Current Status of Freshwater Mussels and Associated Communities in the Grand and St. Joseph Rivers, Michigan.

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Table of Contents

Introduction 1
Methods 2
Results 4
Discussion 13
Acknowledgments 15
Literature Cited 15
Appendices 17

Table of Tables

Table 1. Latitude and Longitude, and town-range-section of survey sites on the Grand (G1-G6) and St. Joseph (J1-J10) Rivers. **4**
Table 2. Scientific and common names of unionids found during transect searches in the Grand and St. Joseph Rivers. **5**
Table 3. Substrate, approximate current, and visibility at survey sites in the Grand and St. Joseph Rivers. **6**
Table 4. Numbers of unionids, relative abundance, and density (indvs./m2) recorded from Grand River sites. Occurrence of live Asian clams (*Corbicula fluminea*) or their empty shells is indicated. **7**
Table 5. Numbers of unionids, relative abundance, and density (indvs./m2) recorded from St. Joseph River sites. Occurrence of live Asian clams (*Corbicula fluminea*) or their empty shells is indicated. **9**
Table 6. Zebra mussel colonization data for St. Joseph survey sites. **11**
Table 7. Mean number and range of external annular rings for selected species in the Grand River. **12**
Table 8. Mean number and range of external annular rings for selected species in the St. Joseph River. **12**
Table 9. Mean number and range of external annular rings for Truncilla truncata at selected sites in the St. Joseph River. **12**
Table 10. Fish collected in a rotenone survey of the Grand River by the Michigan DNR in 1978 (Nelson and Smith 1981). **14**

Table of Figures

Figure 1. A midden of *Truncilla truncata* shell on the St. Joseph River (J5). **2**
Figure 2. Boat and jet drive motor used during surveys. **3**
Figure 3. Divers preparing for transect searches on the Grand River. Photo by Dave Kenyon, MI DNR. **3**
Figure 4. Sand and gravel substrate in the St. Joseph River (J9). **6**
Figure 5. A zebra mussel attached to *Truncilla truncata* from the St. Joseph River (J6). **11**

Table of Appendices

Appendix I. Numbers of unionids found in each transect in the Grand River. **17**
Appendix II. Numbers of unionids found in each transect in the St. Joseph River. **19**

Cover photos by Reuben Goforth and Peter Badra. All other photos by Reuben Goforth unless otherwise noted.

Introduction

Native Freshwater mussels (Unionidae) are an important component of Michigan's wildlife. They play a significant role in the ecology of freshwater systems, are useful indicators of water quality, and have historically been economically valuable. They also serve as umbrella taxa for the conservation of aquatic ecosystems because they are comparatively sensitive to habitat degradation and pollution, and rely on fish hosts for reproduction. Unionids inhabit streams and lakes of Central America, North America, Eurasia, and Africa (Bogan 1993), although eastern North America is the region of highest diversity with 292 described species (Williams *et al.* 1993). Forty-five unionid species have been documented in Michigan's rivers and lakes.

The Grand River and St. Joseph River (Lake Michigan drainage) have provided habitat for diverse and abundant unionid communities. Over 50% of the species recorded in Michigan have been reported from these two rivers. Mussel communities of these rivers were once economically valuable. In the early 1900's, live unionids were collected from these and other large rivers to support the button industry. In 1938, Henry van der Schalie, a noted malacologist, documented a rapid decline of unionid mussels during the 1930's due to harvest pressure. In response, The Michigan Conservation Commission closed the harvest for a period of five years beginning in 1944 to allow the resource to recover. By the end of the 1940's much of the demand for unionid shell had subsided due to increased use of plastics to make buttons. Surveys by van der Shalie (1948) later revealed that at least some of the mussel beds had recovered. Although unionid shells are now collected in some parts of the country for the cultured pearl industry, Michigan's unionid communities are not considered stable enough to allow a harvest, and it is illegal to possess or collect them without a permit.

Unionids are now recognized as useful monitors of water quality and for their ecological value. Most species are long-lived, with life spans up to 50 years and more. They are generally sessile, spending most of their lives within a particular stream reach. Unionids tend to accumulate and are sensitive to contaminants because they are filter feeders. Empty unionid shells can reveal historic community composition because they remain intact for many years *post mortem*. These characteristics make unionid mussels valuable indicators of water quality (Strayer 1999a). Chemical analysis of shell material can also reveal environmental information from years past (Mutvei and Westermark 2001). Unionids play a significant ecological role in rivers. The action of filter feeding can change the particle content of river water (Pusch *et al.* 2001). Unionids are a substantial factor in the flow of energy in stream ecosystems. They often comprise the highest percentage of biomass relative to other benthic stream organisms (Strayer *et al.* 1994), and are therefore a key link in the food chain from aquatic microorganisms to crayfish, muskrats, and other large predators. The status of unionids is indicative of the biological integrity of river ecosystems as a whole.

The Unionidae rely upon fish hosts to complete their life cycle. Larvae called glochidia hatch from fertilized eggs and develop within the females' mantle tissues (i.e., marsupia). Glochidia are then released into the water column and must attach to a suitable host fish in order to survive. Unionids transform into the adult form and drop off the host after a period ranging from 6-160 days, depending on the mussel species (Kat 1984). Some unionids are known to have only a few suitable fish host species, while others are generalists and utilize several species. The females of some taxa display mantle flaps or conglutinates that function as lures to fish hosts, thereby increasing the chances that larvae will successfully attach to an appropriate host. Since adult mussels are relatively sessile (Amyot and Downing 1997), the movement of fish hosts infected with glochidia is the primary mode of dispersal for the Unionidae (Kat 1984; Watters 1992).

Over the past century, many factors have contributed negative impacts on Michigan's river ecosystems. Increasing land use intensity within the Grand and St. Joseph River watersheds, point source pollution, direct habitat alteration such as drain clean-outs and dredging, and non-native species have impacted native mussel and fish communities. Without the appropriate fish host species present in sufficient densities the unionid life cycle cannot be completed. Threats to native fish communities can undermine the stability of unionid populations. Barriers to the migration of fish, such as dams, are also barriers to the successful reproduction and dispersal of unionids (Watters 1995). They can inhibit the re-colonization of suitable habitat and prevent the recovery of unionid populations. *Dreissena polymorpha* (the zebra mussel) can have devastating effects on unionid communities (Schloesser *et al.* 1998) and are continuing to spread throughout the surface waters of Michigan.

Over one-third (17) of Michigan's 45 unionids are listed as special concern, threatened, or endangered. A review of the status of U.S. and

Canadian Unionids by the American Fisheries Society found that 97 of the 292 species that occur in the U.S. are considered endangered (Williams *et al.* 1993). The decline of freshwater bivalves is occurring in other parts of the world as well (Bogan 1993). Current knowledge of the status and distribution of the uniondae in Michigan is incomplete. The lower reaches of larger rivers have not been adequately surveyed in part due to the difficulty in accessing and surveying these habitats. The purpose of this project was to increase our knowledge of the status and distribution of unionids in the lower Grand and St. Joseph Rivers, and to collect ecological data relevant to the conservation of unionids such as the distribution and density of the exotic *D. polymorpha*. These surveys are part of an ongoing effort to build an up-to-date knowledge base that can be used to promote the conservation of Michigan's unionids and associated communities.

Methods

River reaches were selected for field visits based on availability of suitable unionid habitat and potential for occurrences of listed unionids. Surveys focused on the lower Grand and St. Joseph Rivers, habitats that have not been systematically surveyed in recent years and would otherwise be inaccessible without the use of a boat and/or SCUBA. The nearest boat ramp to the reach was identified and used as an access point. Mussel habitat and signs of mussel beds such as shells in muskrat middens (Figure 1) were identified from a boat within these reaches and were used as a basis for survey site selection. Handheld GPS units (Garmin 12XL) and topographic maps were used to document the position of each site. Latitude and longitude were recorded at a point in the approximate center of the site. Some sections of the St. Joseph River and most sections of the Grand River that were surveyed had occasional shallow (0.2-0.5m) gravel bars. The use of a jet drive outboard motor made navigating over these bars much more time efficient and mechanical failure was far less likely than with a traditional propeller drive outboard motor (Figure 2).

The field crew typically consisted of two divers and a third person who transcribed data, assisted divers with gear, and tended the boat while divers were in the water (Figure 3). Transects were delineated using 10m lengths of 2.54cm nylon webbing with 4.5kg anchors fastened to each end. A buoy was tied to each anchor to mark the endpoints of each transect. Once signs of a mussel bed were identified, the boat was anchored and transects were set. Two transects were set side by side approximately 3 to 8m apart parallel to river flow. Divers started working each pair of transects at the same time, moving in an upstream direction. Searching in an upstream direction minimized increased turbidity due to disturbance of fine substrate particles during surveys. A few transects were set in

Figure 1. A midden of *Truncilla truncata* shell on the St. Joseph River (J5). These shells were recently emptied and arranged as shown by a predator such as a muskrat.

Figure 2. Boat and jet drive motor used during surveys.

Figure 3. Divers preparing for transect searches on the Grand River. Photo by Dave Kenyon, MI DNR.

water that was shallow enough to allow surveyors to kneel on the bottom and perform tactile searches without the use of SCUBA.

Unionids buried up to approximately 5cm below the substrate surface and located within 0.8m on either side of the transect lines were detectable. Due to low underwater visibility at most sites, mussels were located tactilely by divers passing their hands through the substrate adjacent to the transect lines. Relatively clear water and rocky substrate at a few of the sites made visual searches of transects a more reliable and time efficient method for detecting mussels. Rocks and live mussels were more easily distinguished visually than tactilely at these sites. Live unionids were placed in mesh bags, brought to the surface, and identified after completing each transect.

When possible, external annular rings were counted to provide age estimates. Individuals with rings that were largely obscured were not aged. In some cases, annular rings were distinct up to the shell margin, at which point they became too crowded to effectively count as separate rings. A minimum number of annular rings was recorded in these cases. The number of *D. polymorpha* attached to each live unionid was recorded when present. The exotic Asian clam *C. fluminea* was generally too small to be detected reliably using the methods described previoulsy. Presence/absence of shell or live Asian clams was recorded. 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. Empty shells were returned to the river. Divers spent approximately the same length of time searching transects and 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. The boat and outboard motor were either dried for several days or washed with a bleach solution to prevent the transportation of live *D. polymorpha* and other exotics between different river reaches.

A number of factors were addressed to ensure diver safety. Bacteria counts in both the Grand and St. Joseph 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 (DUI ™) and full facemasks (Scubapro™) were used to minimize direct contact with river water and sediments. Current speeds at most of the sites made it necessary for divers to wear a much heavier weight belt than usual. Over 13.6kg was often needed in order to keep divers from drifting downstream. Transect lines not only delineated the area to be searched, but were also used as a hand line to help divers remain stable in the current. Broken glass, zebra mussel shell, and other sharp debris was frequently encountered during tactile searches. Neoprene gloves (3mm) were worn to minimize the chance of injury. Visibility ranged from a few centimeters to greater than 3 meters, but was usually between 0.3 and 0.6 meters. Transect lines were essential for keeping divers oriented to sampling areas during surveys.

Results

Surveys were conducted at 16 sites on the Grand and St. Joseph Rivers for a total of 126 transect searches. Six sites were in the Grand River between the cities of Portland and Ionia, eight were in the St. Joseph River at sites between Berrien Springs and St. Joseph, MI, and two were in the St. Joseph River at sites near Mendon, MI. Sites in the Grand River were designated as G1, G2, ...G6 and St. Joseph River sites were designated as J1, J2, ...J10. Sites are numbered in order from downstream to upstream. Survey site locations are given in Table 1.

Table 1. Latitude and Longitude, and town-range-section of survey sites on the Grand (G1-G6) and St. Joseph (J1-J10) Rivers. Sites with listed unionids are marked.

Site	Latitude	Longitude	TRS	Listed Sp.
G1	N 42°58.610'	W 85°01.909'	7N 6W sec21 SW4	X
G2	N 42°58.870'	W 85°01.482'	7N 6W sec21 NE4	X
G3	N 42°58.978'	W 84°55.079'	7N 5W sec20 SE4	X
G4	N 42°58.500'	W 84°55.220'	7N 5W sec29 NE4	X
G5	N 42°58.548'	W 84°55.142'	7N 5W sec29 SE4	X
G6	N 42°57.805'	W 84°54.966'	7N 5W sec28 SW4	X
J1	N 42°05.020'	W 86°28.568'	4S 19W sec35 NE4	
J2	N 42°04.330'	W 86°27.300'	5S 18W sec6 NW4	
J3	N 42°03.804'	W 86°24.917'	5S 18W sec5 S2	X
J4	N 42°03.641'	W 86°24.220'	5S 18W sec4 SW4	
J5	N 41°58.566'	W 86°20.583'	6S 18W sec 1 SE4	X
J6	N 41°58.050'	W 86°20.150'	6S 17W sec7 NW4	X
J7	N 41°57.564'	W 86°19.305'	6S 17W sec8 W2	
J8	N 41°57.457'	W 86°19.599'	6S 17W sec7 SE4	X
J9	N 42°00.321'	W 85°27.331'	5S 10Wsec 26 SW4	X
J10	N 42°00.350'	W 85°26.383'	5S 10Wsec 26 SE4	X

Several live occurrences of rare unionids were documented in the Grand River, including the state list as endangered snuffbox (*Epioblasma triquetra*), and the state listed as special concern purple wartyback (*Cyclonaias tuberculata*), round pigtoe (*Pleurobema sintoxia*), and elktoe (*Alasmidonta marginata*). Empty shells of the state listed as special concern slippershell (*Alasmidonta viridis*) and ellipse (*Venustaconcha ellipsiformis*) were also found in the Grand River.

Live occurrences of rare unionids in the St. Joseph River included the state listed as special concern purple wartyback (*Cyclonaias tuberculata*), round pigtoe (*Pleurobema sintoxia*), and elktoe (*Alasmidonta marginata*). In addition, empty shells of the state listed as endangered snuffbox (*Epioblasma triquetra*) and state listed as special concern slippershell (*Alasmidonta viridis*) were documented. Scientific and common names of all unionid species found in the Grand and St. Joseph Rivers during this survey are given in Table 2.

All but a few transects occurred in water deep enough to require the use of SCUBA. Mussels were easily detected, even while wearing neoprene gloves. Descriptions of habitats are given in table 3. Unionids as small as 3cm in length were commonly observed in sandy substrates. Sand and gravel were the most common substrate particle sizes encountered among sites (Figure 4). Detection of small mussels became more difficult as substrate particle size increased from pebble to cobble substrates. Results for sites with larger substrate particles may be skewed slightly towards larger individuals and larger species.

Surprisingly low densities of unionids were observed in both the Grand and St. Joseph Rivers compared to surveys conducted in the Grand River in 1999. Numbers of individuals found, relative abundance, and density at each site are given in Tables 4 and 5. Numbers of unionids found per transect are given in Appendix I and II. Zebra mussels (*D. polymorpha*) were found attached to unionids at several sites in the St. Joseph River (Table 6 and Figure 5). Byssal threads were occasionally found on live unionids and empty shell, indicating that the individual had been colonized by *D. polymorpha.* Additional live zebra mussels were found attached to rocks or substrate other than unionids at sites J1(n=1), J5(n=4), J9(n=10), and J10(n=4). A total of 65 (17% of individuals processed) unionids were found in the St. Joseph with live zebra mussels

Table 2. Scientific and common names of unionids found during transect searches in the Grand and St. Joseph Rivers. (L = represented by live individuals, S = represented only by empty shell, SpC = State listed as special concern, End = State listed as endangered).

Species	Common name	Grand	St. Joseph
Actinonaias ligamentina	Mucket	L	L
Alasmidonta marginata (SpC)	Elktoe	S	L
Alasmidonta viridis (SpC)	Slippershell	S	S
Amblema plicata	Threeridge	L	S
Anodonta grandis	Giant floater	L	S
Anodonta imbecillis	Paper pondshell		S
Anodontoides ferussacianus	Cylindrical papershell		S
Cyclonaias tuberculata (SpC)	Purple wartyback	L	L
Elliptio dilatata	Spike	S	L
Epioblasma triquetra (End)	Snuffbox	L	S
Fusconaia flava	Wabash pigtoe	L	L
Lampsilis ventricosa	Pocketbook	L	L
Lasmigona complanata	White heelsplitter		L
Lasmigona costata	Fluted-shell	S	L
Ligumia recta	Black sandshell	L	L
Leptodea fragilis	Fragile papershell		L
Pleurobema sintoxia (SpC)	Round pigtoe		L
Quadrula pustulosa	Pimpleback	L	S
Quadrula quadrula	Mapleleaf	S	L
Strophitus undulatus	Strange floater	S	
Truncilla truncata	Deertoe		L
Venustaconcha ellipsiformis (SpC)	Ellipse	S	
Corbicula fluminea (Exotic)	Asian clam	S	L
Dreissena polymorpha (Exotic)	Zebra mussel		L

Table 3. Substrate, approximate current, and visibility at survey sites in the Grand and St. Joseph Rivers. (gravel = 4-30mm, pebble = 30-60mm, cobble > 60mm in diameter).

Site	Substrate	Current (approx.)	Visibility
G1	gravel w/ some rock	0.3m/sec.	0.6 - 1m
G2	gravel w/ some sand	0.3m/sec.	0.6 - 1m
G3	ranged from silty sand to gravel and pebble	0.4 - 0.6m/sec.	0.3m
G4	ranged from large gravel w/ some sand to cobble	0.4 - 0.6m/sec.	0.3m
G5	gravel and pebble	0.1m/sec.	0.3m
G6	large gravel and pebble	0.1 - 0.6m/sec.	0.3 - 0.6m
J1	sand	0.3m/sec.	1.5m
J2	sand	0.3m/sec.	1.5m
J3	gravel w/ some sand	0.3m/sec.	0.6m
J4	ranged from sand to sand w/ gravel	0.3m/sec.	0.6m
J5	sand and gravel	0.2 - 0.3m/sec.	0.6 - 0.8m
J6	silty sand and gravel	0 - 0.1m/sec.	< 0.1m
J7	gravel w/ some silt	0.1 - 0.3m/sec.	0.6m
J8	large gravel	0.3m/sec.	1m
J9	sand and gravel	0.1m/sec.	3.5m
J10	sand w/ some gravel and pebble	0.4m/sec.	3m

Figure 4. Sand and gravel substrate in the St. Joseph River (J9). Particles in photo range up to 2cm in diameter.

Table 4. Numbers of unionids, relative abundance, and density (indvs./m^2) recorded from Grand River sites. Occurrence of live Asian clams (*Corbicula fluminea*) or their empty shells is indicated. (SpC = State listed as special concern, End = State listed as endangered, shell = only empty shell was found at the site).

	G1			G2			G3		
Species		rel. ab.	density		rel. ab.	density		rel. ab.	density
Actinonaias ligamentina				2	0.04	0.02			
Alasmidonta marginata (SpC)	shell			shell			shell		
Alasmidonta viridis (SpC)							shell		
Amblema plicata	12	0.63	0.09	34	0.61	0.27	14	0.56	0.11
Anodonta grandis				shell			1	0.04	0.01
Cyclonaias tuberculata (SpC)	shell			5	0.09	0.04	shell		
Elliptio dilatata				shell					
Epioblasma triquetra (End)	1	0.05	0.01	2	0.04	0.02			
Fusconaia flava	shell			3	0.05	0.02	5	0.20	0.04
Lampsilis ventricosa	6	0.32	0.05	5	0.09	0.04	5	0.20	0.04
Lasmigona costata							shell		
Legumia recta	shell			1	0.02	0.01			
Pleurobema sintoxia (SpC)	shell								
Strophitus undulatus				shell			shell		
Quadrula pustulosa	shell			4	0.07	0.03	shell		
Quadrula quadrula							shell		
Venustacocha ellipsiformis (SpC)							shell		
Total	19		0.15	56		0.44	25		0.20
Corbicula fluminea (Exotic)				shell			shell		
Dreissena polymorpha (Exotic)									

Table 4 continued...

Species	G4			G5			G6		
		rel. ab.	density		rel. ab.	density		rel. ab.	density
Actinonaias ligamentina	1	0.06	0.01	1	0.1	0.0			
Alasmidonta marginata (SpC)	shell			shell			shell		
Alasmidonta viridis (SpC)									
Amblema plicata	13	0.76	0.10	2	0.25	0.02	1	0.33	0.01
Anodonta grandis	1	0.06	0.01				1	0.33	0.01
Cyclonaias tuberculata (SpC)									
Elliptio dilatata	shell						shell		
Epioblasma triquetra (End)				shell					
Fusconaia flava	shell						shell		
Lampsilis ventricosa	2	0.12	0.02	5	0.63	0.04	1	0.33	0.01
Lasmigona costata	shell								
Legumia recta									
Pleurobema sintoxia (SpC)	shell								
Strophitus undulatus	shell								
Quadrula pustulosa									
Quadrula quadrula									
Venustacocha ellipsiformis (SpC)				shell					
Total	17		0.13	8		0.06	3		0.02
Corbicula fluminea (Exotic)	shell						shell		
Dreissena polymorpha (Exotic)									

Table 5. Numbers of unionids, relative abundance, and density (indvs./m²) recorded from St. Joseph River sites. Occurrence of live Asian clams (*Corbicula fluminea*) or their empty shells is indicated. (SpC = State listed as special concern, End = State listed as endangered, shell = only empty shell was found at the site).

	J1			J2			J3			J4			J5		
Species		rel. ab.	density		rel. ab.	density		rel. ab.	density		rel. ab.	density		rel. ab.	density
Actinonaias ligamentina							shell			shell			shell		
Alasmidonta marginata (SpC)							4	0.12	0.03				3	0.12	0.02
Alasmidonta viridis (SpC)							shell						shell		
Amblema plicata							shell						shell		
Anodonta grandis										shell					
Anodonta imbecillis	shell	0	0												
Anodontoides ferussacianus										shell			shell		
Cyclonaias tuberculata (SpC)							shell						shell		
Elliptio dilatata							shell						1shell		
Epioblasma triquetra (End)							shell						shell		
Fusconaia flava	1	0.06	0.01				2	0.06	0.02	2	0.02	0.02	2	0.08	0.02
Lampsilis ventricosa							1	0.03	0.01	1	0.01	0.01			
Lasmigona complanata							1	0.03	0.01						
Lasmigona costata							shell						shell		
Ligumia recta							shell						shell		
Leptodea fragilis	1	0.06	0.01				1	0.03	0.01	2	0.02	0.02	1	0.04	0.01
Pleurobema sintoxia (SpC)													shell		
Quadrula pustulosa							shell								
Quadrula quadrula	1	0.06	0.01				3	0.09	0.02	1	0.01	0.01			
Strophitus undulatus															
Truncilla truncata	14	0.78	0.11	1	1	0.01	20	0.61	0.16	113	0.95	0.88	19	0.76	0.15
Venustaconcha ellipsiformis (SpC)															
Total	17		0.13	1		0.01	32		0.25	119		0.93	25		0.20
Corbicula fluminea (Exotic)	shell						Live			shell			shell		
Dreissena Polymorpha (Exotic)	Live						Live			Live			Live		

Table 5 continued...

	J6			J7			J8			J9			J10		
Species		rel. ab.	density		rel. ab.	density		rel. ab.	density		rel. ab.	density		rel. ab.	density
Actinonaias ligamentina							shell			8	0.14	0.06	6	0.35	0.05
Alasmidonta marginata (SpC)										shell			shell		
Alasmidonta viridis (SpC)										shell					
Amblema plicata				shell			shell								
Anodonta grandis															
Anodonta imbecillis															
Anodontoides ferussacianus															
Cyclonaias tuberculata (SpC)							shell			20	0.34	0.16	shell		
Elliptio dilatata				2	0.03	0.02				3	0.05	0.02			
Epioblasma triquetra (End)										shell	0.00	0.00	shell		
Fusconaia flava	24	0.17	0.19	12	0.16	0.09	4	0.17	0.03	7	0.12	0.05	1	0.06	0.01
Lampsilis ventricosa	1	0.01	0.01	9	0.12	0.07	1	0.04	0.01	2	0.03	0.02			
Lasmigona complanata				1	0.01	0.01	shell								
Lasmigona costata										5	0.08	0.04	1	0.06	0.01
Ligumia recta							shell						1	0.06	0.01
Leptodea fragilis	2	0.01	0.02	5	0.07	0.04	16	0.70	0.13						
Pleurobema sintoxia (SpC)	1	0.01	0.01				shell			1	0.02	0.01	shell		
Quadrula pustulosa															
Quadrula quadrula	1	0.01	0.01	1	0.01	0.01									
Strophitus undulatus															
Truncilla truncata	114	0.80	0.89	44	0.59	0.34	2	0.09	0.02						
Venustaconcha ellipsiformis (SpC)															
Total	143		1.12	74		0.58	23		0.18	46		0.36	9		0.07
Corbicula fluminea (Exotic)				shell						Live			Live		
Dreissena Polymorpha (Exotic)	Live			Live			Live			Live			Live		

Table 6. Zebra mussel colonization data for St. Joseph survey sites. Colonization measures include the number of unionids colonized by zebra mussels (UCZ), mean number of zebra mussels per colonized unionid (ZM/U), and the precentage of individuals at a site colonized by zebra mussels (%CU).

	Site																							
	J1			J3			J4			J5			J6			J7			J8			J9		
Species	UCZ	ZM/U	%CU	UCZ	ZM/U	%CU	UCZ	ZM/U	%CU	UCZ	ZM/U	%CU	UCZ	ZM/U	%CU	UCZ	ZM/U	%CU	UCZ	ZM/U	%CU	UCZ	ZM/U	%CU
A. ligamentina																			1 shell	2		1	1	11
A. marginata										1	1	33.3												
C. tuberculata																			1 shell	1		1	1	5
F. flava				1	1	50							5	2	20.8	2	1	16.7	3	2.7	75			
L. ventricosa																6	1.8	66.6	1	1	100			
L. fragilis																1	1	33.3	9	2.1	56.3			
L. recta																			1 shell	2				
T. truncata	1	1	7.1	5	1.2	25	2	1	1.8	1	1	5.3	14	1.1	12.3	11	1.3	25.6						
Total	1	1	5.9	6	1.1	18.8	2	1	1.7	2	1	8	19	1.6	13.3	20	1.3	27	13	1.9	56.5	2	1	4.3

Figure 5. A zebra mussel (*Dreissena polymorpha*) attached to *Truncilla truncata* from the St. Joseph River (J6). The zebra mussel is approximately 3cm in length.

attached. The mean number of zebra mussels attached to unionids for sites surveyed in the St. Joseph was 1.2 zebra mussels per unionid. Most zebra mussels were relatively large, up to 4cm in length. No signs of zebra mussels were found in the Grand River. Live Asian clams (*C. fluminea*) were found at three sites on the St. Joseph River. Asian clam densities at these sites were fairly low and were restricted to a few individuals per transect. Asian clam shell was found at several sites on both the Grand and St. Joseph Rivers.

Ease of distinguishing external annular rings varied among species and to some degree among individuals of the same species. Annular ring data was collected only from individuals from which relatively accurate counts could be made (Table 7–8). The sample size for *Truncilla truncata* in the St. Joseph River was large enough to make comparisons of annular ring data among sites (Table 9).

Table 7. Mean number and range of external annular rings for selected species in the Grand River.

	mean	range	sample size
Actinonaias ligamentina	12.0	9-16	3
Amblema plicata	12.1	6-20	62
Cyclonaias tuberculata (SpC)	12.4	9-15	5
Epioblasma triquetra (End)	6		1
Fusconaia flava	10.2	4-15	6
Lampsilis ventricosa	9.2	4-18	9
Legumia recta	9		1
Quadrula pustulosa	11.0	6-15	4

Table 8. Mean number and range of external annular rings for selected species in the St. Joseph River.

	mean	range	sample size
Actinonaias ligamentina	20.2	15-23	6
Alasmidonta marginata (SpC)	6.7	4-8	7
Cyclonaias tuberculata (SpC)	15.0	4-21	20
Elliptio dilatata	15		1
Fusconaia flava	10.7	3-15	39
Lampsilis ventricosa	9.3	4-16	3
Lasmigona costata	16.7	15-18	3
Leptodea fragilis	3.8	1-7	4
Pleurobema sintoxia (SpC)	4		1
Quadrula quadrula	9.6	4-16	7
Truncilla truncata	6.6	2-14	296

Table 9. Mean number and range of external annular rings for *Truncilla truncata* at selected sites in the St. Joseph River.

	mean	range	sample size
J1	4.2	2-6	10
J2	3		1
J3	5.5	2-11	20
J4	7.0	3-14	111
J5	5.1	2-11	19
J6	7.3	3-12	111
J7	5.2	2-11	23
J8	3		1

Discussion

Shells provide a temporary record of the past composition of unionid communities. The rate at which empty shells show wear is highly variable depending on environmental conditions, but they can remain intact for years. The fact that only nine of the 16 native species recorded at the Grand River sites were represented by live individuals during this survey suggests that the community was once much more species rich than it is currently. For example, *Elliptio dilatata*, a species that was once reported as common in the Grand River (van der Schalie 1948), was represented only by empty shell in this study. Another recent survey of Grand River unionids found no live *E. dilatata* (Goforth *et al.* 2000). It is possible that populations are displaying an inherent boom and bust cycle driven by fluctuations in fish host densities or other factors. However, the decline is likely indicative of impacts such as a loss of appropriate fish hosts or habitat degradation. The absence of *D. polymorpha* or live *C. fluminea* in the Grand River suggests that the decline has not been driven by the presence of non-parasitized fish hosts (Table 10). Updated fish surveys would provide valuable data for comparison with these historical data to evaluate the status of fish communities at the mussel survey sites.

Although greater species richness was found in the St. Joseph River, most species were found in low densities compared to densities of these species that are typically observed in upstream tributaries of southern Michigan. The efficiency of methods used in this study is validated by the fact that numerous young, *Truncilla truncata* were detected at several sites. Individuals of this species were typically smaller (2-6cm) in relation to all other species in the St. Joseph. Behavioral or morphological characteristics of *T. truncata* may make it more resistant to negative impacts from zebra mussels, thus allowing it to remain in higher densities while other unionids decline. Although *T. truncata* was colonized by zebra mussels at six different sites, the rate of colonization may be lower than the colonization rates in other species. A larger sample size is needed to test this statistically. An alternate hypothesis is that *T. truncata*, which is a large river species, is better adapted to the habitats sampled at these downstream sites than the other species present and was therefore observed in greater abundance than other species during this survey.

Sites G1 and G2 correspond to locations of two sites surveyed by van der Schalie in 1945 east of Ionia (sites 9 and 8 respectively). The unionid communities at these sites are somewhat similar but have shown a general decline in species richness and abundance with a few exceptions. The state endangered *E. triquetra* was found at both sites in 2001 and not found at site 8 or 9 in 1945. Shell of A. grandis and S. undulatus were found at G2 and were not reported from site 9 in 1945. *A. ligamentina*, *E. dilatata*, *L. cosatata*, and *V. ellipsiformis* were found at site 9 in 1945 and were not found at G1 in 2001. *L. cosatata*, *P. sintoxia*, and *V. ellipsiformis* were found at site 8 in 1945 and not found at G2 in 2001. Three species found in both 1945 and 2001 were represented by shell only in 2001.

Epioblasma triquetra is a relatively small species, reaching 8cm in length. It's size makes it less likely to be collected by the brail bars (or crow-foot bars) that were used to survey unionids in 1945, and may have been overlooked for this reason. Locations of sites G1(2001) and 9(1945) are within 50m of each other, and G2(2001) and 8(1945) within 400m. It is possible that variations in habitat over these distances contributes to the differences seen between the two surveys.

Live zebra mussels and occurrences of state listed as special concern and/or endangered unionids were documented at several sites in the St. Joseph River (J3, J5, J6, J8, J9, and J10). A notable population of *C. tuberculata* was found at one of these sites (J9). Live Asian clams and zebra mussels were present at this site, and two individuals of state listed species of special concern were colonized by zebra mussels, one *C. tuberculata* and one *Alasmidonta marginata*. Most of the zebra mussels observed were large (up to 4cm) with only a few representing young age classes. Reproductive success appears to be low in the St. Joseph River in the vicinity of the sites surveyed. This may indicate that zebra mussel densities have stabilized at relatively low levels at these sites. There is little stable substrate for zebra mussels to attach to other than unionids. This might be a limiting factor for the species at certain sites. The moderate current velocities observed at these sites are also likely to be significant limiting factors for zebra mussel settling and colonization, keeping them at low densities.

Due to their dramatic impact on industry and recreation, zebra mussels have developed an infamous reputation as an invasive non-native species. The ability of zebra mussels to smother unionids by attaching to them in high densities is also well established. However, densities of zebra mussels observed at survey sites in the St. Joseph River were low. The continued presence and spread of this species in Michigan's rivers and lakes jeopardizes communities of native unionids throughout the state. The Grand and St. Joseph Rivers are important resources for recreational boating,

Table 10. Fish collected in a rotenone survey of the Grand River by the Michigan DNR in 1978 (Nelson and Smith 1981). Sites 15 and 16 correspond to sites G1-G2 and G3-G6 respectively.

Species	Common name	Site 15 (G1-2)	Site 16 (G3-6)
Ichthyomyzon castaneus	Chestnut lamprey		X
Lepisosteus osseus	Longnose gar		X
Oncorhynchus tshawytscha	Chinook salmon		X
Esox lucius	Northern pike	X	X
Carpiodes cyprinus	Quillback	X	X
Moxostoma spp.	Redhorse spp.	X	X
Moxostoma erythrurum	Golden redhorse	X	X
Moxostoma macrolepidotum	Northern redhorse	X	
Hypentelium nigricans	Northern hogsucker	X	X
Cyprinus carpio	Carp	X	X
Carassius auratus	Goldfish	X	
Notropis atherinoides	Emerald shiner		X
Notropis cornutus	Common shiner		X
Notropis hudsonius	Spottail shiner		X
Notropis spilopterus	Spotfin shiner	X	X
Notropis stramineus	Sand shiner		X
Pimnephales notatus	Bluntnose minnow	X	X
Ictalurus spp.	Bullhead spp.	X	X
Ictalurus melas	Black bullhead		X
Ictalurus punctatus	Channel catfish	X	X
Pylodictis olivaris	Flathead catfish		X
Micropterus dolomieui	Smallmouth bass	X	X
Lepomis cyanellus	Green sunfish		X
Lepomis gibbosus	Pumpkinseed	X	X
Lepomis megalotis	Longear sunfish		X
Ambloplites rupestris	Rock bass	X	X
Pomoxis nigromaculatus	Black crappie	X	X
Stizostedion vitreum	Walleye		X
Percina maculata	Blackside darter	X	X
Percina caprodes	Logperch	X	X
Etheostoma nigrum	Johnny darter		X

making them vulnerable to zebra mussel introduction and/or spread.

Another exotic bivalve, the *Corbicula fluminea* (Asian clam), has been in the eastern U.S. since the late 1950's. Although it has successfully established itself across a wide range, it has received relatively little attention. It has had little impact on industry, but its effect on river ecosystems and native unionid mussels is not well known. Several potential ways *C. fluminea* may be impacting native mussels have been proposed by various researchers and are summarized by Strayer (1999b). Being filter feeders, *C. fluminea* may compete with unionids for phytoplankton and other food suspended in the water column. *C. fluminea* also can pedal feed, removing edible particles from sediments. Juvenile unionids and sphaeridae (another family of native bivalve) also feed this way, and could potentially complete with *C. fluminea* for these resources. In high densities, *C. fluminea* might kill unionids by ingesting unionid sperm, glochidia, and newly metamorphosed juveniles. Density of *C. fluminea* was not high at any site surveyed. However, they were not targeted by the current surveys due to their small size. Alternate methods would need to be used in order to obtain quantitative density estimates for *C. fluminea.* It seems unlikely that unionids at sites visited in the Grand and St. Joseph Rivers would currently be under competitive pressures from *C. fluminea.* This species is known to have cycles of dramatic fluctuations in population density, so competition pressures could be periodic. Monitoring zebra mussel and Asian clam populations in the Grand and St. Joseph Rivers would help reveal the degree to which unionids in these rivers are at risk from non-native species.

The status of unionid populations mirrors the biological integrity of river systems. The rivers of southern Michigan have undergone direct and indirect impacts over the past century. The unionid communities of the Grand and St. Joseph Rivers are not only a product of the unique bio-geographical and evolutionary history of the region, they also reflect a recent history of impacts from habitat degradation, fluctuating status of fish hosts, and non-native species.

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Appendix I. Numbers of unionids found in each transect in the Grand River. Any shell found inside or outside transects are listed in the sum column. Unless otherwise noted "shell" = several empty shell were found at the site.

Site	G1									G2									G3								
Transect	1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8	
Species	# live indvs.								sum	# live indvs.								sum	# live indvs.								sum
Actinonaias ligamentina									0	2								2									0
Alasmidonta marginata (SpC)									1 valve									shell									shell
Alasmidonta viridis (SpC)									0									0									shell
Amblema plicata	3	2	1	1	1	1	3		12	12	11	2	9					34	3	1	5	2	1	2			14
Anodonta grandis									0									shell	1								1
Cyclonaias tuberculata (SpC)									1 valve	2	2					1		5									shell
Elliptio dilatata									0									shell									0
Epioblasma triquetra (End)		1							1	1m	1f							0									0
Fusconaia flava									shell	1			2					3	1				3	1			5
Lampsilis ventricosa	2	1	1		1		1		6	1		1	2	1				5	1	1				3			5
Lasmigona costata									0									0									shell
Legumia recta									shell						1			1									
Pleurobema sintoxia (SpC)									1 valve									0									
Quadrula pustulosa									shell				1	1		2		4									shell
Quadrula quadrula									0									0									shell
Strophitus undulatus									0									shell									shell
Venustaconcha ellipsiformis (SpC)									0									0									shell

Appendix I continued...

Site	G4									G5									G6								
Transect	1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8	
Species	# live indvs.								sum	# live indvs.								sum	# indvs.								sum
Actinonaias ligamentina							1		1					1				1									0
Alasmidonta marginata (SpC)									shell									shell									shell
Alasmidonta viridis (SpC)									0									0									0
Amblema plicata	1	1	1	1		1	1	7	13								2	2			1						1
Anodonta grandis	1								1									0			1						1
Cyclonaias tuberculata (SpC)									0									0									0
Elliptio dilatata									shell									0									shell
Epioblasma triquetra (End)									0									1 shell									0
Fusconaia flava									shell									0									shell
Lampsilis ventricosa	1							1	2					3		2		5					1				1
Lasmigona costata									shell									0									0
Legumia recta									0									0									0
Pleurobema sintoxia (SpC)									shell									0									0
Quadrula pustulosa									0									0									0
Quadrula quadrula									0									0									0
Strophitus undulatus									shell									0									0
Venustaconcha ellipsiformis (SpC)									0									shell									0

Appendix II. Numbers of unionids found in each transect in the St. Joseph River. Any shell found inside or outside transects are listed in the sum column. Unless otherwise noted "shell" = several empty shell were found at the site.

Site	J1									J2									J3								
Transect	1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8	
Species	# live individuals								sum	# indvs.								sum	# indvs.								sum
Actinonaias ligamentina									0									0									shell
Alasmidonta marginata (SpC)									0									0					1	3			4
Alasmidonta viridis (SpC)									0									0									1valve
Amblema plicata									0									0									shell
Anodonta grandis									0									0									0
Anodonta imbecillis									1 shell									0									0
Anodontoides ferussacianus									0									0									0
Cyclonaias tuberculata (SpC)									0									0									4 valves
Elliptio dilatata									0									0									shell
Epioblasma triquetra (End)									0									0									2 valves
Fusconaia flava							1		1									0	1		1						2
Lampsilis ventricosa									0									0								1	1
Lasmigona complanata									0									0	1								1
Lasmigona costata									0									0									shell
Ligumia recta									0									0									shell
Leptodea fragilis								1	1									0							1		1
Pleurobema sintoxia (SpC)									0									0									0
Quadrula pustulosa									0									0									shell
Quadrula quadrula				1					1									0	3								3
Strophitus undulatus									0									0									0
Truncilla truncata			1		3		4	6	14							1		1	6	2	1	3	1		2	5	20

Appendix II continued...

Site	J4									J5									J6								
Transect	1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8		1	2	3	4	5	6	7	8	
Species	# indvs.								sum	# indvs.								sum	# indvs.								sum
Actinonaias ligamentina									shell									shell									0
Alasmidonta marginata (SpC)									0		2		1					3									0
Alasmidonta viridis (SpC)									0									1 valve									0
Amblema plicata									0									1 shell									0
Anodonta grandis									shell									0									0
Anodonta imbecillis																		0									0
Anodontoides ferussacianus									shell									1 fresh shell									0
Cyclonaias tuberculata (SpC)									0									4 valves, 3 shells									0
Elliptio dilatata									0									1shell									0
Epioblasma triquetra (End)									0									3 female, 6 male valves									0
Fusconaia flava					1			1	2		2							2		1	3	6	5	6	1	2	24
Lampsilis ventricosa						1			1									0	1								1
Lasmigona complanata									0									0									0
Lasmigona costata									0									2 shells									0
Ligumia recta									0									1 shell									0
Leptodea fragilis	1	1							2		1							1			1				1		2
Pleurobema sintoxia (SpC)									0									1 valve	1								1
Quadrula pustulosa									0									0									0
Quadrula quadrula							1		1									0	1								1
Strophitus undulatus									0									0									0
Truncilla truncata		8	2	18	19	27	24	15	113	1	15	1	1		1			19	17		22	11	17	22	11	14	114

Appendix II continued...

Site	J7								
Transect	1	2	3	4	5	6	7	8	
Species	# indvs.								sum
Actinonaias ligamentina									0
Alasmidonta marginata (SpC)									0
Alasmidonta viridis (SpC)									0
Amblema plicata									shell
Anodonta grandis									0
Anodonta imbecillis									0
Anodontoides ferussacianus									0
Cyclonaias tuberculata (SpC)									0
Elliptio dilatata	1	1							2
Epioblasma triquetra (End)									0
Fusconaia flava	1		3		1	2	3	2	12
Lampsilis ventricosa	1	1	1	1	2	3			9
Lasmigona complanata				1					1
Lasmigona costata									0
Ligumia recta									0
Leptodea fragilis	2				2		1		5
Pleurobema sintoxia (SpC)									0
Quadrula pustulosa									0
Quadrula quadrula				1					1
Strophitus undulatus									0
Truncilla truncata	9		15	2	6	2	6	4	44

Site	J8								
Transect	1	2	3	4	5	6	7	8	
Species	# indvs.								sum
Actinonaias ligamentina									shell
Alasmidonta marginata (SpC)									0
Alasmidonta viridis (SpC)									0
Amblema plicata									shell
Anodonta grandis									0
Anodonta imbecillis									0
Anodontoides ferussacianus									0
Cyclonaias tuberculata (SpC)									shell
Elliptio dilatata									0
Epioblasma triquetra (End)									0
Fusconaia flava				1		3			4
Lampsilis ventricosa	1								1
Lasmigona complanata									shell
Lasmigona costata									0
Ligumia recta									shell
Leptodea fragilis	2	2	1	3		2	2	4	16
Pleurobema sintoxia (SpC)									shell
Quadrula pustulosa									0
Quadrula quadrula									0
Strophitus undulatus									0
Truncilla truncata	1			1					2

Site	J9								
Transect	1	2	3	4	5	6	7	8	
Species	# indvs.								sum
Actinonaias ligamentina				1		1	1	5	8
Alasmidonta marginata (SpC)									shell
Alasmidonta viridis (SpC)									2 valves
Amblema plicata									0
Anodonta grandis									0
Anodonta imbecillis									0
Anodontoides ferussacianus									0
Cyclonaias tuberculata (SpC)	3		2	2	7		3	3	20
Elliptio dilatata				1	2				3
Epioblasma triquetra (End)									shell
Fusconaia flava	1		1	2		1		2	7
Lampsilis ventricosa				1	1				2
Lasmigona complanata									0
Lasmigona costata		1		2	2				5
Ligumia recta									0
Leptodea fragilis									0
Pleurobema sintoxia (SpC)				1					1
Quadrula pustulosa									0
Quadrula quadrula									0
Strophitus undulatus									0
Truncilla truncata									0

Appendix II continued...

Site	J10								
Transect	1	2	3	4	5	6	7	8	
Species	# indvs.								sum
Actinonaias ligamentina	3		2					1	6
Alasmidonta marginata (SpC)									shell
Alasmidonta viridis (SpC)									0
Amblema plicata									0
Anodonta grandis									0
Anodonta imbecillis									0
Anodontoides ferussacianus									0
Cyclonaias tuberculata (SpC)									shell
Elliptio dilatata									0
Epioblasma triquetra (End)									2 valves
Fusconaia flava	1								1
Lampsilis ventricosa									0
Lasmigona complanata									0
Lasmigona costata	1								1
Ligumia recta				1					1
Leptodea fragilis									0
Pleurobema sintoxia (SpC)									shell
Quadrula pustulosa									0
Quadrula quadrula									0
Strophitus undulatus									0
Truncilla truncata									0