence of rare species. Site 19 in the Manistee River could be a good candidate population for such an effort, based on the relatively high abundance of spike, high number of species represented, and heavy infestation from zebra mussels present there. A study of the effectiveness of periodic manual zebra mussel removal from native mussels at Site 19 or other similar sites could help determine whether this method would be feasible for reducing their impact on native mussels in the Manistee River Watershed as a whole.

Minimizing the spread of zebra mussels from the Manistee River, where they are well established, to rivers and lakes that are zebra mussel free is a critical step to conserving native mussels in Michigan. Michigan Sea Grant promotes education on reducing the spread of zebra mussels and other aquatic exotic species through the Clean Boats, Clean Waters program. Posting additional educational material at boat ramps and canoe/kayak access points throughout the watershed could help spread awareness and contribute to the control of zebra mussels.

Recommendations for minimizing the spread of zebra mussels and other aquatic exotic species include:

- Inspecting and removing any visible mud, plants, fish, or other animals before transporting boats, trailers, canoes, kayaks, fishing tackle, and any other gear.
- Draining water from boats, motors, trailers, live wells, etc. before transporting them
- Drying watercraft and equipment for at least five days before using in a different body of water

Table 1. Locations sites surveyed in the Pine River and Manistee River.

Site #	River	Access	Latitude (N)	Longitude (W)
1	Pine River	Canoe - Lincoln Bridge to Elm Flats	44.13450	85.69401
2	"	"	44.14069	85.69521
3	"	"	44.14329	85.70242
4	"	Canoe - Peterson Bridge to Low Bridge	44.20428	85.80787
5	"	"	44.20193	85.81820
6	"	"	44.19892	85.83711
7	Manistee River	Motor boat - Red Bridge	44.30039	85.85435
8	"	"	44.30253	85.84919
9	"	"	44.30763	85.84912
10	"	"	44.31290	85.85559
11	"	Motor boat - Bear Creek ramp	44.29511	86.13416
12	"	Motor boat - Rainbow Bridge	44.28296	86.16966
13	"	"	44.27662	86.19705
14	"	Motor boat - High Bridge	44.26710	85.94554
15	"	"	44.26767	85.95406
16	"	"	44.27171	85.97506
17	"	"	44.26811	85.98030
18	"	"	44.26872	86.00368
19	"	"	44.26762	86.01272

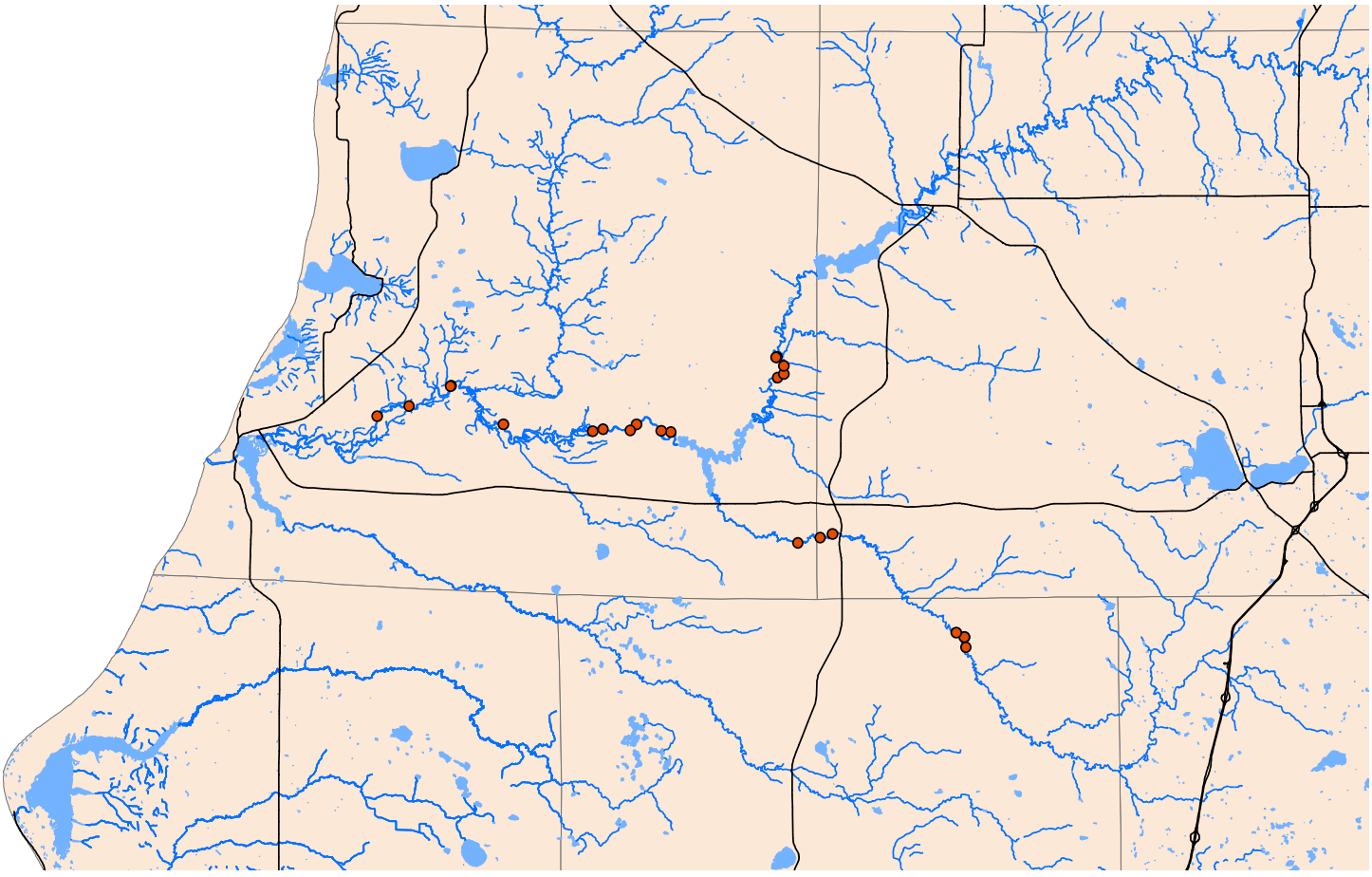

Figure 1. Overview of survey sites in the Manistee River and Pine River.

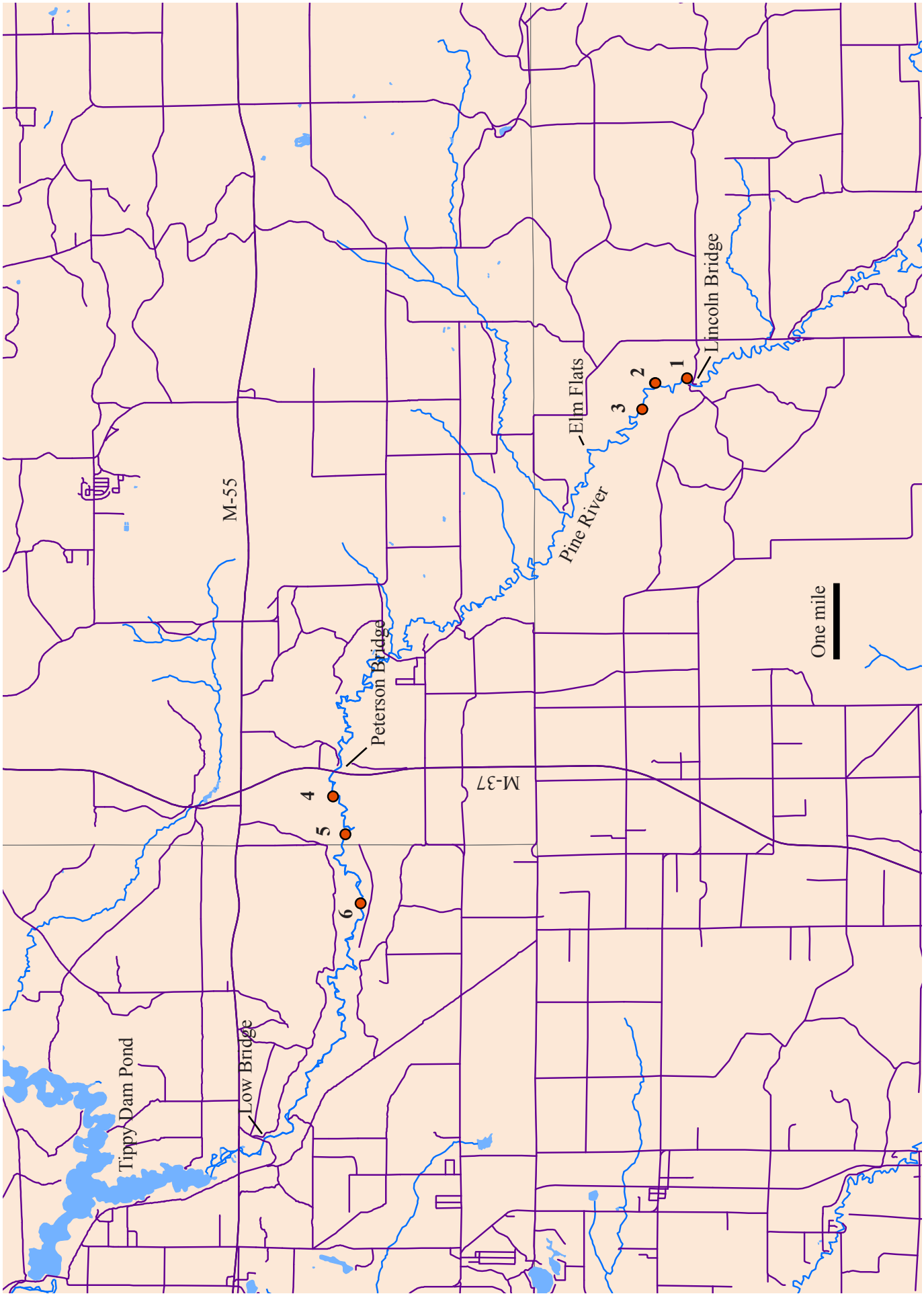

Figure 2. Survey Sites 1-6 in the Pine River.

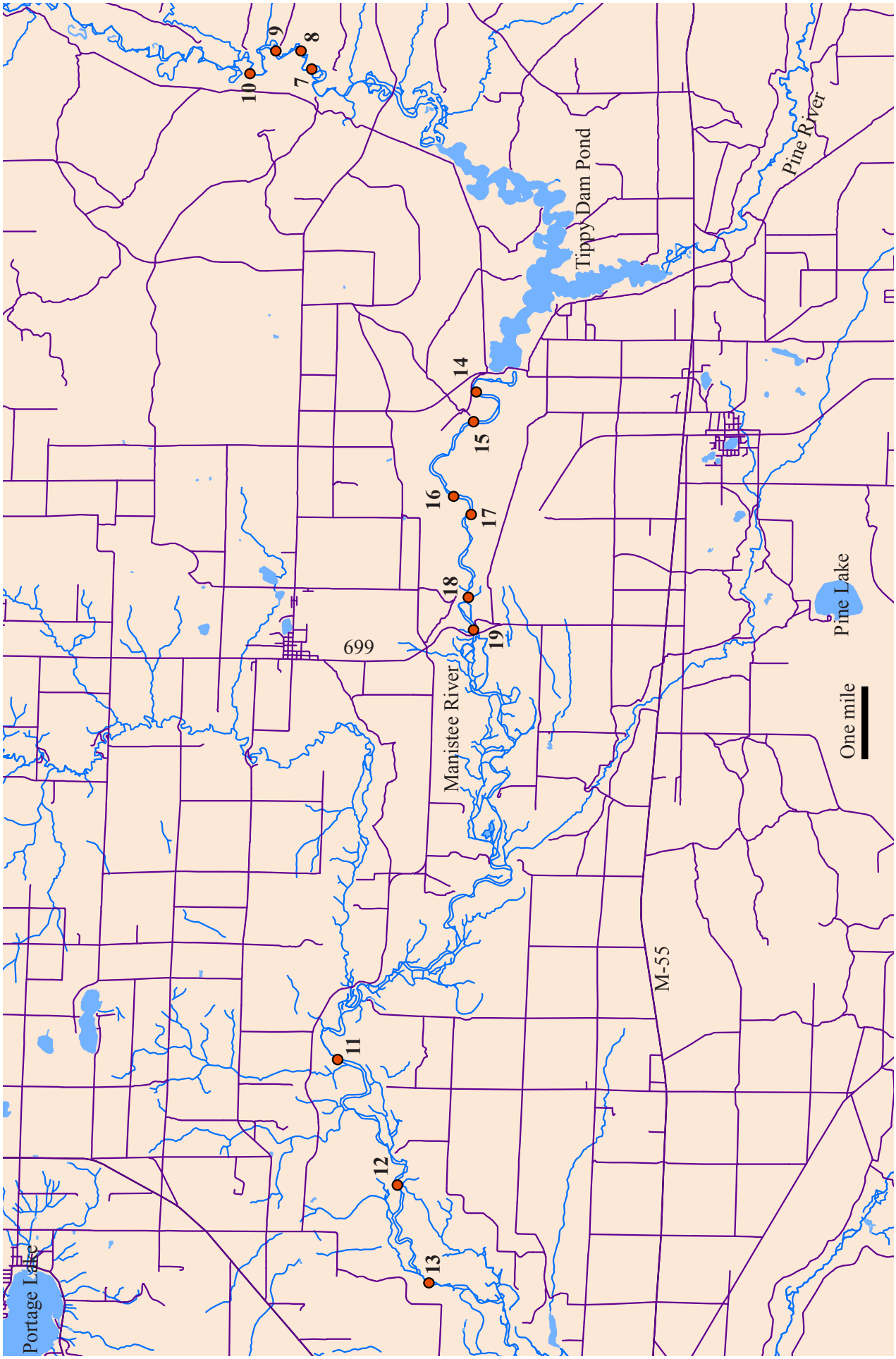

Figure 3. Survey sites 7-19 in the Manistee River.

Table 2. Numbers of unionid mussels (#), relative abundance (RA), and density (D, indvs./m^2) recorded at each survey site in Pine River and Manistee River (Summer 2011). Numbers of unionid shells found are given in parentheses, S(#). Presence/absence of non-native bivalves are given (S=shell only, L=live individuals) (E=endangered; T= threatened; SC=species of special concern)

		Pine River								Manistee River			
		1			2	3	4	5	6	7	8	9	10
Species	Common name	#	RA	D	#	#	#	#	#	#	#	#	#
Alasmidonta marginata (SC)	Elktoe												
Alasmidonta viridis (T)	Slippershell												
Anodontoides ferussacianus	Cylindrical papershell												
Elliptio dilatata	Spike												
Fusconaia flava	Wabash pigtoe												
Lampsilis siliquoidea	Fatmucket	S(1)											
Lampsilis ventricosa	Pocketbook												
Lasmigona complanata	White heelsplitter												
Lasmigona compressa	Creek heelsplitter												
Ligumia recta (E)	Black sandshell												
Pyganodon grandis	Giant floater												
Strophitus undulatus	Strange floater												
Utterbackia imbecillis (SC)	Paper pondshell												
Total # individuals and density		0		0.00	0	0	0	0	0	0	0	0	0
# species live		0			0	0	0	0	0	0	0	0	0
# species live or shell		1			0	0	0	0	0	0	0	0	0
Area searched (m^2)		128			128	128	128	128	128	128	132	132	90
Corbicula fluminea													
Dreissena polymorpha										S	S	S	S

Table 2. cont.

		Manistee River														
		11			12*			13			14			15	16		
Species	Common name	#	RA	D	#	RA	D	#	RA	D	#	RA	D	#	#	RA	D
Alasmidonta marginata (SC)	Elktoe										S(1)						
Alasmidonta viridis (T)	Slippershell										S(1)						
Anodontoides ferussacianus	Cylindrical papershell																
Elliptio dilatata	Spike	87	0.99	3.18	S(1)			6	1.00	0.04							
Fusconaia flava	Wabash pigtoe																
Lampsilis siliquoidea	Fatmucket														S(1)		
Lampsilis ventricosa	Pocketbook	1	0.01	0.04											S(1)		
Lasmigona complanata	White heelsplitter																
Lasmigona compressa	Creek heelsplitter																
Ligumia recta (E)	Black sandshell																
Pyganodon grandis	Giant floater																
Strophitus undulatus	Strange floater																
Utterbackia imbecillis (SC)	Paper pondshell																
Total # individuals and density		88		3.21	0		0.00	6		0.04	0		0.00	0	0		0.00
# species live		2			0			1			0			0	0		
# species live or shell		2			1			1			2			0	2		
Area searched (m^2)		27			128			168			128			128	128		
Corbicula fluminea																	
Dreissena polymorpha		LA			L			LA			L			L	L		

*Spike, pocketbook, strange floater, and cylindrical papershell shells were found outside transect during a qualitative meander search

Table 2. cont.

		Manistee River						
		17	18			19		
Species	Common name	#	#	RA	D	#	RA	D
Alasmidonta marginata (SC)	Elktoe							
Alasmidonta viridis (T)	Slippershell							
Anodontoides ferussacianus	Cylindrical papershell							
Elliptio dilatata	Spike		3	0.50	0.01	146	0.97	1.13
Fusconaia flava	Wabash pigtoe							
Lampsilis siliquoidea	Fatmucket					1	0.01	0.01
Lampsilis ventricosa	Pocketbook		3	0.50	0.01	2	0.01	0.02
Lasmigona complanata	White heelsplitter							
Lasmigona compressa	Creek heelsplitter							
Ligumia recta (E)	Black sandshell							
Pyganodon grandis	Giant floater							
Strophitus undulatus	Strange floater					2	0.01	0.02
Utterbackia imbecillis (SC)	Paper pondshell							
Total # individuals and density		0	6		0.02	151		1.17
# species live		0	2			4		
# species live or shell		0	2			4		
Area searched (m^2)		128	300			129		
Corbicula fluminea								
Dreissena polymorpha		L	LA			LA		

Figure 4. Site 11 in the Manistee River where native mussels were found with zebra mussels attached.

Figure 5. Pebble, gravel, and sand substrate at Site 11, Manistee River.

Table 3. Zebra mussel colonization data, including number of unionid mussels colonized by zebra mussels per site (ucz), mean number of zebra mussels per colonized unionid (zm/u), and the percent of individuals at each site colonized by zebra mussels (%cu).

		11			13			18			19		
Species		ucz	zm/u	%cu	ucz	zm/u	%cu	ucz	zm/u	%cu	ucz	zm/u	%cu
Elliptio dilatata	Spike	42	3.38	48	2	1.00	33	3	25.33	100	140	9.96	96
Lampsilis siliquoidea	Fatmucket										1	19.00	100
Lampsilis ventricosa	Pocketbook	1	2.00	100				3	4.67	100	2	4.00	100
Strophitus undulatus	Strange floater										1	6.00	50
	Total	43	3.35	49	2	1.00	33	6	15.00	100	144	9.91	95

Table 4. Composition of each substrate size class, estimated visually as a percentage within each survey area.

Site #	River	Boulder	Cobble	Pebble	Gravel	Sand	Silt	Other
1	Pine River		5	30	30	35		
2	"		2		5	50	43	
3	"			25	50	25		
4	"		5	15	20	60		
5	"		20	30	20	20	10	
6	"			20	20	50	10	
7	Manistee River			20	35	35	10	zebra mussel shells
8	"			10	45	40	5	zebra mussel shells
9	"			20	35	40	5	zebra mussel shells
10	"			40	40	20		zebra mussel shells
11	"		10	25	25	20	20	
12	"				15	80	5	
13	"			10	30	50	10	
14	"				60	30		10% zebra mussel shells
15	"				80	20		
16	"				50	40		10% zebra mussel shells
17	"				75	20		5% zebra mussel shells
18	"					70	30	
19	"				20	50	30	

Figure 6. Site 1 in the Pine River with substrate dominated by gravel and sand.

Figure 7. Site 12 in the Manistee River with sand dominated substrate.

Table 5. Physical habitat characteristics, including percent pool/riffle/run estimated visually within each survey area.

Site #	River	Current speed*	Aquatic vegetation?	Woody debris?	%Pool	%Riffle	%Run
1	Pine River	med/fast	N	Y	0	0	100
2	"	med/fast	Y	Y	0	25	75
3	"	med/fast	N	Y	0	0	100
4	"	eddy area within med/fast	N	Y	0	0	100
5	"	med/fast	Y	Y	0	100	0
6	"	medium	N	Y	0	0	100
7	Manistee River	fast/med	Y	Y	0	0	100
8	"	med/fast	Y	Y	0	0	100
9	"	medium	Y	Y	0	0	100
10	"	very fast	N	Y	0	0	100
11	"	slow/eddy	Y	Y	0	0	100
12	"	medium	N	N	0	0	100
13	"	medium	N	N	0	0	100
14	"	medium	Y	Y	0	0	100
15	"	med/fast	Y	N	0	0	100
16	"	med/fast	N	N	0	0	100
17	"	med/fast	N	Y	0	0	100
18	"	slow	Y	N	0	0	100
19	"	slow	Y	Y	0	0	100

*slow = approx. 0.2m/second; medium = approx. 1m/second; fast = approx. 2m/second

Figure 8. Site 14 in the Manistee River where shells of slippershell (*Alasmidona viridis*) and elktoe (*Alasmidonta marginata*) were found.

Table 6. Michigan's unionid mussel species. Species documented in the Manistee River Watershed are noted. (E=endangered; T= threatened; SC=species of special concern)

Species	Common Name	Documented in Manistee Watershed	MI Status	Federal Status
Actinonaias ligamentina	Mucket			
Alasmidonta marginata	Elktoe	A	SC	
Alasmidonta viridis	Slippershell	A	T	
Amblema plicata	Threeridge			
Anodontoides ferussacianus	Cylindrical papershell	C		
Cyclonaias tuberculata	Purple wartyback		T	
Elliptio complanata	Eastern elliptio			
Elliptio crassidens	Elephant-ear			
Elliptio dilatata	Spike	ABC		
Epioblasma obliquata perobliqua	White catspaw		E	E
Epioblasma torulosa rangiana	Northern riffleshell		E	E
Epioblasma triquetra	Snuffbox		E	E
Fusconaia flava	Wabash pigtoe	C		
Lampsilis fasciola	Wavy-rayed lampmussel		T	
Lampsilis siliquoidea	Fatmucket	ABC		
Lampsilis ventricosa	Pocketbook	AC		
Lasmigona complanata	White heelsplitter	C		
Lasmigona compressa	Creek heelsplitter	C		
Lasmigona costata	Fluted-shell			
Leptodea fragilis	Fragile papershell			
Leptodea leptodon	Scaleshell		SC	E
Ligumia nasuta	Eastern pondmussel		E	
Ligumia recta	Black sandshell	C	E	
Obliquaria reflexa	Three-horned wartyback		E	
Obovaria olivaria	Hickorynut		E	
Obovaria subrotunda	Round hickorynut		E	
Pleurobema clava	Clubshell		E	E
Pleurobema sintoxia	Round pigtoe		SC	
Potamilus alatus	Pink heelsplitter			
Potamilus ohiensis	Pink papershell		T	
Ptychobranchus fasciolaris	Kidney-shell		SC	
Pyganodon grandis	Giant floater	BC		
Pyganodon lacustris	Lake floater		SC	
Pyganodon subgibbosa	Lake floater		T	
Quadrula pustulosa	Pimpleback			
Quadrula quadrula	Mapleleaf			
Simpsonaias ambigua	Salamander mussel		E	
Strophitus undulatus	Strange floater	AC		
Toxolasma lividus	Purple lilliput		E	
Toxolasma parvus	Lilliput		E	
Truncilla donaciformis	Fawnsfoot		T	
Truncilla truncata	Deertoe		SC	
Utterbackia imbecillis	Paper pondshell	C	SC	
Venustaconcha ellipsiformis	Ellipse		SC	
Villosa fabalis	Rayed bean		E	E
Villosa iris	Rainbow		SC	
Corbicula fluminea	Asian clam		Exotic	Exotic
Dreissena polymorpha	Zebra mussel	ABC	Exotic	Exotic

A= Documented by MNFI in this 2011 survey of Pine River and Manistee River.
B= Documented in a separate 2011 survey of Hinton Creek, Pine Creek, and Pine Lake (Badra 2012a).
C= Records from previous surveys and/or University of Michigan Museum of Zoology Mollusk Collection.

Figure 9. Spike with zebra mussels attached from Site 19 in the Manistee River.

Figure 10. Site 18 in the Manistee River where native mussels were found with zebra mussels attached. This site was previously surveyed in 2002 and 2005. A decline in native mussel density and species richness was seen in each revisit.

Table 7. Native mussel occurrence data for Site 18 during 2002, 2005, and 2011 surveys by MNFI. (Note that over 2 times the amount of area was searched in 2011 than in 2002 and 2005. Comparing density values accounts for the difference in amount of area searched.)

		2002			2005			2011		
Species	Common name	#	RA	D	#	RA	D	#	RA	D
Alasmidonta marginata (SC)	Elktoe									
Alasmidonta viridis (T)	Slippershell									
Anodontoides ferussacianus	Cylindrical papershell									
Elliptio dilatata	Spike	2	0.08	0.02				3	0.50	0.01
Fusconaia flava	Wabash pigtoe									
Lampsilis siliquoidea	Fatmucket	2	0.08	0.02						
Lampsilis ventricosa	Pocketbook	9	0.36	0.07	7	0.78	0.05	3	0.50	0.01
Lasmigona complanata	White heelsplitter				1	0.11	0.01			
Lasmigona compressa	Creek heelsplitter									
Ligumia recta (E)	Black sandshell	3	0.12	0.02						
Pyganodon grandis	Giant floater	1	0.04	0.01						
Strophitus undulatus	Strange floater	7	0.28	0.05	1	0.11	0.01			
Utterbackia imbecillis (SC)	Paper pondshell	1	0.04	0.01						
Total # individuals and density		25		0.20	9		0.07	6		0.02
# species live		7		0.055*	3		0.023*	2		0.007*
# species live or shell		7			3			2		
Area searched (m^2)		128			129			300		
Corbicula fluminea										
Dreissena polymorpha		LA			LA			LA		

* Number of species found per m^2 area searched.

Table 8. Zebra mussel (*Dreissena polymorpha*) colonization intensity (zm/u) and frequency (%cu) for Site 18. (ucz = number of unionid mussels colonized by zebra mussels; zm/u = mean number of zebra mussels attached to each unionid mussel; %cu = percentage of unionids colonized by zebra mussels)

		2002			2005			2011		
Species	Common name	ucz	zm/u	%cu	ucz	zm/u	%cu	ucz	zm/u	%cu
Alasmidonta marginata (SC)	Elktoe									
Alasmidonta viridis (T)	Slippershell									
Anodontoides ferussacianus	Cylindrical papershell									
Elliptio dilatata	Spike							3	25.3	100
Fusconaia flava	Wabash pigtoe									
Lampsilis siliquoidea	Fatmucket	2	5.0	100						
Lampsilis ventricosa	Pocketbook	9	8.6	100	7	22.1	100	3	4.7	100
Lasmigona complanata	White heelsplitter				1	10.0	100			
Lasmigona compressa	Creek heelsplitter									
Ligumia recta (E)	Black sandshell	2	13.5	67						
Pyganodon grandis	Giant floater	1	5.0	100						
Strophitus undulatus	Strange floater	7	6.4	100	1	8.0	100			
Utterbackia imbecillis (SC)	Paper pondshell	1	2.0	50						
	Total	22	7.9	88	9	19.2	100	6	15.0	100

Figure 11. Native mussels at Site 18 with zebra mussels attached. The top-left and bottom two individuals are spike (*Elliptio dilatata*). The center-left, center, and center-right individuals are pocketbook (*Lampsilis ventricosa*).

Figure 12. Photo on left is a clump of zebra mussels attached to a native unionid mussel (pocketbook) partially buried in the stream bottom at Site 18. Photo on the right is the same individual removed from the substrate.

Literature Cited

Badra, P.J. and R.R. Goforth. 2003. Freshwater mussel surveys of Great Lakes tributary rivers in Michigan. Report number MNFI 2003-15. Report to Michigan Dept. of Environmental Quality, Coastal Zone Management Unit. Lansing, MI. 40pp.

Badra, P.J. 2004. Freshwater mussel surveys of Great Lakes tributary river in Michigan. Report number MNFI 2004-22. Report to Michigan Dept. of Environmental Quality, Coastal Zone Management Unit. Lansing, MI. 34pp.

Badra, P.J. 2005. Freshwater mussel surveys of Great Lakes tributary rivers in Michigan. Report number MNFI 2005-13. Report to Michigan Dept. of Environmental Quality, Coastal Management Program. Lansing, MI. 25pp.

Badra, P.J. 2010. Assessment of the status and distribution of native mussels (Unionidae) in Michigian, and results of unionid surveys in the Eastern Upper Peninsula and Huron-Clinton Metroparks. Report number MNFI 2010-11. Report to Michigan Department of Natural Resources and Environment, Water Bureau. Lansing, MI. 71pp.

Badra, P. J. 2012a. Unionid Mussel Surveys at Selected Sites in Osborn Creek, Swinton Creek, and White River - White River Watershed, Michigan. Michigan Natural Features Inventory Report No. 2012-14. Report to Oceana County Road Commission, USFWS, and USDA Forest Service. Lansing, MI. 10pp.

Badra, P.J. 2012b. Unionid Mussel Surveys at Selected Sites in Hinton Creek, Pine Creek, and Pine Lake - Manistee River Watershed, Michigan. Michigan Natural Features Inventory Report No. 2012-09. Report to Huron-Manistee National Forest, USDA Forest Service, Lansing, MI. 13pp.

Hynes, H.B.N. 1970. The Ecology of Running Waters. Liverpool University Press, Liverpool, pg. 24.

Johnson, P.T.J., J.D. Olden, M.J. Vander Zanden. 2008. Dam invaders: impoundments facilitate biological invasions into freshwaters. Frontiers in Ecology and the Environment 6:357-363.

Rozich, T.J. 1998. Manistee River Assessment. Michigan Department of Natural Resources, Fisheries Division, Special Report Number 21. Ann Arbor, Michigan.

Strayer, D. 1983. The effects of surface geology and stream size on freshwater mussel (Bivalvia, Unionidae) distribution in southeastern Michigan, U.S.A. Freshwater Biology 13:253-264.

Watters, G.T. 1992. Unionids, Fishes, and the Species-Area Curve. Journal of Biogeography 19:481-490.

Watters, G.T., M.A. Hoggarth, and C.H. Stansbery. 2009. The Freshwater Mussels of Ohio. The Ohio State University Press, Columbus.