

**Freshwater mussels of the Kalamazoo River, Michigan, from Battle
Creek to Saugatuck**

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INTRODUCTION

The Kalamazoo River from Morrow Dam, near Galesburg, to its mouth at Lake Michigan is being investigated as part of a Remedial Investigation/Feasibility Study for the Allied Paper Inc./Portage Creek/Kalamazoo River Superfund Site. Because of the nature and extent of contamination by polychlorinated biphenyls (PCBs), remedial alternatives being considered include channelization with bank stabilization, dredging, and capping of contaminated sediments. These types of activities may significantly impact benthic invertebrate communities of the river, including freshwater mussels.

The Kalamazoo River has never been systematically surveyed for freshwater mussels. The goal of this study was to survey areas of the river likely impacted by releases of hazardous substances or likely to be impacted by remediation efforts. The objectives were (1) to determine substrates used by, and species, population structure and densities of freshwater mussels at potential remediation areas; (2) to determine substrate, species, population structure, and densities of freshwater mussels at less contaminated areas in the river; and (3) to assess the status of two known bed areas that were excavated/dredged to remove PCBs and other waste material.

METHODS

Fourteen sites on the river were surveyed from one to nine person hours between July 27 and August 26, 2000 (Table 1, Figure 1). GPS coordinates were taken at all sites except below Allegan City Dam and Lake Allegan (above Calkin's Dam). Coordinates were taken at upper and lower boundaries of the mussel beds for nine sites. Types of substrate (cobble, gravel, sand, or silt) were noted at each site. The area covered was from Wattles Park, Battle Creek, to Schultz Park, Douglas. Sites searched are either potential remediation sites or fairly undisturbed areas. A-Site/Willow Boulevard and King Highway were visited to assess potential damage due to sediment removal activity.

Mussels were collected by snorkeling, searching by hand, or using nets to scoop the substrate (done where water was too deep to snorkel or search by hand). The Allegan City Impoundment and Lake Allegan were searched by checking the shoreline for shells and searching by hand in shallower areas. Parts of Lake Allegan were also dragged with a crowfoot dredge.

Individuals were identified, measured and aged (by counting growth rings on the outer shell) to determine if any species are reproducing. After processing, mussels were returned to the approximate areas where they were found. Occasionally, voucher specimens were collected to be deposited into the University of Michigan Museum of Zoology's (UMMZ) Mollusk Collection. Since first year mussels are difficult to find, species with individuals three years old or less were considered to be reproducing.

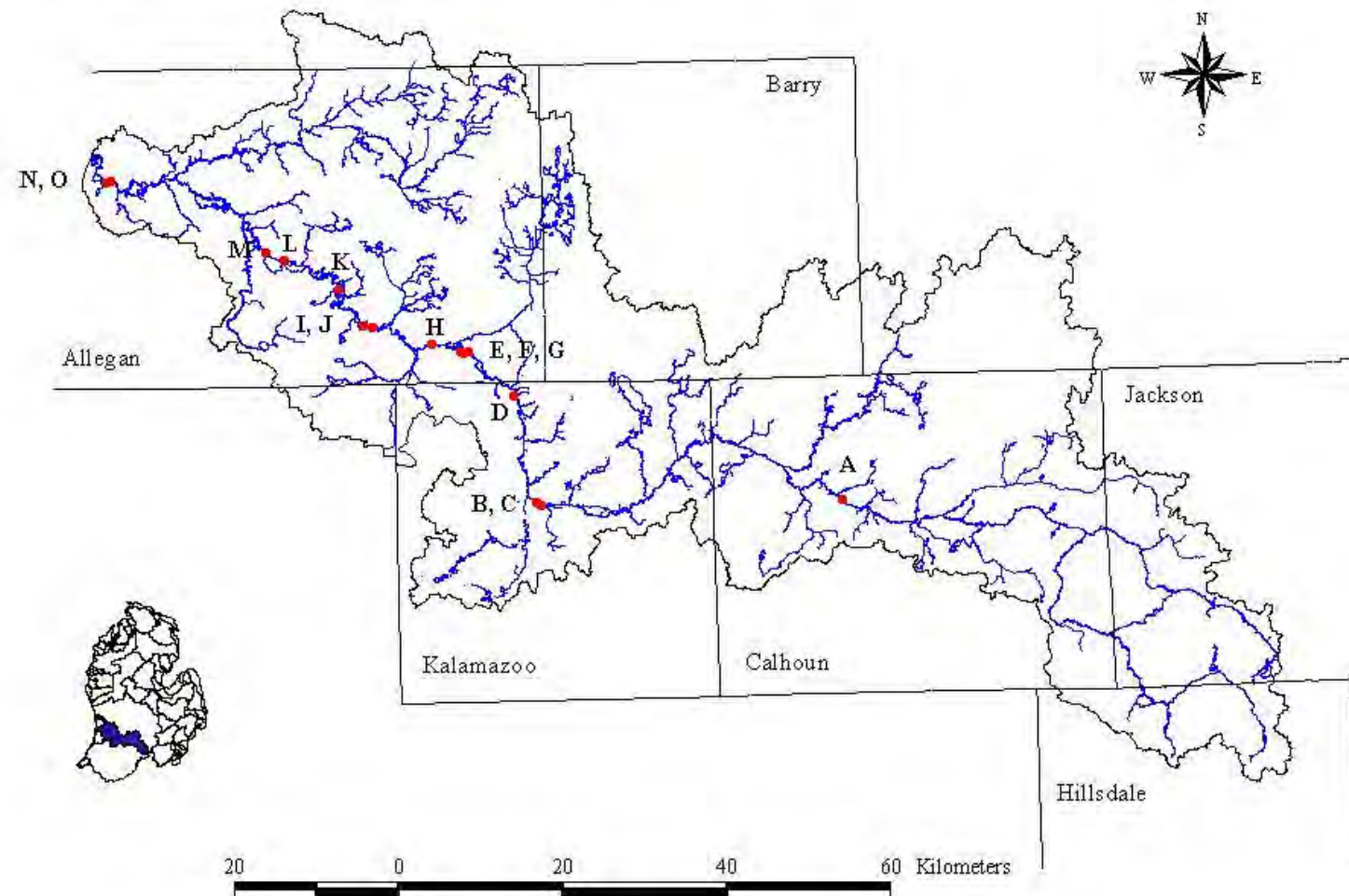
The zebra mussel, *Dreissena polymorpha* and the Asian Clam, *Corbicula fluminea*, are two introduced bivalve species that were noted in the mussel survey. Both species are of concern because of problems involving intake pipes in water treatment plants and effects on unionids. *Dreissena polymorpha* are especially detrimental because several individuals will settle directly on the unionids, impairing movement and possibly starving the native mussels.

Historical mussel records were gathered from the UMMZ's Mollusk Collection. Dates of collection were noted when available.

Table 1. Collection sites, dates and GPS locations. 2000

Map Key	Date	Site Name	North GPS location	West GPS location
A	September 15	Wattle's Park	N 42 deg 17.431'	W 85 deg 06.977'
B	August 1	A Site/Willow Boulevard, upper boundary	N 42 deg 17.023'	W 85 deg 33.045'
B	August 1	A Site/Willow Boulevard, lower boundary	N 42 deg 17.026'	W 85 deg 33.061'
C	August 1	King Highway, upper boundary	N 42 deg 17.264'	W 85 deg 33.429'
C	August 1	King Highway, lower boundary	N 42 deg 17.279'	W 85 deg 33.507'
D	July 27	Coggin's Farm (B Avenue)	N 42 deg 24.205'	W 85 deg 35.258'
E	August 22	Plainwell, Below U. S. 131 bridge	N 42 deg 27.281'	W 85 deg 39.316'
E	August 22	Plainwell, Below U. S. 131 bridge	N 42 deg 27.312'	W 85 deg 39.356'
F	August 22	Plainwell Impoundment	N 42 deg 27.189'	W 85 deg 39.775'
G	August 24	Below Plainwell Dam	N 42 deg 27.384'	W 85 deg 40.078'
H	August 24	Otsego City Impoundment, upper boundary	N 42 deg 27.556'	W 85 deg 40.980'
H	August 24	Otsego City Impoundment, lower boundary	N 42 deg 27.620'	W 85 deg 41.217'
I	August 15	Trowbridge Impoundment, upper boundary	N 42 deg 29.032'	W 85 deg 46.702'
I	August 15	Trowbridge Impoundment, lower boundary	N 42 deg 28.971'	W 85 deg 46.948'
J	August 15	Below Trowbridge Dam, upper boundary	N 42 deg 28.906'	W 85 deg 48.186'
J	August 15	Below Trowbridge Dam, lower boundary	N 42 deg 28.943'	W 85 deg 48.286'
K	September 26	Below Allegan City Dam	no reading	
L	August 3	Lake Allegan	no reading	
M	August 3	Below Calkin's Dam, upper boundary	N 42 deg 33.961'	W 85 deg 57.185'
M	August 3	Below Calkin's Dam, lower boundary	N 42 deg 33.979'	W 85 deg 57.163'
N	August 31	Saugatuck Township, upstream from U. S. 131, upper boundary	N 42 deg 38.851'	W 86 deg 11.176'
N	August 31	Saugatuck Township, upstream from U. S. 131, lower boundary	N 42 deg 38.897'	W 86 deg 11.083'
O	August 31	Douglas, Schultz Park 1	N 42 deg 38.564'	W 86 deg 11.505'
O	August 31	Douglas, Schultz Park 2	N 42 deg 38.718'	W 86 deg 11.348'

Figure 1. Mussel Survey localities along the Kalamazoo River



Map Sources: Michigan Rivers Inventory
University of Michigan SNRE GIS Research Facility

RESULTS AND DISCUSSION

Twenty-two species of mussels were found in the pre-1936 UMMZ collection records (Table 2). Only two sites from the historical collection (3 miles west of Ceresco, and 1.5 miles below Allegan) were directly comparable to those surveyed in 2000. Details of historical collection data are presented in Appendix 1. In general, the list of species found in the Kalamazoo River in 2000 is similar to that found in the historical collection. Specific differences are discussed with the results of the 2000 survey.

Table 2. UMMZ mussel collection records (site names in parentheses are those of comparable sites sampled in 2000)

<u>Species</u>	3 miles west of Ceresco (Wattle's Park), 1934	0.5 mi east of Galesburg, 1934	Comstock, 1934	"Above Kalamazoo", pre-1936	5 miles above Kalamazoo, 1929	1.5 miles below Allegan (Allegan City Dam) 1929	Saugatuck, pre-1936
Mucket, <i>Actinonaias ligamentina</i>	X	X	X				X
Elktoe, <i>Alasmidonta marginata</i>	X						
Three ridge, <i>Amblema plicata</i>							X
Cylindrical papershell, <i>Anodontoides ferruscianus</i>			X				
Purple wartyback, <i>Cyclonaias tuberculata</i>							X
Spike, <i>Elliptio dilatata</i>	X	X	X		X	X	X
Wabash pigtoe, <i>Fusconaia flava</i>	X	X	X		X	X	
Fat mucket, <i>Lampsilis siliquoidea</i>							X
Pocketbook, <i>Lampsilis ventricosa</i>	X		X				X
White heelsplitter, <i>Lasmigona complanata</i>							X
Creek heelsplitter, <i>Lasmigona compressa</i>	X						
Fluted shell, <i>Lasmigona costata</i>							X
Fragile papershell, <i>Leptodea fragilis</i>							X
Black sandshell, <i>Ligumia recta</i>							X
Round pigtoe, <i>Pleurobema coccineum</i>	X		X		X		
Pink heelsplitter, <i>Proptera alata</i>							X
Floater, <i>Pyganodon grandis</i>							X
Pimpleback, <i>Quadrula pustulosa</i>							X
Squawfoot, <i>Strophitus undulatus</i>	X		X		X		
Deertoe, <i>Truncilla truncata</i>						X	X
Ellipse, <i>Venustaconcha ellipsiformis</i>	X		X	X			
Rainbow shell, <i>Villosa iris</i>	X		X		X		X

Species present

Sixteen species with live individuals and seven species of shell only were found throughout the entire collection area for a total of 23 species (Table 3). The highest number of species was found at Schultz Park, in Douglas, with 14 species. Coggin's Farm, below Calkin's Dam, and below Trowbridge Dam had 11, 9 and 9 species, respectively.

Nine sites had mussels that were age three or younger, indicating the species were reproducing (Table 3). Coggin's farm (B Avenue) had the highest number of reproducing species. Four sites (Wattle's Park, A-Site/Willow Avenue, Trowbridge Impoundment, and below Allegan City Dam) had only older individuals. Complete data on mussel ages and lengths are presented in Appendix 2.

Of the five species of special concern found within the Superfund site, only the elktoe, *Alasmidonta marginata*, was found live. Four other species, the purple wartyback, *Cylconaias tuberculata*, the pigtoe, *Pleurobema coccineum*, the ellipse, *Venustaconcha ellipsiformis*, and the rainbow, *Villosa iris*, were found as shells only. *Cyclonaias tuberculata* was only found below Trowbridge Impoundment, and the shell was well worn. A preliminary mussel survey in 1999 found six live *C. tuberculata* at the Pottawattamie Marsh, upstream from the U. S. 131/I-196 bridge (C. Mehne, pers. obs.). This species was historically found in Saugatuck, but the record did not describe what part of the river in Saugatuck. This species may be found more near the mouth of the river, or in deeper areas not covered in this survey. Shells were found in dredge spoils from the mouth of the river in 1994 (Michigan Natural Features Inventory).

Host fish are a significant factor influencing mussel populations. Mussels have a parasitic larval stage (glochidia) and must attach to the gills or fins of a fish to metamorphose into juveniles. Certain mussel species metamorphose on a narrow range of fish species. Channel catfish and yellow bullhead have been found to be suitable fish hosts for *C. tuberculata* (Hove, et al, 1994). Both these species have been historically found below Calkin's Dam (UMMZ Fish Division Catalogue nos. 212204 and 229864). Several yellow bullhead have recently been observed in this area (C. Mehne, pers obs).

State endangered species were not found in historical records or in this survey. However, a worn specimen of the snuffbox mussel, *Epioblasma triquetra*, was found below Calkin's Dam by the MDNR boat launch in 1996. This specimen was deposited in the Illinois Natural History Survey collection (INHS no. 18730). This is the first record of this species on the Kalamazoo River. However, its presence is not surprising since *E. triquetra* has been found in both the Grand and St. Joseph Rivers (van der Schalie, 1936; 1941). Further investigations of populations below Calkins Dam may locate live individuals of this species. Its host fish, the logperch, *Percina caprodes*, was collected below the dam in 1993 (UMMZ Fish Div. Cat. no. 229218).

Mussel abundance was not related to type of substrate (Table 4). Numbers of mussels per person hour searched were divided into three categories: 0-5, 6 to 9 and 10 or greater. Within these categories, the proportion of the total types of substrate recorded was calculated (Table 5). These proportions did show any particular patterns—i. e. more mussels were not found when a particular substrate had a higher proportion. Substrate itself cannot predict the presence of mussel populations across sites (Strayer, 1981; 1993). Unionid communities in general are patchy, and this patchiness may be explained by their presence in “flow refugia” (Strayer, 1999). Flow refugia are areas where shear stress is low enough during flooding events to not displace unionids. However, these flow refugia do not explain patchiness of unionids in lakes or hydrologically stable streams. The absence or reduced abundance of unionids in impounded areas, generally considered stable during floods, is probably due to the lack of suitable fish hosts and presence of excess silt.

In a comparison of areas with similar substrates and geologic histories, the presence of two species of mussels were found to be correlated with the presence of their respective fish hosts (Sherman-Mulcrone, 2000). Both stable substrate areas (flow refugia) and host fish likely influence the persistence of mussel populations. These characteristics must be maintained to ensure the survival of the mussel populations.

SPECIES	Wattle's Park	A-site/Willow Blvd	King Highway	Coggin's farm (B Avenue)	Below U. S. 131 bridge	Plainwell Impoundment	Below Plainwell dam	Otsego (Menasha) Impoundment	Below Trowbridge Dam	Trowbridge impoundment 1, 2	Allegan City Impoundment	Below Allegan City Dam	Lake Allegan (above Calkin's Dam)	Below Calkins Dam	Saugateck Twp, upstream from U. S. 31/I-196 bridge	Douglas, Schultz Park
Mucket, <i>Actinonaias ligamentina</i>	27	18	32	27	68*	15*	25*	7	7*	10		5		D		
Elktoe, <i>Alasmodonta marginata</i>	1	D	1*	3*	1*			1*	D	D						
Three ridge, <i>Amblema plicata</i>															D	
Purple wartback, <i>Cyclonaias tuberculata</i>									D							
Spike, <i>Elliptio dilatata</i>		D		D						D						D
Wabash pigtoe, <i>Fusconaia flava</i>	1	7	7	D	D				D	D				3	4*	4*
Fat mucket, <i>Lampsilis siliquoidea</i>		1					D									D
Pocketbook, <i>Lampsilis ventricosa</i>		3	2	6*	9*	2*	5	1	1	2		3		7*		D
White heelsplitter, <i>Lasmigona complanata</i>	D	17	17	24*	15*	3	3*	1	4	8		1		6	3	2
Creek heelsplitter, <i>Lasmigona compressa</i>	1													1		
Fluted shell, <i>Lasmigona costata</i>	D		2	2*	2		D			D				D		
Fragile papershell, <i>Leptodea fragilis</i>				1*	1									14*	3*	2
Black sandshell, <i>Ligumia recta</i>									D							
Round pigtoe, <i>Pleurobema coccineum</i>				D												D
Pink heelsplitter, <i>Proptera alata</i>																D
Floater, <i>Pyganodon grandis</i>														1	1*	3
Pimpleback, <i>Quadrula pustulosa</i>															2	D
Mapleleaf, <i>Quadrula quadrula</i>														52*	34*	47*
Squawfoot, <i>Strophitus undulatus</i>	D	1	1	1		1*		2	D	D		1		5		
Fawnsfoot, <i>Truncilla donaciformis</i>														1*		1
Deertoe, <i>Truncilla truncata</i>																4*
Paper pondshell, <i>Utterbackia imbecilis</i>															1	D
Ellipse, <i>Venustaconcha ellipsiformis</i>				D					D							
TOTAL	30	47	62	64	96	21	33	12	12	20	0	10	0	90	48	63

D = shell only * = population likely reproducing (live individuals ≤ 3 years old present)

Table 4. Substrate types found and numbers of live mussels collected at each site

SITE	Cobble	Gravel	Sand	Silt	Other	Total	No. mussels per person hour searching
						No. Live Mussels	
Wattle's Park	X	X				30	10
A-site/Willow Blvd			X			47	4.5
King Highway	X		X	X	paper waste	62	6.9
Coggin's farm (B Avenue)	X	X				64	3.2
Plainwell, below U. S. 131 bridge		X		X	Clay or paper waste	96	10.4
Plainwell Impoundment		X	X			21	20.1
Below Plainwell Dam		X	X			33	7
Otsego (Menasha) Impoundment		X	X			12	2.8
Below Trowbridge Dam	X	X	X			12	2.1
Trowbridge impoundment 1, 2		X		X	mud	20	1.6
Below Allegan City Dam			X	X		10	1.6
Lake Allegan (Calkin's Dam)				X	packed gravel	0	0
Below Calkin's Dam		X	X			90	10
Saugatuck Twp, upstream from U. S. 131/I-196 bridge			X	X		48	6.4
Douglas, Schultz Park				X		63	21

Table 5. Proportion of total substrate for numbers of mussels per person hour searched

No. of mussels per person hour	Substrate			
	Cobble	Gravel	Sand	Silt
0 to 5	0.15	0.31	0.31	0.23
5 to 9	0.14	0.14	0.43	0.29
10 or greater	0.11	0.44	0.22	0.22

Species abundance

The mucket, *Actinonaias ligamentina*, was the most abundant mussel across most all the sites (Table 6). The white heelsplitter, *Lasmigona complanata* and the pocketbook, *Lampsilis ventricosa*, also made up a large percentage of the mussel fauna across most of the sites.

Table 6. Species percent of total fauna found at each site, live individuals only

SPECIES	Wattle's Park	A-site/Willow Blvd	King Highway	Coggin's farm (B Avenue)	Plainwell, at U. S. 131 bridge	Plainwell Impoundment	Below Plainwell Dam	Otsego (Menasha) Impoundment	Below Trowbridge Dam	Trowbridge Impoundment	Below Allegan City Dam	Below Calkins Dam	Saugatuck Twp, upstream from U. S. 31/I-196 bridge	Douglas, Schultz Park
Mucket, <i>Actinonaias ligamentina</i>	90	38	52	42	71	71	76	58	58	50	50			
Elktoe, <i>Alasmidonta marginata</i>	3		2	5	1			8						
Wabash pigtoe, <i>Fusconaia flava</i>	3	15	11									3	8	6
Fat mucket, <i>Lampsilis siliquoidea</i>		2												
Pocketbook, <i>Lampsilis ventricosa</i>		6	3	9	9	10	15	8	8	10	30	8		
White heelsplitter, <i>Lasmigona complanata</i>		36	27	38	16	14	9	8	33	40	10	7	6	3
Creek heelsplitter, <i>Lasmigona compressa</i>	3											1		
Fluted shell, <i>Lasmigona costata</i>			3	3	2									
Fragile papershell, <i>Leptodea fragilis</i>				2	1							16	6	3
Floater, <i>Pyganodon grandis</i>												1	2	5
Pimpleback, <i>Quadrula pustulosa</i>													4	
Mapleleaf, <i>Quadrula quadrula</i>												58	71	75
Squawfoot, <i>Strophitus undulatus</i>		2	2	2		5		17			10	6		
Fawnsfoot, <i>Truncilla donaciformis</i>												1		2
Deertoe, <i>Truncilla truncata</i>														6
Paper pondshell, <i>Utterbackia imbecilis</i>													2	
NUMBER INDIVIDUALS COLLECTED	30	47	62	64	96	21	33	12	12	20	10	90	48	63

The fat mucket, *Lampsilis siliquoidea*, the creek heelsplitter, *Lasmigona compressa*, and the paper pondshell, *Utterbackia imbecilis*, were fairly rare. *Lampsilis siliquoidea* is often found in lakes and smaller streams. *Lasmigona compressa* is also often found in streams, rather than larger river areas (van der Schalie, 1938).

A change in the distribution of mussel fauna was apparent below Calkin's Dam. Upstream of the dam, *A. ligamentina* was most abundant. Below the dam, the mapleleaf, *Quadrula quadrula*, makes up the greatest percentage of the mussel population. The

pimpleback, *Q. pustulosa*, the fawnsfoot, *Truncilla donaciformis*, and the deertoe, *Truncilla truncata*, are only found below Calkin's Dam. This is consistent with findings of van der Schalie's study (1938) on the Huron River that *Q. quadrula*, *Q. pustulosa*, *T. truncata* and *T. donaciformis* are generally more abundant in downstream areas. The floater, *Pyganodon grandis* is only noted below Calkin's Dam in this survey. *Pyganodon grandis* is generally found in slower waters, lakes, or smaller streams. In an earlier study, it was found at several sites upstream of Wattle's Park (Sherman, 1997). A thinner shelled species, *P. grandis* may be more vulnerable to man-made impacts than thicker shelled mussels.

The absence of *A. ligamentina* below Calkin's Dam and downstream sites may be due to limitations of fish hosts or unsuitable habitat. Historical records indicate *A. ligamentina* were found in Saugatuck. Host fish for *A. ligamentina* found in other river basins include several centrarchids (bluegill, green sunfish, largemouth bass, rock bass, smallmouth bass, white crappie) and yellow perch (Watters, 1994). While these fish species are likely to be found in waters around Saugatuck, habitat may not have been suitable for the mussels at the specific areas searched.

Sites with the greatest number of mussels include below U. S. 131 in Plainwell (96), below Calkin's Dam (90), King's Highway (62), Coggin's Farm (64), Schultz Park in Douglas (63), and upstream from the U. S. 131/I-196 bridge in Saugatuck Township (48) (Table 3). Fewest total mussels were found below Allegan City Dam (10), Otsego Impoundment (12), below Trowbridge Dam (12), Trowbridge Impoundment (20), and Plainwell Impoundment (21). Moderate numbers were found at Wattle's Park (30), A-Site/Willow Boulevard (47), and upstream from the U. S. 31/I-196 bridge in Saugatuck (48). No live individuals or shells were found in Lake Allegan (above Calkin's Dam) or above the Allegan City Dam.

Schultz Park in Douglas had the highest number of live mussels collected per unit effort (21), recorded as person hours spent searching (Table 7). However, these numbers may have been skewed by an unusually high number of *Q. quadrula*. Sixty-eight were found along the shore with four people searching for a half hour, and no other species were found. Conditions may be ideal for this species, since it was also found in great numbers in the Pottawattamie Marsh in 1999 (Chuck Mehne, per. obs.). However, *Q. quadrula* is a commercially important species and is harvested in other states. Michigan does not allow mussel harvests, but poaching on the Grand River is known. The unusually high numbers of this species alone along the shore raised suspicions that the mussels had been placed near shore by poachers.

Higher numbers of catch per unit effort were also found at the Plainwell Impoundment (20.1), the U. S. 131 bridge below Plainwell (10.4), below Calkin's Dam (10), and Wattle's Park (10). Lower numbers of catch per unit effort were at the U. S. 31/I-196 bridge in Saugatuck Township (6.4), Trowbridge Impoundment (1.6), below the Trowbridge Impoundment (2.1), Otsego City (2.8) and below Allegan City Dam (2.7).

Table 7. Live mussels collected per person hour searching

	Wattle's Park	A-site/Willow Blvd	King Highway	Coggin's farm (B Avenue)	Plainwell, at U. S. 131 bridge	Plainwell Impoundment	Below Plainwell Dam	Otsego (Menasha) Impoundment	Below Trowbridge Dam	Trowbridge Impoundment	Allegan City Impoundment	Below Allegan City Dam	Lake Allegan (above Calkin's Dam)	Below Calkin's Dam	Saugatuck Twp, upstream from U. S. 31/I-196 bridge	Douglas, Schultz Park
Person-hours spent searching	3.0	8.0	2.3	20.0	9.3	1.0	4.8	4.3	5.7	12.8	4.5	3.8	2.8	9.0	7.5	3.0
SPECIES																
Mucket, <i>Actinonaias ligamentina</i>	9.0	2.3	3.6	1.4	7.4	15.0	5.3	1.6	1.2	0.8		1.3				
Elktoe, <i>Alasmidonta marginata</i>	0.3		0.1	0.2	0.1			0.2								
Wabash pigtoe, <i>Fusconaia flava</i>	0.3	0.9	0.8											0.3	0.5	1.3
Fat mucket, <i>Lampsilis siliquoidea</i>		0.1														
Pocketbook, <i>Lampsilis ventricosa</i>		0.4	0.2	0.3	1.0	2.0	1.1	0.2	0.2	0.2		0.8		0.8		
White heelsplitter, <i>Lasmigona complanata</i>		0.9	1.9	1.2	1.6	3.0	0.6	0.2	0.7	0.6		0.3		0.7	0.4	0.7
Creek heelsplitter, <i>Lasmigona compressa</i>	0.3													0.1		
Fluted shell, <i>Lasmigona costata</i>			0.2	0.1	0.2											
Fragile papershell, <i>Leptodea fragilis</i>				0.1	0.1									1.6	0.4	0.7
Floater, <i>Pyganodon grandis</i>														0.1	0.1	1.0
Pimpleback, <i>Quadrula pustulosa</i>															0.3	
Mapleleaf, <i>Quadrula quadrula</i>														5.8	4.5	15.7
Squawfoot, <i>Strophitus undulatus</i>		0.1	0.1	0.1		0.1		0.5				0.3		0.6		
Fawnsfoot, <i>Truncilla donaciformis</i>														0.1		0.3
Deertoe, <i>Truncilla truncata</i>																1.3
Paper pondshell, <i>Utterbackia imbecilis</i>															0.1	
TOTAL	10.0	4.5	6.9	3.2	10.4	20.1	6.9	2.8	2.1	1.6	0.0	2.7	0.0	10.0	6.4	21.0

Species diversity

No trends in number of species found or species diversity were found among sites (Table 8). Shannon-Wiener indices of diversity (H') ranged from 0.19 to 0.61 while the H' max indicating maximum evenness of diversity ranged from 0.48 to 0.95 among sites. J' , the observed diversity as a proportion of the maximum possible diversity, ranged from 0.31 to 0.86.

To compare diversity (H') among sites, sites with similar species richness (numbers of live species) can be matched. Of the sites with seven to nine live species, the area below Calkin's Dam had the highest diversity (.61), and Schultz Park had the lowest (.43). Of sites with five to six species, A-Site/Willow Boulevard had the highest (.59) and Plainwell at the U. S. 131 bridge was the lowest (.41). Wattle's Park had the lowest diversity index (.19) of sites with three to four species, and below Allegan City Dam had the highest (.51).

The equability of species diversity (J'), showed somewhat different results from the diversity index (H'). Coggin's Farm had the highest (.69) and Schultz Park the lowest (.51) of

the sites with seven to nine species. For sites with five to six species, Plainwell at the U. S. 131 bridge had the lowest evenness value (.52) and both the other sites had approximately equal indices (.76 and .77 at A-Site/Willow Boulevard and Otsego Impoundment, respectively). Of the sites with the fewest species, Wattle's Park had the lowest index of evenness (.31) while the Trowbridge Impoundment had the highest (.86).

The mussel faunas in the Kalamazoo did not show a steady increase in diversity from upstream to downstream, as is usually observed (van der Schalie, 1938). Coggin's Farm, one of the farther upstream sites, had 11 species, and Schultz Park, the most downstream site, had 14 species. Below Plainwell Dam (downstream) to below Trowbridge Dam had only five species. Below the Allegan City Dam, only four species were found. In general, the diversity was lowest in the middle reaches of the river, from Plainwell to below Allegan City Dam. Impoundments and historically poor water quality in these reaches have likely impacted mussel diversity.

Table 8. Species diversity at each site, listed from upstream to downstream

	Wattle's Park	A-site/Willow Blvd	King Highway	Coggin's farm (B Avenue)	Plainwell, at U. S. 131 bridge	Plainwell Impoundment	Below Plainwell Dam	Otsego (Menasha) Impoundment	Below Trowbridge Dam	Trowbridge Impoundment	Below Allegan City Dam	Below Calkins Dam	Saugatuck Twp, upstream from U. S. 31/I-196 bridge	Douglas, Schultz Park
Total number of species	7	8	7	11	7	4	5	5	9	8	4	11	8	14
Number of species with live individual	4	6	7	7	6	4	3	5	3	3	4	9	7	7
Number of species with shell only	3	2		4	1		2		6	5		2	1	7
H'	0.19	0.59	0.56	0.58	0.41	0.39	0.31	0.54	0.39	0.41	0.51	0.61	0.47	0.43
H' max	0.60	0.78	0.85	0.85	0.78	0.60	0.48	0.70	0.48	0.48	0.60	0.95	0.85	0.85
J'	0.31	0.76	0.67	0.69	0.52	0.64	0.65	0.77	0.81	0.86	0.84	0.64	0.56	0.51

Disturbed areas

Generally, mussel numbers declined in the two areas surveyed before and after sediment removal actions (Table 9). The 1999 survey before the removal actions were conducted by one of us (CJM) in June. In 1999, mussel counts were stopped after 40 or more of one species were found. The complete survey data from 1999 are in Appendix 3. At A-Site/Willow, the overall numbers of mussels decreased because of declines in the three most abundant species, *A. ligamentina*, *F. flava*, and *L. complanata*. At the King Highway site, the overall numbers also decreased, showing *L. complanata* with the greatest declines.

Table 9. A-Site/Willow Boulevard and King Highway, before and after remediation, 1999 and 2000

	Total mussels collected				Mussels per person hour searched			
	A-site/Willow Blvd, 1999	A-site/Willow Blvd, 2000	King Highway, 1999	King Highway, 2000	A-site/Willow Blvd, 1999	A-site/Willow Blvd, 2000	King Highway, 1999	King Highway, 2000
Person hours spent searching	3	8	3	2.3	3	8	3	2.3
SPECIES								
Mucket, <i>Actinonaias ligamentina</i>	>40	18	>40	32	>13	2	>13	14
Elktoe, <i>Alasmidonta marginata</i>		D	D	1				
Spike, <i>Elliptio dilatata</i>	1	D	D		<1			
Wabash pigtoe, <i>Fusconaia flava</i>	>40	7	7	7	>13	<1	2	3
Fat mucket, <i>Lampsilis siliquoidea</i>		1				<1		
Pocketbook, <i>Lampsilis ventricosa</i>	1	3	5	2	<1	<1	2	1
White heelsplitter, <i>Lasmigona complanata</i>	>40	17	>40	17	>13	2	>13	7
Fluted shell, <i>Lasmigona costata</i>			1	2			<1	1
Floater, <i>Pyganodon grandis</i>			3				1	<1
Squawfoot, <i>Strophitus undulatus</i>		1		1				
TOTAL	>122	47	>96	62	>40	5	>32	27

Introduced species

Corbicula fluminea was noted at the most upstream site, at Wattle's Park down to below Calkin's Dam. This species was previously noted at this site (Sherman, 1997). *Dreissena polymorpha* was only noted below Calkin's Dam in 2000, but clusters were observed in Lake Allegan in 2000 (Chuck Mehne, pers. obs.) and 2001 (Jeff Cooper, Michigan DEQ, Surface Water Quality Division, pers. obs.). The presence of these two species should be noted if remediation efforts include dredging infested areas and transferring spoils to uninfested areas.

CONCLUSIONS

Mussel populations persist in the Kalamazoo River area studied throughout the Allied Paper Inc./Portage Creek/Kalamazoo River Superfund Site. Fewer individuals were found from the Otsego Impoundment to Lake Allegan. Fewer species were found reproducing in impoundment areas than in the free flowing sections of the river.

Catch per unit effort was greatest at Schulz Park, probably due to high numbers of *Q. quadrula*. Higher catches per unit effort were also at Wattle's Park, Plainwell Impoundment, and below Calkin's Dam. Available data indicate that Wattle's Park had the least amount of contamination and habitat modification. Although impoundments are generally detrimental to mussels, Plainwell Impoundment likely has enough current to be suitable for mussels. Mussels in general persist in tailwaters of dams, likely due to the water flow and availability of fish hosts. Below Calkin's Dam probably had high catches per unit effort due to both these conditions.

Higher species diversity was found at the most downstream sites, as expected. However, diversity did not steadily increase from the farthest upstream site to the lowest downstream site. Site characteristics, such as flow refugia, impoundments, and fish hosts are likely the reason for the deviation from a steadily increasing trend. These characteristics are probably better indicators of diversity for the Kalamazoo River.

Dams and other habitat alterations have likely impacted mussel populations. Dam removal to return the river to its "natural" state would likely improve water quality and access to fish hosts for mussels. However, removing dams could release PCBs buried in sediments behind the impoundments. Dredging behind dams to remove PCB-contaminated sediment before dam removal could physically destroy mussel beds and may increase suspended solids in the water column. However, present mussel populations could be transplanted, and populations could recolonize after dam removal. Keeping dams in place and reinforcing banks to prevent erosion and release of additional PCBs may damage fish habitat and affect mussels by reducing populations of potential fish hosts. Reinforcing stream banks using standard engineering techniques (sheet pile walls, stone rip rap, etc.) will also increase stream velocity at high flows, which may result in a loss of instream habitat due to streambed erosion.

Mussels at A-Site/Willow and King Highway show a decline in overall numbers. These changes may reflect impacts from sediment removal activities. Dredging activities probably either destroyed or shifted mussel beds.

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