Freshwater Mussel Surveys of Great Lakes Tributary Rivers in Michigan

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Background photo: The Manistee River. Photo by Josh Moffi. **Left inset photo:** Surveying a shallow site in the St. Joseph River. Photo by Josh Moffi. **Right inset photo:** A *Lampilis siliquoidea* (fatmucket) colonized by *Dreissena polymorpha* (zebra mussels). Photo by Kurt Stepnitz. **Photos in body of text:** Figures 1-3 by Josh Moffi; Figures 4-6, 17, and 18 by Pete Badra.

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Introduction

This project is part of an ongoing effort by Michigan Natural Features Inventory (MNFI) to assess Michigan's native freshwater biodiversity and investigate ecological factors affecting aquatic species and communities. Results of freshwater mussel (Unionidae) surveys conducted in 2005 are presented in this report, including the St. Joseph (Lake Michigan drainage), Manistee, Au Sable, and Pinnebog and Pigeon (Huron Co.) Watersheds. Similar surveys have been conducted each year from 2001 to the present (Badra and Goforth 2002, Badra and Goforth 2003, Badra 2004). The goal is to develop a more complete understanding of the status, distribution, and ecology of the Uniondae in Michigan, in order to assist the management of this endangered group and of aquatic ecosystems as a whole. This information is being incorporated into decision making tools (such as the MNFI and NatureServe databases) to assist in the management of aquatic ecosystems and provide information needed to evaluate the State of Michigan and global status and distribution of native freshwater species and communities.

In addition to the mussel surveys reported here, this year 2005 project included the development and production of a freshwater mussels of Michigan poster and brochure. Photographs of the native unionid mussel species that occur in Michigan are presented in the 24 x 36 inch poster. The brochure has text and figures that describe the range of bivalve taxa found in Michigan, the life history of unionid mussels, their ecological role and value, conservation, and how to find them. A limited number of posters and brochures are available by request from MNFI. For a general introduction to unionid mussels and context for this ongoing research effort refer to MNFI report #2004-22 (Badra 2004) or the Mussels of Michigan brochure.

Methods

Methods for this project follow protocols developed by MNFI over the past several years in surveying mussels in both deep and shallow river reaches. Sites that are greater than approximately 70cm deep required SCUBA. Sites that are in less than 70cm of water are surveyed by wading with glass bottom buckets. Sites A5 and A6 in the Au Sable River required the use of SCUBA. All other sites were surveyed by wading with glass bottom buckets. A boat was used to access all sites on the Manistee and Au Sable Rivers, and sites J11, J12, J13, and J14 on the St. Joseph River. Additional qualitative surveys were performed with snorkel gear in the Manistee River starting at site M10 and continuing downstream for approximately 1000 meters. The Fawn River (St. Joseph River Watershed, St. Joseph Co.) was assessed for unionid habitat at four locations between its confluence with the St. Joseph River and the Michigan-Indiana border.

In reaches where a boat and SCUBA were used, the nearest boat ramp to the reach was identified and used as an access point. The use of a jet drive outboard motor made navigating in shallow areas more time-efficient, and mechanical failure was far less likely than with a traditional propeller drive outboard motor (Figure 1). Mussel habitat and signs of mussel beds, such as shells in muskrat middens, were identified from a boat within these reaches and were used as a basis for selecting survey sites. Handheld GPS units (Garmin 12XL) and topographic maps were used to document the position of sites where a boat was used to access the area. Latitude and longitude were recorded at a point in the approximate center of the site.

The field crew typically consisted of two divers and a third person who recorded data, assisted divers with gear, and tended the boat while divers were in the water. Once signs of a mussel bed were identified, the boat was anchored and transects were set. In some cases, sites were surveyed without prior evidence of shell or live individuals other than apparently suitable habitat. Transects were set side by side approximately 3 to 8m apart, parallel to river flow. Transects were delineated using 10m lengths of 2.54cm nylon webbing with 4.5kg anchors fastened to each end. An arms-width (approx. 0.8m) on each side of each transect was searched by passing the hands over and through the substrate to a depth of approximately 5cm of substrate. A buoy was tied to one or both anchors to mark the endpoints of each transect. Divers started working each pair of transects at the same time, moving in an upstream direction. Searching in an upstream direction prevented a decrease in visibility due to disturbance of fine sediments during surveys. Divers searched a total of eight transects at each site (four transects per diver). Subsequent pairs of transects were placed directly upstream from the previous pair. Transects that were in water shallow enough to wade (approx. <70cm) allowed surveyors to kneel on the bottom and perform tactile searches without the use of SCUBA. Glass bottom buckets were also used at these sites to help detect mussels visually (Figure 2). When stream width was less than approximately 6m, the entire width of the stream was surveyed without transect lines for a reach length that would allow an area of at least $128m^2$ to be covered.

Unionids buried up to approximately 5cm below the substrate surface and located within 0.8m on either side of transect lines were detectable. At sites with low underwater visibility, mussels were located primarily by feel as divers passed their hands through the substrate adjacent to the transect lines. Relatively clear water at a few of the sites made visual detection of mussels possible in addition to locating by hand.

Live unionids were placed in mesh bags, brought to the surface, and identified after completing each transect. Length measurements of all individuals were taken (Figure 3). The presence of *D. polymorpha* within transects was recorded, and the number of *D. polymorpha* attached to each live unionid was determined. The presence of shell or live *C. fluminea* was recorded when detected. Empty unionid shell found during transect searches was either identified underwater or brought to the surface for identification. Additional species represented only by empty shell were noted. After processing, live unionids were planted in the substrate, anterior end down, along transect lines in approximately the same density as they were found. Most empty shells were returned to the river. Approximately 50 shells were collected. The boat and outboard motor were either dried overnight or washed with a bleach solution to prevent the transportation of live *D. polymorpha* and other exotics between different river reaches. The 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).

To maximize diver safety three factors had to be addressed; water quality, current, and visibility.

Figure 1. Boat used for accessing large river habitats.

Figure 2. Surveying shallow river habitat.

Figure 3. Taking measurements of unionid mussels in the St. Joseph River.

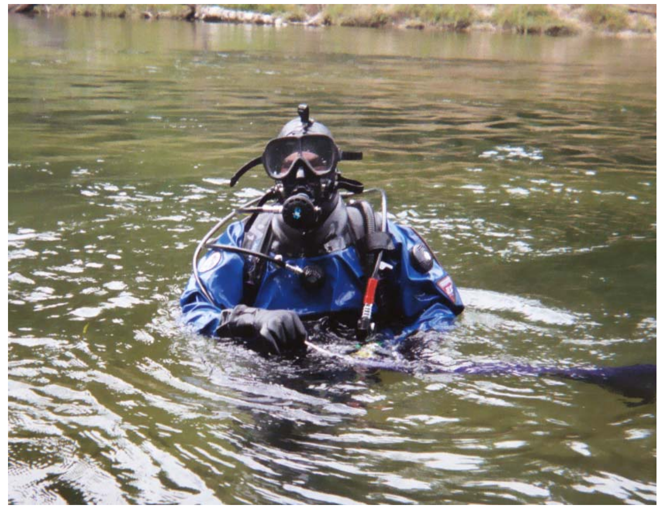

Figure 4. Diver with full facemask and drysuit used during SCUBA surveys.

Figure 5. Diver performing a transect survey for mussels in the Au Sable River.

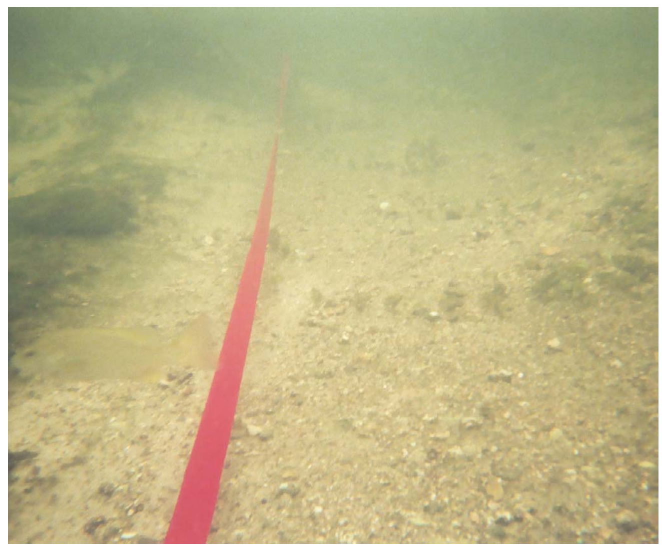

Figure 6. Transect set and ready for survey.

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 were monitored and no diving occurred downstream from points of discharge for at least a week after the event. Drysuits (D.U.I. ™) and full facemasks (Scubapro™) were used to minimize direct contact with river water and sediments (Figure 4). Current speeds at most of the sites made it necessary for divers to wear a much heavier weight belt than usual. Transect lines not only delineated the area to be searched, but were also used as a hand line to help divers stabilize themselves in the current. Broken glass, scrap metal, zebra mussel shell, and other sharp debris was frequently encountered during tactile searches. Neoprene gloves (3mm) with kevlar reinforcement were worn to minimize the chance of injury. Visibility typically ranged from a few cm to greater than 3m in the rivers surveyed. Transect lines were essential for keeping divers oriented to sampling areas during surveys (Figures 5 and 6). The person on the boat also spotted divers to help them avoid hazards.

Results

A total of 25 sites were surveyed in five watersheds in the summer and fall of 2005. Latitude and longitude of survey sites are given in Table 1. Surveys site locations are illustrated in Figures 7-16.

Twenty-one unionid species were found during the surveys (Table 2). Density and relative abundance measures for each species at each site are given in

Table 3. The highest density and species richness measures were recorded in the St. Joseph Watershed at sites J11, J15, and J16. Very low unionid densities were recorded at sites surveyed in the Manistee and Au Sable Rivers. Species richness was also very low for the Manistee River sites. A relatively large number of species were found in four sites surveyed on the Au Sable River (8), but only one (*Elliptio dilatata*) was represented by live individuals. The Pinnebog and Pigeon River sites both had a moderate number of species represented and a low density of live individuals (maximum of 0.18 individuals/meter^2).

A relatively low but consistent density of unionids was observed during the qualitative snorkel survey in the Manistee River. All species found during the snorkel survey were also represented in transect surveys. A large proportion of the substrate was sand that appeared to be unstable. No empty shells were found during brief qualitative surveys of the Fawn River. Substrate at Fawn River sites was almost entirely sand and mud, and the water was very turbid.

Three new occurrences for the state endangered *Epioblasma triquetra* (snuffbox) were documented in the St. Joseph River, east of Mendon, MI (sites J11, J12, and J13). These consisted of empty shells only. New occurrences for several species of special concern were documented, including *Alasmidonta marginata* (elktoe) in the St. Joseph River (J11-J14) and Pigeon River (J15 and J16, St. Joseph Watershed, St. Joseph Co.); *Alasmidonta viridis* (slippershell) in the St. Joseph River (J11-J14), Pigeon River (J16, St. Joseph Watershed, St. Joseph Co.), Rocky River (J19, St. Joseph Watershed, St. Joseph Co.), Au Sable River (A7), Pinnebog River (Pg1, Pg3, and Pg4), and Pigeon River (Pn3, Lake Huron Watershed, Huron Co.); *Cyclonaias tuberculata* (purple wartyback) in the St. Joseph River (J11-J14); *Pleurobema sintoxia* (round pigtoe) in the St. Joseph River (J11-J13) and Rocky River (J19, St. Joseph Watershed, St. Joseph Co.); *Venustaconcha ellipsiformis* (ellipse) in the St. Joseph River (J13 and J14), Pigeon River (J15 and J16, St. Joseph Watershed, St. Joseph Co.), Pinnebog River (Pg3 and Pg4), and Pigeon River (Pn1, Pn3, and Pn4, Lake Huron Watershed, Huron Co.); and *Villosa iris* (rainbow) in the St. Joseph River (J12), Pinnebog River (Pg1, Pg3, and Pg4), and Pigeon River (Pn1, Pn2, and Pn4, Lake Huron Watershed, Huron Co.).

Ligumia recta (black sandshell), a rare species that is currently not listed, was found in the Au Sable River at sites A5 and A6. These occurrences consisted solely of empty shells. Particularly dense populations of *Actinonaias ligamentina* (mucket) were found at sites J11 and J16.

Live *Dreissena polymorpha* (zebra mussel) were found in the St. Joseph, Manistee, and Au Sable Rivers. *Corbicula fluminea* (Asian clam) was found in the St. Joseph Watershed (St. Joseph, Pigeon, Prairie, Swan, and Rocky Rivers), Manistee River, and Au Sable Rivers (Table 4). Live *D. polymorpha* were found attached to unionid mussels in the St. Joseph River at sites J11, J12, and J13, and in the Manistee River at site M6. A very high rate and intensity of *D. polymorpha* colonization was found at M6 (Table 5). The number of *D. polymorpha* per unionid ranged from 7 to 50. A large amount of woody debris was present in the Au Sable River (Figure 17). Though most of the smaller branches and logs appeared to be unstable and gradually moving downstream with the current, some had live *D. polymorpha* attached.

Table 1. Latitude and longitude for survey sites.

Site	Latitude	Longitude
J11	42.00655	-85.42928
J12	42.00893	-85.42228
J13	42.00881	-85.41650
J14	42.00743	-85.41210
J15	41.76996	-85.77342
J16	41.77411	-85.60277
J17	41.90326	-85.59050
J18	41.89759	-85.35985
J19	42.01730	-85.70338
M6	44.26916	-86.00277
M9	44.26815	-85.98015
M10	44.61666	-84.98333
M11	44.76666	-84.85000
A5	44.43252	-83.40400
A6	44.42758	-83.40677
A7	44.75724	-84.76095
A8	44.77890	-84.76197
Pb1	43.88638	-83.12305
Pb2	43.87312	-83.08222
Pb3	43.78624	-83.12063
Pb4	43.77836	-83.10056
Pg1	43.75397	-83.23804
Pg2	43.74931	-83.19965
Pg3	43.73119	-83.14955
Pg4	43.71719	-83.16654

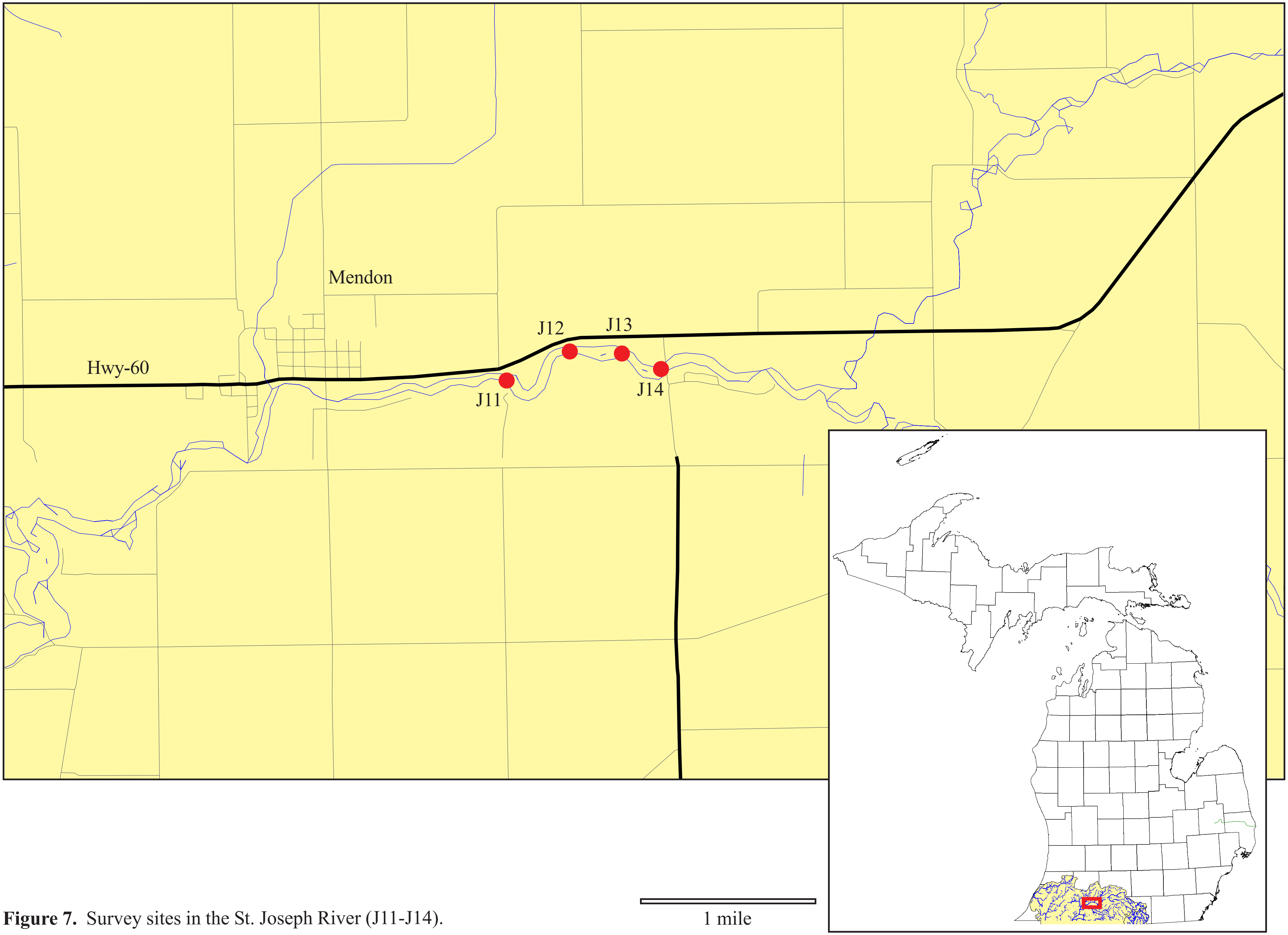

Figure 7. Survey sites in the St. Joseph River (J11-J14).

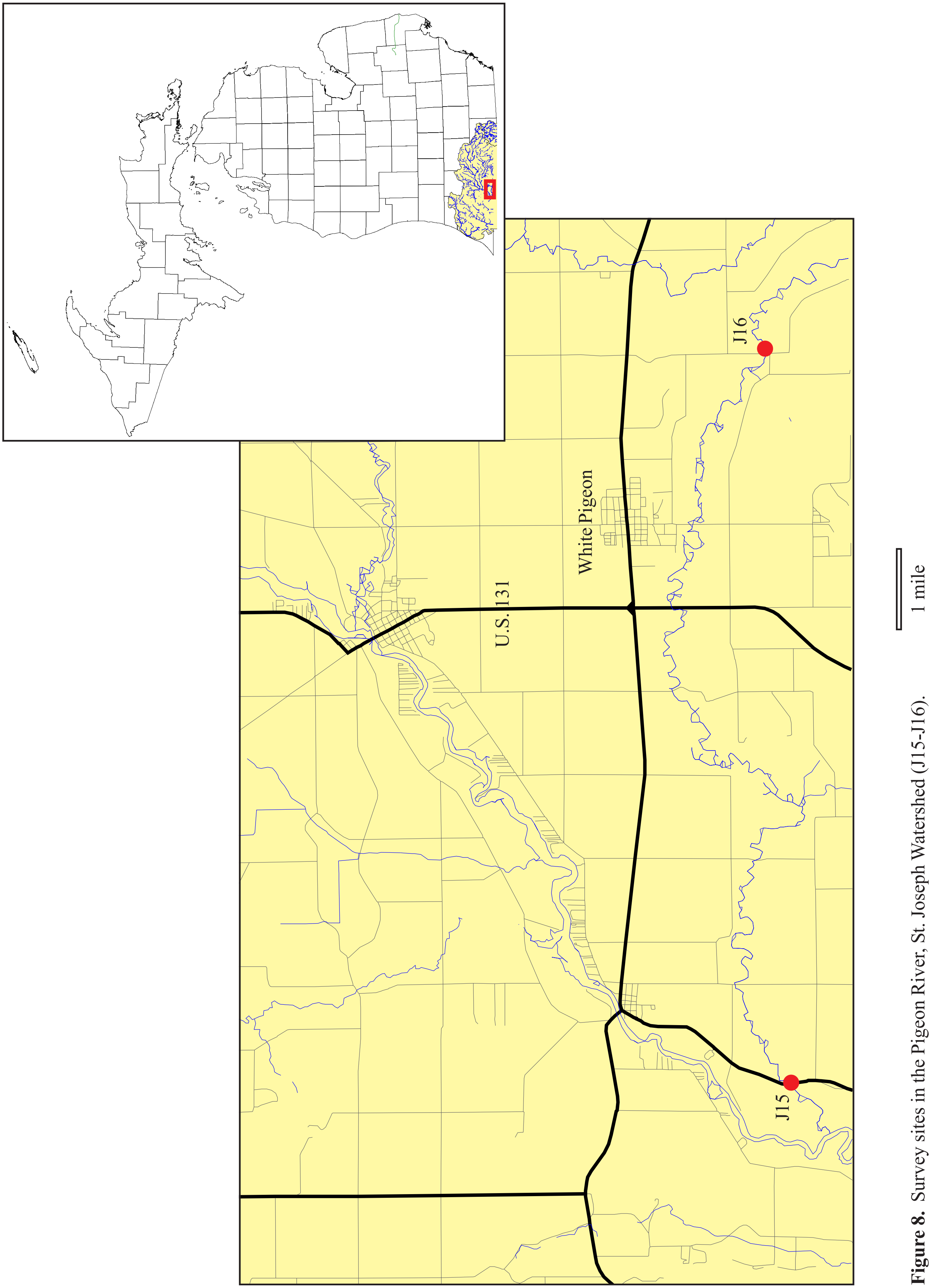

Figure 8. Survey sites in the Pigeon River, St. Joseph Watershed (J15-J16).

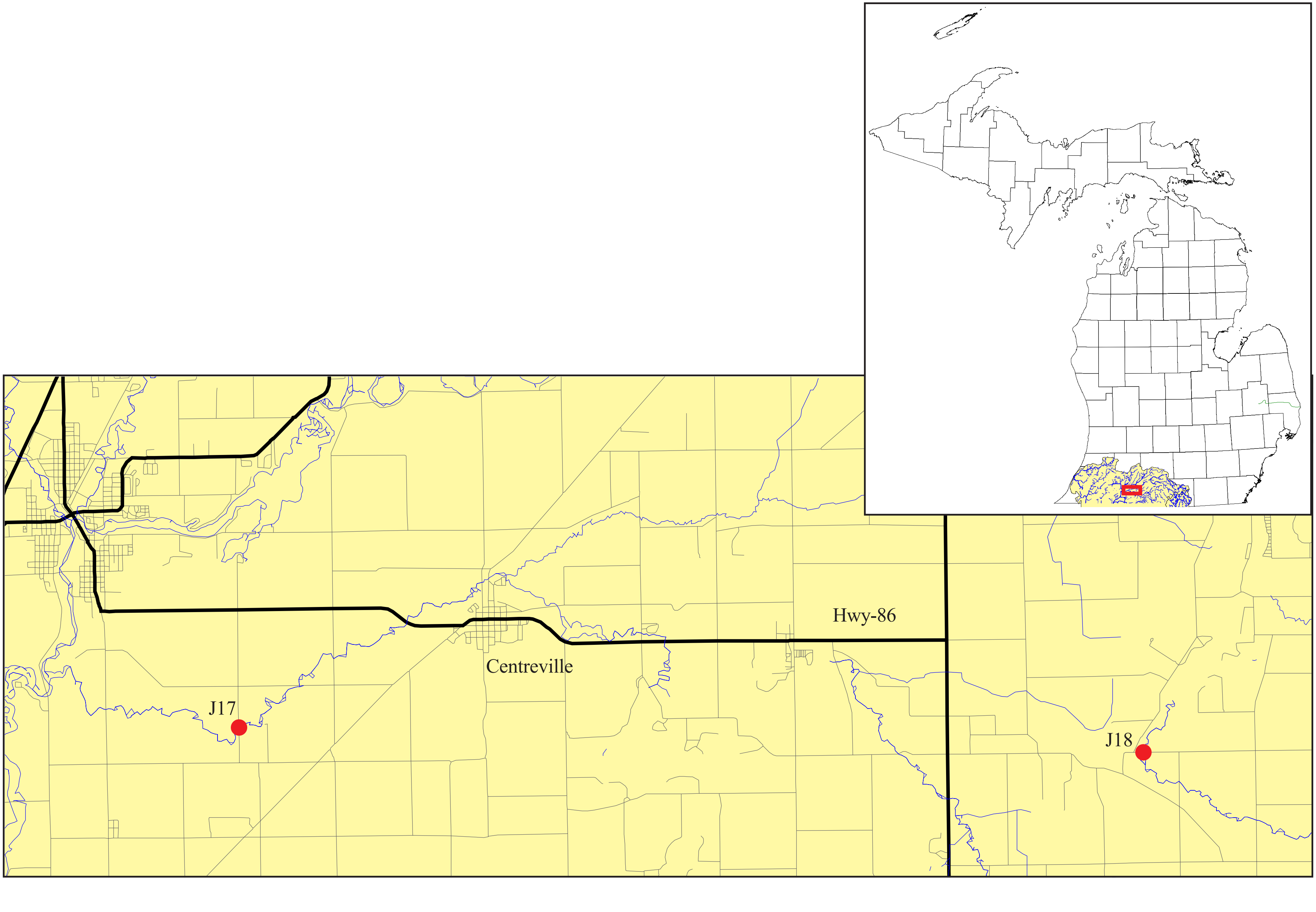

Figure 9. Survey sites in the Prairie (J17) and Swan (J18) Rivers, St. Joseph Watershed.

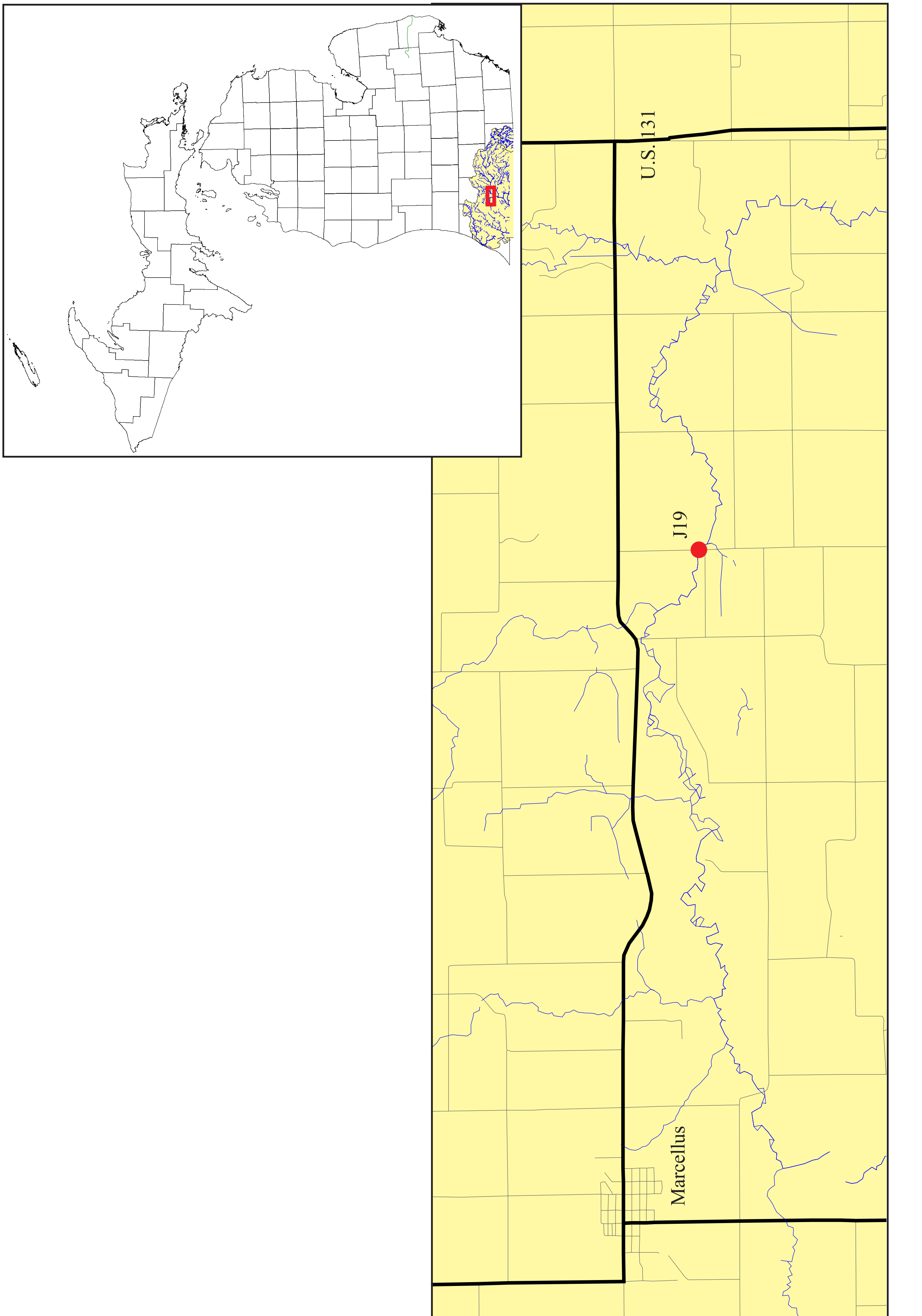

Figure 10. Survey site in the Rocky River, St. Joseph Watershed (J19).

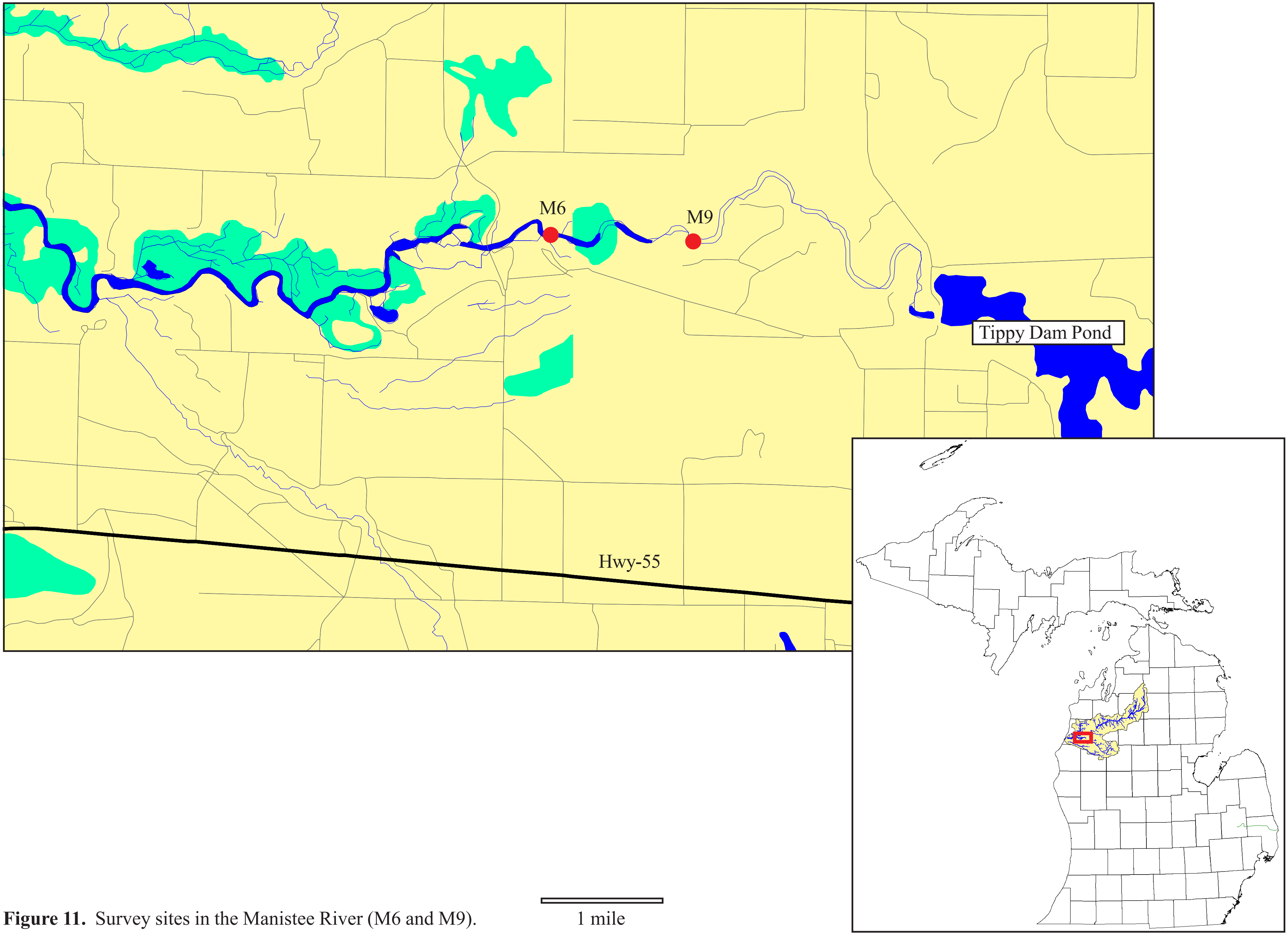

Figure 11. Survey sites in the Manistee River (M6 and M9).

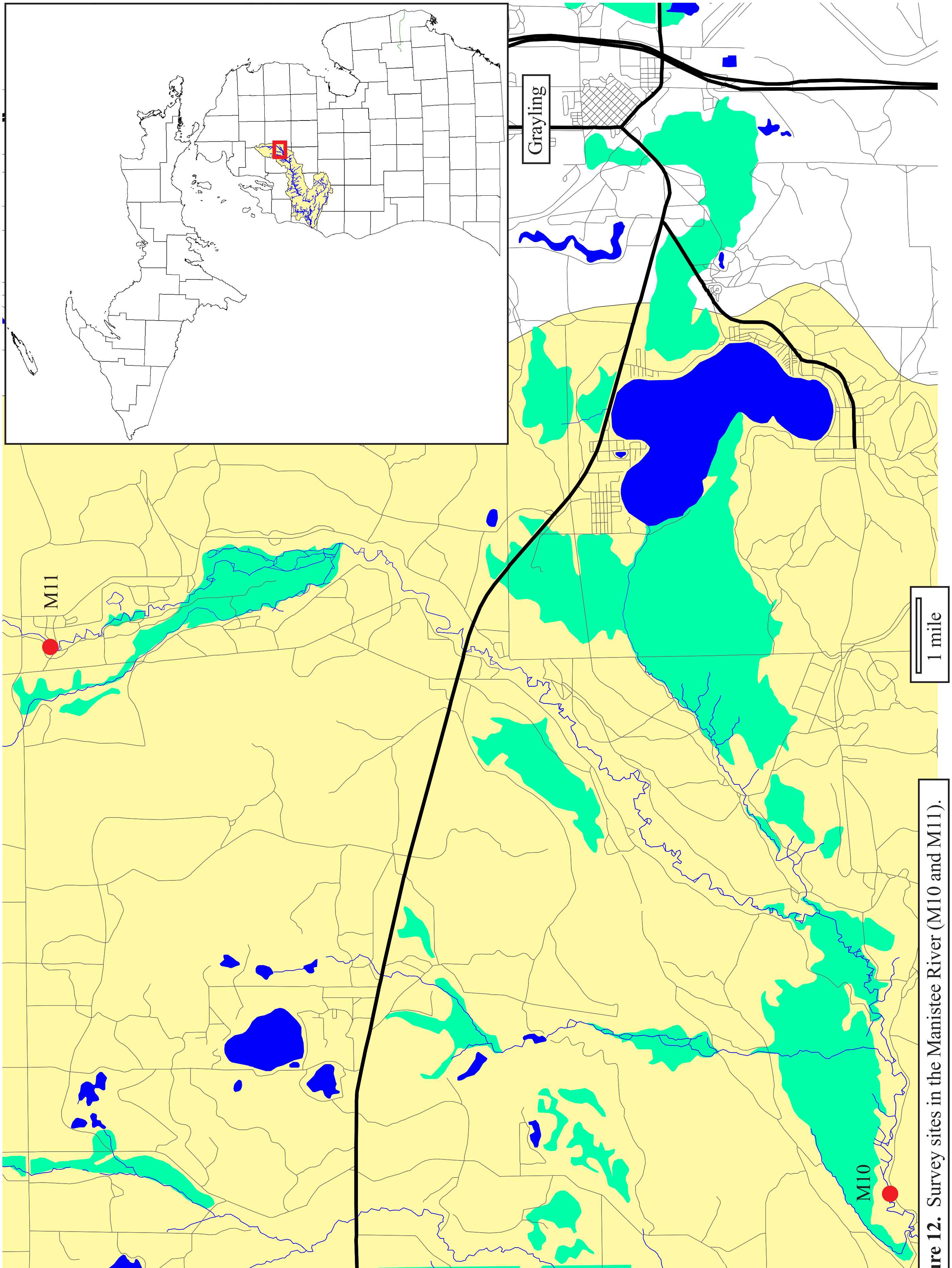

Figure 12. Survey sites in the Manistee River (M10 and M11).

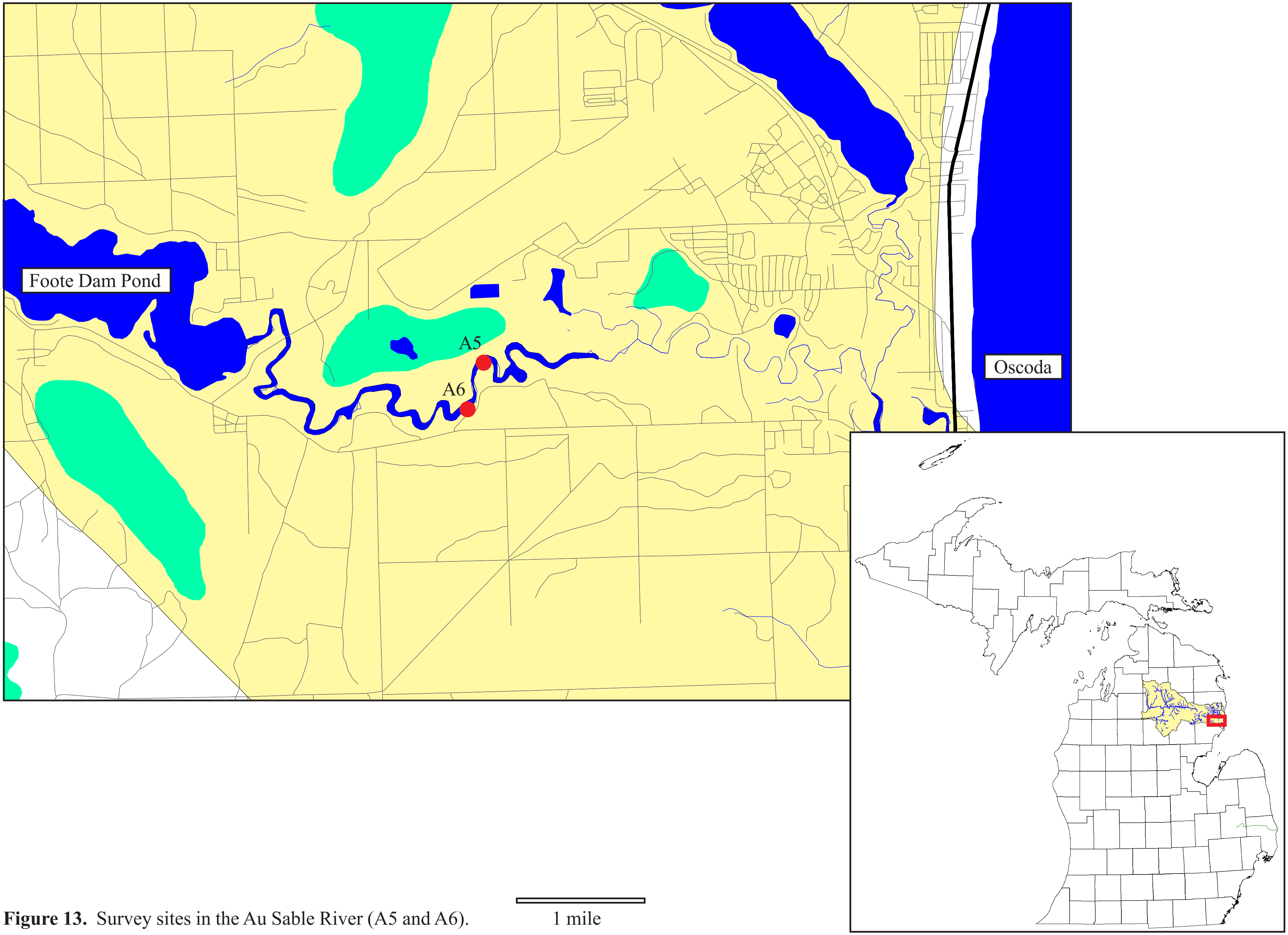

Figure 13. Survey sites in the Au Sable River (A5 and A6).

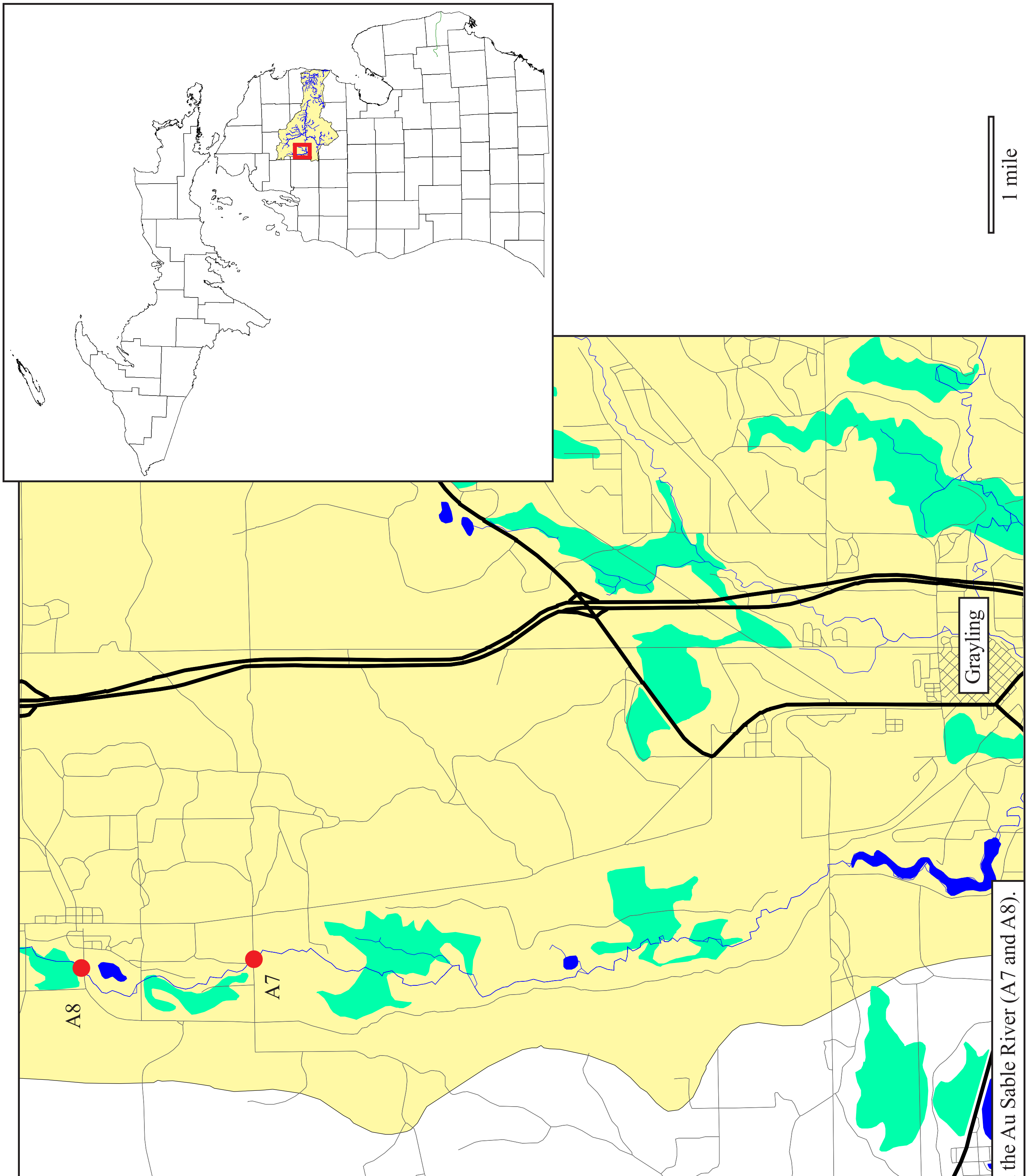

Figure 14. Survey sites in the Au Sable River (A7 and A8).

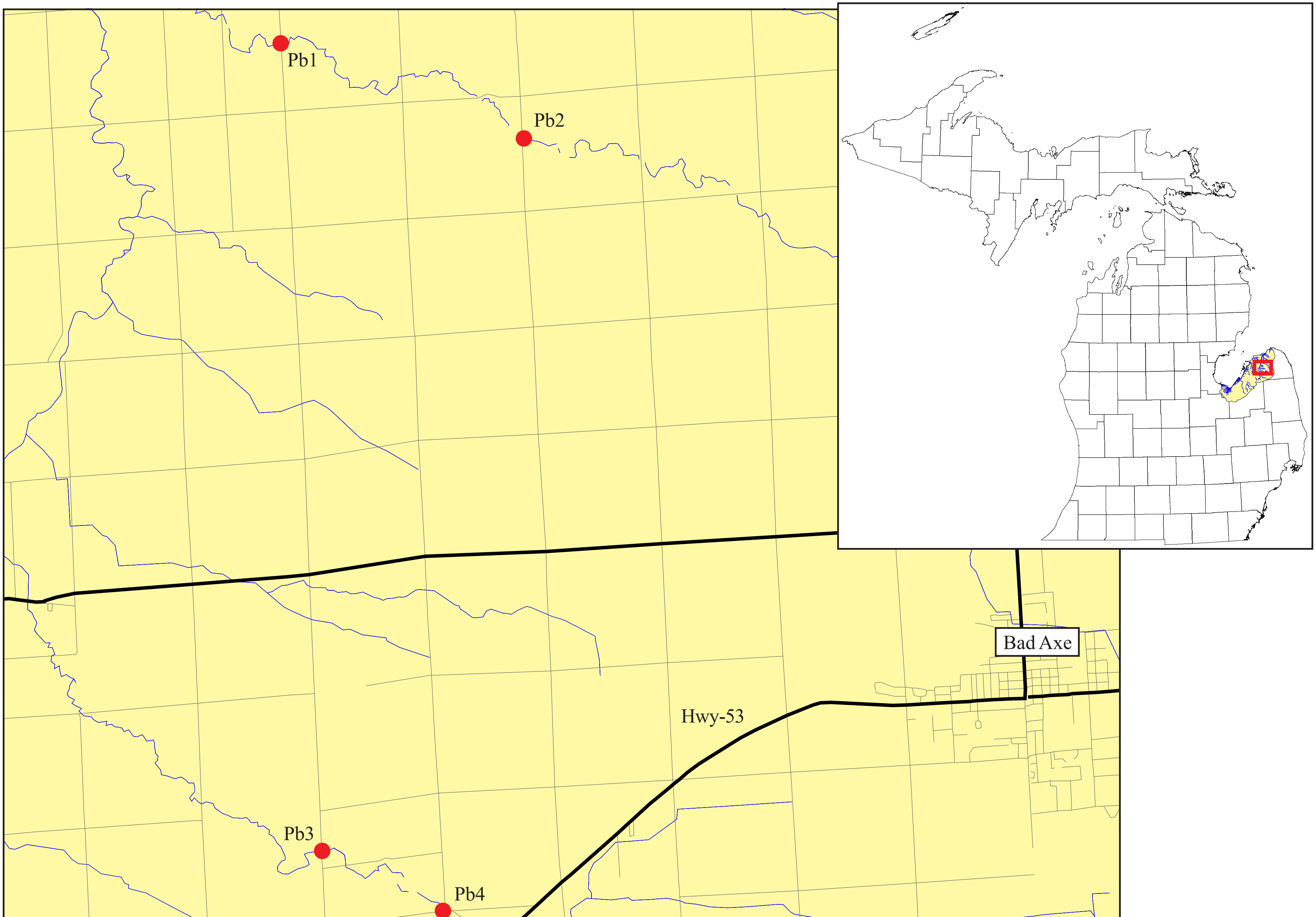

Figure 15. Survey sites in Bad Axe Creek (Pb1-Pb2) and Pinnebog River (Pb3-Pb4) within the Pinnebog Watershed.

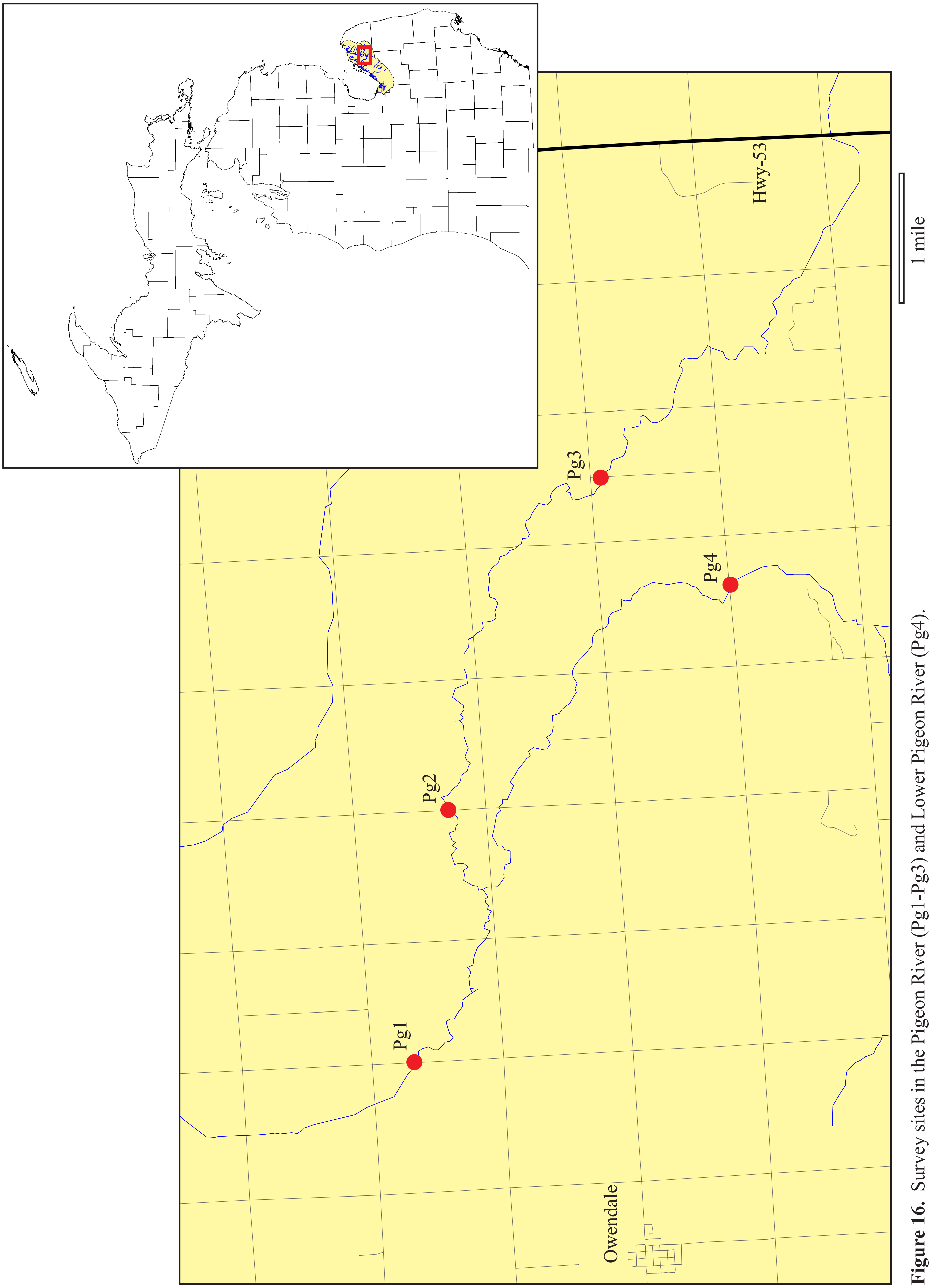

Figure 16. Survey sites in the Pigeon River (Pg1-Pg3) and Lower Pigeon River (Pg4).

Table 2. Scientific and common names of unionids found during year 2005 surveys. (L=species represented by live individuals; S=species represented by shell only; E= state listed as endangered; SpC=state listed as special concern)

Species	Common Name	St. Joseph Watershed	Manistee River	Au Sable River	Pinnebog Watershed	Pigeon River
Actinonaias ligamentina	Mucket	L		S		
Alasmidonta marginata (SpC)	Elktoe	L				
Alasmidonta viridis (SpC)	Slippershell	S		S	S	S
Anodontoides ferussacianus	Cylindrical papershell				L	
Cyclonaias tuberculata (SpC)	Purple wartyback	L				
Elliptio dilatata	Spike	L		L		
Epioblasma triquetra (E)	Snuffbox	S				
Fusconaia flava	Wabash pigtoe	L		S	L	L
Lampsilis siliquoidea	Fatmucket				L	L
Lampsilis ventricosa	Pocketbook	L	L	S		
Lasmigona complanata	White heelsplitter		L			L
Lasmigona costata	Fluted-shell	L				
Leptodea fragilis	Fragile papershell			S		
Ligumia recta	Black sandshell			S		
Pleurobema sintoxia (SpC)	Round pigtoe	L				
Potamilus alatus	Pink heelsplitter	L				
Pyganodon grandis	Giant floater				S	S
Strophitus undulatus	Strange floater	L	L	S	S	L
Truncilla truncata	Deertoe	S				
Venustaconcha ellipsiformis (SpC)	Ellipse	L			S	L
Villosa iris (SpC)	Rainbow	S			L	L
# species live		11	3	1	4	7
# species live or shell		15	3	8	8	8
# sites surveyed		9	4	4	4	4
Corbicula fluminea	Asian clam	L				
Dreissena polymorpha	zebra mussel	L	L	L		

Table 3. Numbers of unionids (#), relative abundance (RA), and density (D, individuals/m^2) recorded at each site surveyed. (J=St. Joseph Watershed; M=Manistee River; A=Au Sable River; Pb=Pinnebog Watershed; Pg=Pigeon Watershed; S=species represented by shell only; L=live individuals found)

	J11			J12			J13			J14			J15		
Species	#	RA	D	#	RA	D	#	RA	D	#	RA	D	#	RA	D
Actinonaias ligamentina	65	0.68	0.43	8	0.35	0.06	12	0.38	0.09	9	0.41	0.07	24	0.44	0.14
Alasmidonta marginata (SpC)	1	0.01	0.01	1	0.04	0.01	S			S(3)			1	0.02	0.01
Alasmidonta viridis (SpC)	S(1)			S(4)			S(3)			S(3)					
Anodontoides ferussacianus															
Cyclonaias tuberculata (SpC)	22	0.23	0.15	8	0.35	0.06	10	0.31	0.08	7	0.32	0.05			
Elliptio dilatata	3	0.03	0.02				3	0.09	0.02	1	0.05	0.01	6	0.11	0.11
Epioblasma triquetra (E)	S(1)			S(2)			S(4)								
Fusconaia flava	2	0.02	0.01	4	0.17	0.03	6	0.19	0.05	3	0.14	0.02	S		
Lampsilis siliquoidea															
Lampsilis ventricosa				1	0.04	0.01				1	0.05	0.01	13	0.24	0.08
Lasmigona complanata															
Lasmigona costata							S			1	0.05	0.01	3	0.05	0.02
Leptodea fragilis															
Ligumia recta															
Pleurobema sintoxia (SpC)	S(1)			1	0.04	0.01	1	0.03	0.01						
Potamilus alatus	1	0.01	0.01												
Pyganodon grandis															
Strophitus undulatus	2	0.02	0.01				S						2	0.04	0.01
Truncilla truncata							S								
Venustaconcha ellipsiformis (SpC)							S(6)			S(1)			6	0.11	0.04
Villosa iris (SpC)				S(2)											
Total # individuals and density	96		0.64	23		0.18	32		0.25	22		0.17	55		0.32
# species live	7			6			5			6			7		
# species live or shell	10			9			12			9			8		
Area searched (m^2)	150			129			129			129			170		

Table 3. (cont.)

Species	J16			J17			J18			J19			M6		
	#	RA	D	#	RA	D	#	RA	D	#	RA	D	#	RA	D
Actinonaias ligamentina	88	0.76	0.69	16	0.52	0.12									
Alasmidonta marginata (SpC)	2	0.02	0.02												
Alasmidonta viridis (SpC)	S(4)									S(5)					
Anodontoides ferussacianus															
Cyclonaias tuberculata (SpC)															
Elliptio dilatata	4	0.03	0.07	1	0.03	0.01	S			S					
Epioblasma triquetra (E)															
Fusconaia flava	6	0.05	0.05	10	0.32	0.08				2	0.10	0.01			
Lampsilis siliquoidea															
Lampsilis ventricosa	3	0.03	0.02	3	0.10	0.02	1	1.00	0.01	2	0.10	0.01	7	0.78	0.05
Lasmigona complanata													1	0.11	0.01
Lasmigona costata	9	0.08	0.07	1	0.03	0.01	S			1	0.05	0.01			
Leptodea fragilis															
Ligumia recta															
Pleurobema sintoxia (SpC)										15	0.75	0.11			
Potamilus alatus															
Pyganodon grandis															
Strophitus undulatus	1	0.01	0.01							S			1	0.11	0.01
Truncilla truncata															
Venustaconcha ellipsiformis (SpC)	3	0.03	0.02												
Villosa iris (SpC)															
Total # individuals and density	116		0.91	31		0.23	1		0.01	20		0.15	9		0.07
# species live	8			5			1			4			3		
# species live or shell	9			5			3			7			3		
Area searched (m^2)	128			132			133			136			129		

Table 3. (cont.)

	M9			M10			M11			A5			A6			A7		
Species	#	RA	D	#	RA	D	#	RA	D	#	RA	D	#	RA	D	#	RA	D
Actinonaias ligamentina													S					
Alasmidonta marginata (SpC)																		
Alasmidonta viridis (SpC)																S(4)		
Anodontoides ferussacianus																		
Cyclonaias tuberculata (SpC)																		
Elliptio dilatata													1	1	0.01			
Epioblasma triquetra (E)																		
Fusconaia flava										S			S					
Lampsilis siliquoidea																		
Lampsilis ventricosa										S			S					
Lasmigona complanata																		
Lasmigona costata																		
Leptodea fragilis										S			S					
Ligumia recta										S			S					
Pleurobema sintoxia (SpC)																		
Potamilus alatus																		
Pyganodon grandis																		
Strophitus undulatus	S												S					
Truncilla truncata																		
Venustaconcha ellipsiformis (SpC)																		
Villosa iris (SpC)																		
Total # individuals and density	0		0.00	0		0.00	0		0.00	0		0.00	1		0.01	0		0.00
# species live	0			0			0			0			1			0		
# species live or shell	1			0			0			4			7			1		
Area searched (m^2)	129			128			405			129			128			150		

Table 3. (cont.)

	A8			Pb1			Pb2			Pb3			Pb4			Pg1		
Species	#	RA	D	#	RA	D	#	RA	D	#	RA	D	#	RA	D	#	RA	D
Actinonaias ligamentina																		
Alasmidonta marginata (SpC)																		
Alasmidonta viridis (SpC)				S(1)						S(4)			S(2)					
Anodontoides ferussacianus				1	0.50	0.01							S					
Cyclonaias tuberculata (SpC)																		
Elliptio dilatata																		
Epioblasma triquetra (E)																		
Fusconaia flava										3	0.75	0.02	S					
Lampsilis siliquoidea				1	0.50	0.01	S			S			S			1	0.04	0.01
Lampsilis ventricosa																		
Lasmigona complanata																1	0.04	0.01
Lasmigona costata																		
Leptodea fragilis																		
Ligumia recta																		
Pleurobema sintoxia (SpC)																		
Potamilus alatus																		
Pyganodon grandis				S						S			S					
Strophitus undulatus				S												1	0.04	0.01
Truncilla truncata																		
Venustaconcha ellipsiformis (SpC)										S(4)			S(13)			16	0.70	0.12
Villosa iris (SpC)				S(1)						1	0.25	0.01	1	1.00	0.01	4	0.17	0.03
Total # individuals and density	0		0.00	2		0.02	0		0.00	4		0.03	1		0.01	23		0.18
# species live	0			2			0			2			1			5		
# species live or shell	0			6			1			6			7			5		
Area searched (m^2)	196			128			128			128			128			130		

Table 3. (cont.)

	Pg2			Pg3			Pg4		
Species	#	RA	D	#	RA	D	#	RA	D
Actinonaias ligamentina									
Alasmidonta marginata (SpC)									
Alasmidonta viridis (SpC)				S(2 outside transect)					
Anodontoides ferussacianus									
Cyclonaias tuberculata (SpC)									
Elliptio dilatata									
Epioblasma triquetra (E)									
Fusconaia flava	2	1.00	0.02	S					
Lampsilis siliquoidea				S(outside transect)			11	0.48	0.09
Lampsilis ventricosa									
Lasmigona complanata									
Lasmigona costata									
Leptodea fragilis									
Ligumia recta									
Pleurobema sintoxia (SpC)									
Potamilus alatus									
Pyganodon grandis	S						S		
Strophitus undulatus							1	0.04	0.01
Truncilla truncata									
Venustaconcha ellipsiformis (SpC)				S(10)			1	0.04	0.01
Villosa iris (SpC)	S(1 all soft tissue intact)						10	0.43	0.08
Total # individuals and density	2		0.02	0		0.00	23		0.18
# species live	1			0			4		
# species live or shell	3			3			5		
Area searched (m^2)	128			137			128		

Table 4. Occurrence of *Corbicula fluminea* (Asian clam) and *Dreissena polymorpha* (zebra mussel) by site. (L=live individuals found; S=species represented by shell only; LA=*D. polymorpha* found attached to unionids; L*=no live unionids were present at this site)

Exotic bivalves	J11	J12	J13	J14	J15	J16	J17	J18	J19	M6 revisit	M9	A5	A6
Corbicula fluminea (Asian clam)	L		L	L	L	L	L	S	S				
Dreissena polymorpha (zebra mussel)	LA	LA	LA	L						LA	L*	L*	L

Table 5. *Dreissena polymorpha* (zebra mussel) colonization data, including the number of unionids colonized by *D. polymorpha* per site (ucz), mean number of *D. polymorpha* per colonized unionid (zm/u), and the percentage of individuals at a site colonized by *D. polymorpha* (%cu).

	J11			J12			J13			M6		
Species	ucz	zm/u	%cu	ucz	zm/u	%cu	ucz	zm/u	%cu	ucz	zm/u	%cu
A. ligamentina	10	1.1	15.4									
C. tuberculata	1	1.0	4.5				1	1.0	10.0			
E. dilatata							1	1.0	33.3			
L. fasciola												
L. siliquoidea												
L. ventricosa				1	1	100				7	22.1	100
L. complanata										1	10.0	100
L. recta												
P. grandis												
S. undulatus										1	8.0	100
Total	11	1.1	12.6	1	1	4.3	2	1.0	15.4	9	19.2	100

Figure 17. Woody debris in the Au Sable River.

Discussion

The four sites surveyed in the St. Joseph River, upstream of Mendon, MI in 2005 (J11-J14) were located approximately 800m and 1600m upstream of two sites that were surveyed in 2001 (Badra and Goforth 2002). Five species were documented in 2005 surveys that were not found in 2001. Of these five, two are species of special concern (Venustaconcha ellipsiformis, ellipse and Villosa iris, rainbow).

Truncilla truncata (deertoe) was represented by empty shell at only one site in the St. Joseph Watershed. Eight of ten sites surveyed in the main stem of the St. Joseph River in 2001 were dominated by T. truncata, with densities up to 0.89 individuals/meter^2. This difference in frequency and abundance of T. truncata between sites surveyed in 2001 (J1-J10) and sites surveyed in 2005 (J11-14) most likely reflects a preference for large river habitat, though this may be due to an indirect factor such as use of a fish host that prefers large river habitat. Stizostedion canadense (sauger) and Aplodinotus grunniens (freshwater drum) have been determined to be suitable hosts for T. truncata (Watters 1994). Both are known to occupy large river or large river and lake habitats (Trautman 1981).

Very few live individuals or shells were found at the four sites surveyed in the Manistee (M6 and M9-M11). Unionids may be excluded from some Manistee River reaches by unstable sand substrates. Though the substrate at all four sites contained a high proportion of sand (85-100%), only site M6 was in a low current area where the sand was more stable. M6 was the only site out of four that had live unionids.

Though eight species were found at the four Au Sable River sites (A5-A8), all but one (Elliptio dilatata, spike) was represented solely by empty shell (Figure 18). This contrasts with what was found at sites further downstream in the Au Sable (A1-A4) surveyed in 2002 (Badra and Goforth 2003). A total of 11 species were found including eight represented by live individuals.

In spite of a history of heavy agricultural land use in the thumb region (Huron Co.) the Pinnebog and Pigeon Rivers support several unionid species including three special concern species.

Three new occurrences for the state endangered Epioblasma triquetra (snuffbox) were documented in the St. Joseph River, east of Mendon, MI (sites J11, J12, and J13). A historic (1940) record exists for this species several kilometers upstream and two recent records (Badra and Goforth 2002) were documented approximately 800m and 1600m downstream of site J11. Live D. polymorpha were present at these sites and found attached to four species of unionid. Negative impacts from D. polymorpha are a potential threat to the persistence of E. triquetra in this reach of the St. Joseph River.

An important population of Cyclonaias tuberculata (purple wartyback) was documented in the St. Joseph River at sites J11-J14. A relatively large number of this species resides in this reach. Unfortunately, these C. tuberculata are also threatened by D. polymorpha. Two individuals were found with one live D. polymorpha each. Dense populations of Actinonaias ligamentina (mucket) were found at sites J11 and J16. These sites are potentially important for the maintenance of this species' common status.

Ligumia recta (black sandshell) is a very rare species in Michigan that likely warrants state endangered status. Considering L. recta shell was found at two out of the four sites surveyed on the Au Sable in 2005 (A5 and A6), and that live individuals were found at two out of four sites surveyed in 2002 (Badra and Goforth 2003), the Au Sable is potentially important river for the recovery of this species.

A very high rate and intensity of D. polymorpha colonization was found in the Manistee River at site M6. The number of D. polymorpha per unionid ranged from 7 to 50. This amount of colonization has clear negative effects on unionid mussels. Many of the unionids at this site had enough D. polymorpha bysal threads attached to them that they appeared to be unable to open their valves. This site was previously surveyed in 2002 (Badra and Goforth 2003). A maximum number of D. polymorpha per individual was 20. There were six unionid species detected in the 2002 survey that were not detected in the 2005 survey. One species detected in the 2005 survey was not found in the 2002 survey (Table 6). Overall, in 2005 site M6 was found to have fewer unionid species, lower abundance of unionids, higher mean and maximum number of D. polymorpha per colonized unionid, and a higher percentage of unionids at the site colonized by D. polymorpha (Table 7). D. polymorpha is a clear threat to the persistence of unionid mussels in this reach of the Manistee River.

Dreissena polymorpha have free-swimming larvae that can be displaced by water currents. The current in rivers tends to make D. polymorpha populations less likely to persist unless there is reoccurring introduction of them to an upstream site. Free flowing rivers can act as natural refugia that protect unionids from D. polymorpha impacts (Sickel et al. 1997)(Harman et al. 1998 and Clarke 1992 cited in Nichols et al. 2000). D. polymorpha can be incidentally transported among different river reaches by recreational boats. The fact that there is a long term presence of this species in fast flowing rivers like the Manistee and Au Sable suggests that boating is contributing to their persistence by regularly introducing larvae to upstream habitats. Additional outreach efforts to promote washing/drying of boats and boat trailers to minimize the spread of veligers may reduce the impact of D. polymorpha in these rivers. Though D. polymorpha uses a wide variety of substrates including pebble and cobble, woody debris, and trash (Figure 19). The spread and persistence of D. polymorpha appears to be somewhat inhibited by a limited amount of stable substrate in some reaches of the Au Sable and Manistee. In contrast, areas with low current (e.g. site M6) may lead to higher negative impacts of D. polymorpha on unionid mussels.

Figure 18. Unionid shells found at site A6 in the Au Sable River.

Table 6. Unionid occurence data for site M6 in the Manistee River for 2005 and 2002.

	M6 (2005)			M6 (2002)		
Species	#	RA	D	#	RA	D
Anodonta imbecillis				1	0.04	0.01
Elliptio dilatata				2	0.08	0.02
Fusconaia flava				Lmdr		
Lampsilis siliquoidea				2	0.08	0.02
Lampsilis ventricosa	7	0.78	0.05	9	0.36	0.07
Lasmigona complanata	1	0.11	0.01			
Ligumia recta				3	0.12	0.02
Pyganodon grandis				1	0.04	0.01
Strophitus undulatus	1	0.11	0.01	7	0.28	0.05
Total # individuals and density	9		0.07	25		0.20
# species live	3			8		
# species live or shell	3			8		
Area searched (m^2)	129			128		

Table 7. *Dreissena polymorpha* colonization data for site M6 in the Manistee River for 2005 and 2002.

	M6 (2005)			M6 (2002)		
Species	ucz	zm/u	%cu	ucz	zm/u	%cu
E. dilatata				1	2.0	50
L. siliquoidea				2	5.0	100
L. ventricosa	7	22.1	100	9	8.6	100
L. complanata	1	10.0	100			
L. recta				2	13.5	67
P. grandis				1	5.0	100
S. undulatus	1	8.0	100	7	6.4	100
Total	9	19.2	100	22	7.9	88

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