Final Report

Mussel Habitat Enhancement Monitoring
Upper Mississippi River Pool 11
Bertom and McCartney Lakes Upper Mississippi River Restoration
Habitat Restoration Enhancement Project
October 2014.

Prepared by Dan Kelner
Biologist
Regional Planning and Environment Division North
U.S. Army Corps Engineers, St. Paul District
180 Fifth Street East
St. Paul, Minnesota 55101

January 2015

Acknowledgements

The project was funded by the U.S. Army Corps of Engineers (Corps), Rock Island District, Upper Mississippi River Restoration (UMRR) Habitat and Restoration Enhancement Project (HREP). Dan Kelner from the Corps, St. Paul District was the field team leader and author of this report. Mike Davis, Minnesota Department of Natural Resources (MNDNR) provided malacological assistance in the field and Shelby Marr and Zeb Secrist (both from MNDNR) provided diving services. Joe Jordan and Davi Michl (both from the Corps, Rock Island District) assisted with the field effort. Scott Gritters (Iowa Department of Natural Resources) and Jeff Janvrin (Wisconsin Department of Natural Resources) were helpful in providing project information and assisted with the study design.

Introduction

The Corps is interested in developing a greater understanding of native mussel mussel habitat requirements within its waterways and whether habitat can be enhanced or created. In particular, the three Corps districts in the Upper Mississippi River (UMR), St. Louis, Rock Island, and St. Paul are evaluating whether mussel habitat enhancement can be incorporated into the Upper Mississippi River Restoration (UMRR) program (Environmental Management Program) and into routine UMR channel maintenance activities. Few projects have attempted to create physical mussel habitat. From a literature search by ESI (2014) only four projects have been identified, only one of which has been attempted on the UMR, the current Bertom and McCartney Lakes UMRR-Habitat Restoration and Enhancement Project (HREP) that this report addresses.

The Bertom and McCartney Lake HREP occurs near Cassville, Grant County, Wisconsin in UMR Pool 11 near River Mile 602 (Figure 1). The features of the fish and mussel enhancement features of the HREP were constructed from 1990-92. The project consisted of creating a high velocity run (Habitat Channel) connected to another secondary channel with no modifications (Control Channel) for comparison (Figure 2). The high velocity run contained a gradation of substrate sizes and fish LUNKERS (Little Underwater Neighborhood Keepers Encompassing Rheotactic Salmonids). Conceptual drawings are provided in Figure 3. The project goal was to establish a mussel bed by creating both fish and mussel habitat as a means of introducing mussels via fish host life history requirement and eventual self sustained mussel recruitment.

Overall, UMR Pool 11 contains a diverse assemblage of native mussels with 32 species including two federally endangered species, sheepnose (*Plethobasus cyphyu*s) and Higgins eye (*Lampsilis higginsii*), and several additional state listed species in Wisconsin and Iowa (Table 1). One of fourteen Higgins eye Essential Habitat Areas (EHA) occurs in the pool near Cassville, WI, approximately five river miles upstream of the Bertom and McCartney Lakes HREP. Mussels are patchily distributed throughout the pool and mussel species richness and abundance is relatively low within the Bertom and McCartney HREP fish and mussel enhancement area. Given the close proximity and potential for mussel colonization from the Cassville Higgins eye EHA and elsewhere in the pool, the Bertom and McCartney HREP fish and mussel enhancement project provides an excellent opportunity for mussel habitat creation. Lucchesi and Thiel (1988) conducted brail surveys in the area and reported a total of 10 live species (see Table 1). They reported very few mussels in the Habitat Channel area pre-project with only eleven individual juvenile mussels of five species recorded. In the Control Channel they reported 16 juvenile mussels of the same five species as in the Habitat Channel. It was assumed that no mussels occurred in the Habitat Channel immediately post construction as mussels would have been removed by dredging or buried by rock placement.

Fish and mussel habitat was enhanced by lining approximately 1,500 ft (457 m) of an existing side channel adjacent to the main channel and upstream of Coalpit Slough (see Figure 3). The channel was designed as a high velocity area to deter *Dreissena polymorpha* (zebra mussel) colonization while favoring riverine native mussels. The selected side channel had a minimum bottom width of 50 ft (15 m). Rock of several different sizes, gradations, and types was used to further diversify the habitat. Side slopes were constructed as 1:2, rock depth averaged 2 ft (0.6 m), and minimum depth over the rock was 4 ft (1.2 m). A total of 9,000 tons (5,625 CY) of quarry rock of different sizes were used. The channel was divided into seven discrete sections. The first section immediately following the partial closing structure was 300 ft (91 m) long; the remaining sections were 200 ft (61 m) long. The existing channel was excavated by dragline or clamshell as required to achieve the minimum bottom width and to provide for unrestricted channel flow. The excavated material was placed on the right bank of the channel and spread to prevent the creation of a berm. Each channel section had a different rock substrate material placed in generally placed in descending order by size such that Segment 1, immediately adjacent to the main navigation channel will have the largest graded stone. Table 2 shows gradation, size, and type of rock placed.

The Habitat Channel had stable banks pre-project and did not show signs of active erosion. Since bank armoring was required in the vicinity of the fish structures, bank protection was provided for the entire Habitat Channel to prevent migration of the channel. Conventional barge-mounted equipment was used for the construction of partial closing structure, fish and mussel rock habitat, and containment levee. The fish and mussel rock habitat also included habitat structures such as sections of reinforced concrete pipe and LUNKERS. These structures, originally designed as part of a trout habitat improvement program initiated by the Wisconsin Department of Natural Resources (WIDNR), consisted of a submerged system of planking that was installed into a stream bank to provide resting, feeding, and escape cover for fish.

Mussel surveys were planned every five years but never conducted until 2014. The objective of the 2014 monitoring project was to collect information on mussel habitat, native mussel density, relative abundance, community composition, population demographics in the Habitat Channel, Control Channel, and downstream of the Control Channel and Habitat Channel. This study will assist the Corps in evaluating whether the project succeeded in enhancing mussel habitat and guide future attempts in enhancing native mussel habitat.

Methods

The survey was conducted 7-9 October, 2014 by the Corps St. Paul District and MNDNR biologists. Both quantitative and qualitative survey methods were used to evaluate habitat conditions and collect mussels. The goal was to collected both quantitative and qualitative samples within each rock substrate segment and at each sample point within the Control Channel and downstream of the Control Channel and Habitat Channel. Within Segments 1, 3, 4 rock substrate gradations sizes where too large to effectively collect whole substrate quantitative samples so only timed qualitative dive searches where done. Also at a site downstream of the Habitat Channel, water depths where only a few inches deep and no mussels were observed during a timed qualitative search so quantitative sampling was not done. Conversely, within Segment 6 substrate was small (2-4" diameter) and extremely consolidated and very difficult for divers to collect mussels tactually or visually under near zero visibility conditions that only whole substrate quadrat samples were collected.

Quantitative sampling was necessary to accurately estimate density, age/length structure, and relative abundance. Five quadrat samples of 0.25 square meters (m^2) were collected from at each sample point by throwing the quadrat in a semicircle around the downstream side of the anchored boat. At each quadrat collection, a diver hand placed the quadrat on the river bottom and excavated all the material to approximately a depth of 10 centimeters (cm). The excavated material was placed into a ¼ inch mesh collection bag attached to the quadrat frame and sent to the surface for processing. The contents of the mesh bag were evaluated for mussels and substrate composition. Sampled substrate was additionally described as observed by the diver, and water depth was recorded to the nearest 0.5 ft. Mussels were identified and enumerated, aged (external annuli count), and measured for length in millimeters (mm); shells were recorded as fresh dead (FD) or weathered dead (WD). Zebra mussel infestation on native live mussels was also recorded if present. Native mussels were then placed back to near their collected area after processing.

Size and age were analyzed for the quantitative data to assess recent recruitment and age/size class demography in the mussel community. Mussel length (mm) and age (number of annuli) were recorded for each live specimen. The mean, minimum, and maximum were then calculated for each species as well as the mussel community as a whole. Data were summarized in three categories; % individuals less than 30 mm and having ≤ 3 and ≤ 5 external annuli (years old).

Qualitative sampling (visual and tactual searching by diver) was used to estimate the species composition and relative abundance within the sites. Timed searches at each site averaged 20 minutes total (10 min. x two divers). Mussels collected in qualitative samples were identified, enumerated, and classified as young (≤ 3 and ≤ 5 years, ≤ 30mm) or mature (> 5 years, > 30mm) based on age and length. The presence and quantity of zebra mussels was also recorded. Substrate type as well as minimum and maximum depths were also recorded at each of the qualitative dive sites

Results

Habitat

Surveys were conducted 7-9 October, water temperature was 53°F (11.6°C), and flows were typical for fall and lower than typical spring and summer flows. Discharge at Lock and Dam 10, approximately 13 river miles upstream, ranged from 46,000 – 50,000 cfs. Within the Habitat Channel where the higher velocity run was constructed, flows were near or exceeded 3ft/sec, a velocity near the maximum extent in which a boat can anchor and divers can safely work. In mid September the site was visited to assess conditions, discharge at Lock and Dam 10 was 105,000 cfs and current velocity was extremely high and exceeded 6 ft/sec. in the Habitat Channel. Not surprisingly, there is a positive correlation with discharge at Lock and Dam 10 and flows at the Habitat Channel and Control Channel. Since the project was constructed in 1992, spring to fall discharge rarely dropped below 40,000 cfs. Only in winter months did discharge drop below 30,000 cfs. It's safe to assume that flows near or exceeding 3 ft/sec occur in the Habitat Channel the majority of the year deterring zebra mussel settlement while albeit on the high end of optimal current velocity for riverine mussels, potentially providing conditions for most native riverine mussel species.

Habitat Channel - For the most part the rock substrate that was placed remained in placed with a few exceptions (Table 2). Larger angular rip rap rock placed in Segments 1, 3, and 4 was observed during 2014 and was clean and silt free. The 2-4" rounded river stone placed in Segment 5 remained during 2014 and was also silt free. However, the 2-4" crushed angular rock placed in Segment 6 contained approximately a 50/50% mix of the 2-4" rounded river stone, undoubtedly washed in from Segment 5. There appeared a fine layer of silt/sand within Segment 2 over the smaller crushed angular fragments by the island protected from higher flows of the main channel. Also, a depositional back eddy area within Segment 7 had accumulated sand with some empty zebra mussel shells, again protected from higher flows. As previously mentioned, flows were near or exceeded 3 ft/sec through most of the channel. Water depths at sites sampled ranged from 2-8 ft. For the most past rip rap rock placed along the bank remained in place except for an area along Segment 3 the bank was exposed and rock appeared to have disappeared (see Appendix photo documentation, photo of Segment 3).

Downstream of Habitat Channel (Coalpit Slough) – Flow velocity downstream of the Habitat Channel was considerably less to non-existent (see Table 2). Substrate consisted of silt/sand/clay, most of which probably deposited from the bed load passing through the Habitat Channel when flows decrease. Water depths ranged from 1 to 3 ft. Immediately downstream of the Habitat Channel was a scour hole 20-25' deep, the results of high velocity flows exiting the stable rock lined Habitat Channel into softer unprotected substrates.

Control Channel - Flows were slightly less than the Habitat Channel ranging from 2-3 ft/sec. Substrate consisted of 100% sand and was loose shifting in nature at all four sites; 10, 12, 13, 14, a substrate not conducive to native mussels (see Table 2). Water depth ranged from 3-6 ft.

Downstream of Control Channel - Flows were less than in the Control Channel ranging from 1-2 ft/sec. Substrate consisted of compact and stable silt and sand mixture, a substrate more conducive to native mussels than was observed in the Control Channel (see Table 2). Water depth was 3.5 ft.

Main Channel Border – Flows along the Main Channel Border site was 1-2 ft/sec and substrate consisted of 100% sand. Water depth ranged from 8-12 ft. (see Table 2).

Mussels

A total of 17 sites were sampled (eight in the Habitat Channel, three in Coalpit Slough, four in the Control, and one each downstream of the Control Channel and along the Main Channel Border) (Figure 3). Overall, 209 live native mussels representing 14 live species were collected in the areas from this study (Table 3). An additional five species were represented with empty shells only. Overall, *Amblema plicata* (threeridge) (34.0%) and *Obliquaria reflexa* (threehorn wartyback) (31.1%) dominated the collection(s) and within each study area (see Table 3 and Table 4). Two species listed for protection in either Iowa or Wisconsin were collected live but were rare (*Quadrula nodulata* [wartyback] and *Truncilla donaciformis* [fawnsfoot]). No live federally endangered mussels were collected however, a relatively fresh dead Higgins eye shell was collected in Segment 5 of the Habitat Channel (see Table 3 and 4 and Appendix photo documentation) and a weather dead specimen was collected downstream of the Control Channel at Site 15. No live zebra mussels were collected in the entire study, only empty shell were observed at a few sites. In addition, byssal threads attached to native shells (indicative of recent attachment) were not observed.

Habitat Channel – Forty (40) live mussels were collected representing eleven species. However, no mussels were collected in Segments 1, 3, 4, areas where larger rip rap rock was placed (see Table 4). At Sites 2a, 5, 6, 7 densities were $0.8/m^2$, $4.8/m^2$, $4.0/m^2$, and $1.6m^2$, respectively (see Table 4). In addition to Sites 5 and 6 having the highest density they contained the most species (five) (see Table 4 and Figure 5). Average age of mussels was 6.8 years old and all individuals were ≤ 10 years old which indicates all individuals collected colonized the area within the past 10 years but > 10 years post construction of the Habitat Channel. There's no evidence of colonization from 1-12 years post construction.

Downstream (Coalpit Slough) – Forty one (41) live mussels were collected at two of the three sites representing nine species (see Table 3 and 4). No live mussels were collected at Site 17. Density at Site 8 was $1.6/m^2$ and no mussels were collected in quadrats at Site 9, however Site 9 contained more live species (seven) when timed searches are included. Average age was 5.0 years old with all mussels ≤ 7 years old (see Table 5).

Control Channel - A total of only 11 live mussels were collected representing six live species (see Table 3). No live mussels were collected in quadrats at three of the four sites ($0/m^2$). Density at Site 13 was $0.8/m^2$ (see Table 4). Only one live mussel was collected in quadrats (*Utterbackia imbecillis* [paper pondshell]) and was one year old and 27mm in length. It was not included on Table 5.

Downstream of Control Channel - A total of 108 live mussels were collected representing eleven species (see Table 3 and Figure 5). Density was $6.8/m^2$ at Site 15 (see Table 4). Average age was 3.2 years old and ranged from 0 to 10 years old (see Table 5).

Main Channel Border – A total of nine live mussels representing five live species were collected (see Table 3 and 4). Mussels were not aged or measured as no quantitative samples were collected.

Discussion

From this study, it’s inconclusive as to whether improved fish habitat conditions and colonization of mussels in the Habitat Channel had any impact on Coalpit Slough downstream. It was thought that perhaps downstream drift of juvenile mussels dropping from fish in the Habitat Channel may populate areas in Coalpit Slough. Species composition and richness are similar between the Habitat Channel and Coalpit Slough but without pre-project data from Coalpit Slough it’s difficult to assess affects.

Mussel habitat within the Control Channel was not conducive to native mussels. The Habitat Channel was more stable and harbored more mussels in some areas than the Control Channel. There appears to be a large amount of sand entering from the main channel as evidenced by the large exposed sand bar at the head of the Control Channel and substrate consisted of a moving bedload of 100% shifting sand (see Appendix photo documentation). In addition, there was considerable erosion along the banks. As a result, very few mussels were found. Downstream of the Control Channel habitat conditions were more favorable for mussels (compact silt and sand with moderate flow) and contained a species rich and fairly abundant mussel community.

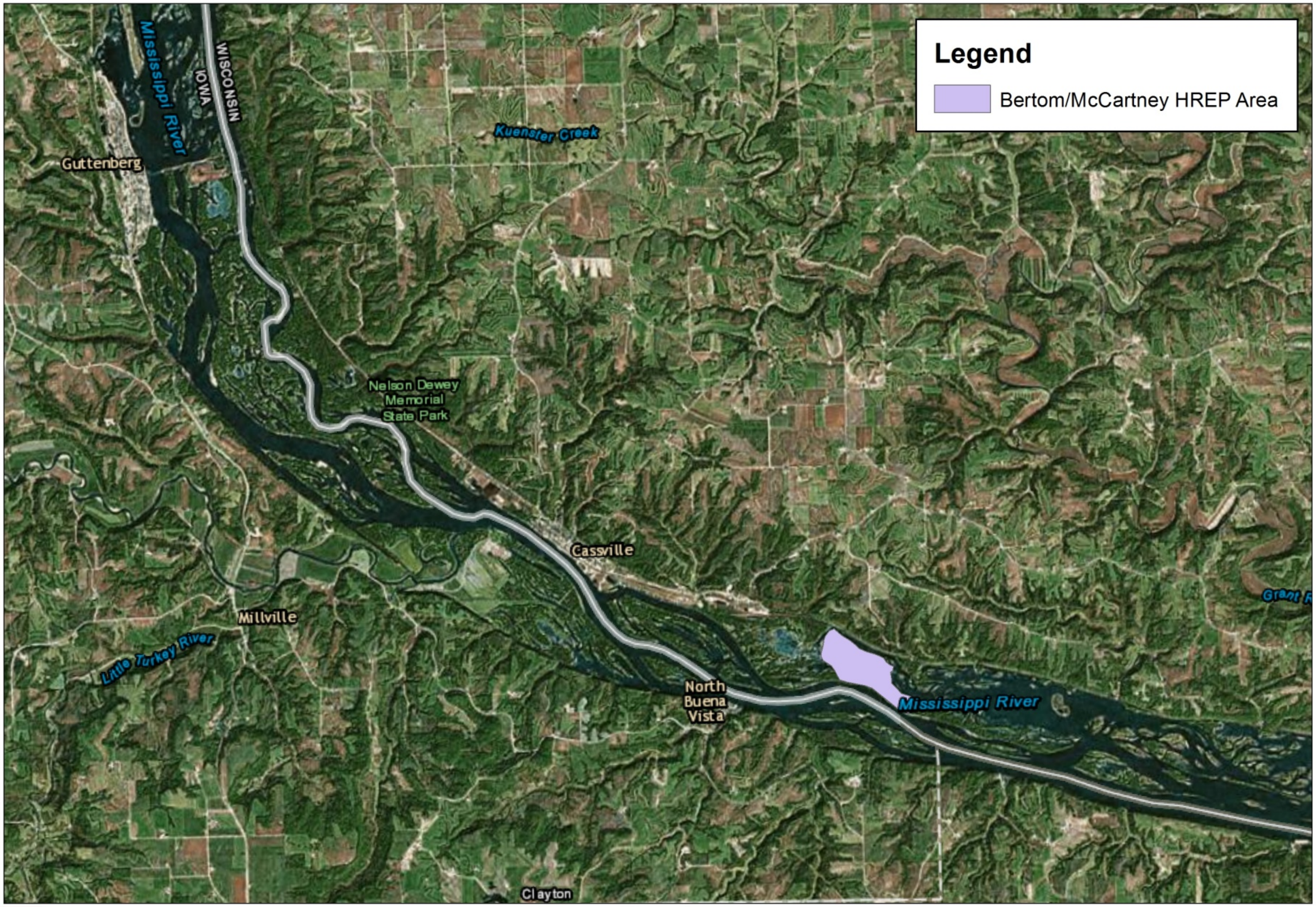
Albeit at low levels, it appears that native mussels have colonized the Habitat Channel in areas where substrate consisted of 2-4” river washed stone (Segment 5), 2-4” river washed stone mixed with 2-4”angular stone (Site 6), and areas protected from higher flows (Segments 2 and 7). Segments 1, 3, and 4, which contained larger rip rap rock probably didn’t provide ideal mussel habitat due to the lack of softer substrate and interstitial space for mussels to burrow into. Smaller rounded river stone provides interstitial space for mussels but is not as stable as angular rock. Angular rip rap by design locks tight together for stability, rounded stone is prone to move under high flows. However, the benefit of providing stability upstream and along the banks of the Habitat Channel is that it stabilized the channel and the preferred substrate. Segments 1, 3, and 4 may have also provided fish habitat in which fish infested with mussel glochidia would occupy those areas and release juvenile mussels which would drift downstream to favorable habitat. Similarly, the fish LUNKERS may have assisted with mussel colonization in a similar manner.

Segments 5 and 6 had similar densities (4.8/m^2 and 4.0/m^2, respectively) and species richness (five each) but substrate slightly differed. It appears the river washed stone in Segment 5 being less stable than angular stone, washed downstream into Segment 6 to mix with the angular stone. This suggests that perhaps a combination of smaller rounded river stone providing interstitial habitat mixed with smaller angular stone providing stability may prove to be excellent mussel habitat. A variation and recommendation to consider for use in a future project design could also be a substrate containing fewer but larger angular stone mixed with a majority smaller rounded river stone which would provide more interstitial space for mussels to burrow and stability and hydrodynamic diversity from the larger angular rock.

Flow conditions and water depth within the Habitat Channel appear to support native mussels given the proper substrate. Depth in Segments 5 and 6 was 6-7 feet and velocity was >3ft/sec and probably comparable for most of the year and among years since the project was constructed. Water depth of 6-7 feet has been targeted for mussel habitat enhancement in other mussel habitat studies (ESI 2014). The fast flowing run habitat likely limited settling of zebra mussel juveniles which typically settle in flows <0.3 ft/sec. (Hunter 1992). Other mussel habitat enhancement studies and field measurements suggest that ideal flows for native riverine mussels range from approximately 0.7 to 2.6ft/sec. (Hornbach 2010 and ESI 2014). In this study, flow velocities may be at the upper threshold within the Habitat Channel for ideal mussel habitat and may explain the relative low density (<5/m^2) and species diversity (11 species) observed compared to other UMR mussel bed densities which routinely exceed >10.m^2 and contain >20 species (Kelner unpubl. data.). Another explanation for the relatively low mussel densities and diversity may be explained by the relatively slow recolonization rate of native mussels into areas either previously disturbed or into newly created habitat. The rate of recovery of certain macroinvertebrates (MacKay 1992, Matthaei et. al. 1996) and fish (Peterson and Bayley, 1993, Sheldon and Meffe 1994) following a disturbance can be rapid due to their greater mobility and short generation times. Freshwater mussels on the other hand are not very mobile as adults, are long lived with a complex life cycle, and depend on fish to disperse their larvae. These characteristics can inhibit mussels from recolonizing rapidly if a community is decimated (Neves 1993).

Estimating age of mussels post-disturbance or habitat creation projects can be used to predict when mussels began to recolonize such areas. Kelner and Davis (2002) and Sietman *et. al* (2001) report native mussels colonizing areas following near extirpation of fish and mussels in reaches of the Upper Mississippi River and the upper Illinois River after conditions improved, respectively. With the passing of the Clean Water Act in 1972 and the addition of other environmental laws and regulations in the 1970s, water quality dramatically improved in these areas, fish populations improved and mussels began to colonize both reaches in about 1980 - 1985. This is supported by Kelner and Davis (2002) in that estimated ages of live mussels collected during 2000-01 suggest colonization began 15-20 years prior (1980-85). Similarly, Sietman *et al.* (2001) surveys were conducted during 1994, 1995, and 1999 and age data suggest colonization began about 1980. This study shows a similar trend in that mussels began to recolonize the Habitat Channel approximately 10 -12 years post Habitat Channel construction (or post disturbance).

Although present mussel community density and diversity are about half of that of healthy mussel beds on the UMR, the data indicate that if habitat conditions are suitable (including adequate host fish habitat) and source populations are nearby, mussels can recolonize habitat that has been created or modified for mussels without being artificially supplemented. Of the additional mussel species that occur in UMR Pool 11which have not re-colonized, there is potential for additional species to recolonize the area given more time. Similarly, Kelner and Davis (2002) and Sietman *et. al.* (2001) reported a reduced mussel community than historically occurred in the reaches. It appears populations have remained stable in the past decade and it remains unknown at this time if additional species will naturally recolonize those reaches. The Bertom and McCartney fish and mussel Habitat Channel should be monitored 5 and 10 years in the future to assess whether the mussel community continues to colonize.



St. Paul District
GIS CENTER
US Army Corps of Engineers®
H:\1_MVP_Functional_Areas\GIS_Center\Kelner\Bertom_Mussel_Monitoring_2014\GIS JFW 01-13-15

Figure 1

Base Image: ESRI Basemap with Labels

0 1 2 4 Miles

N

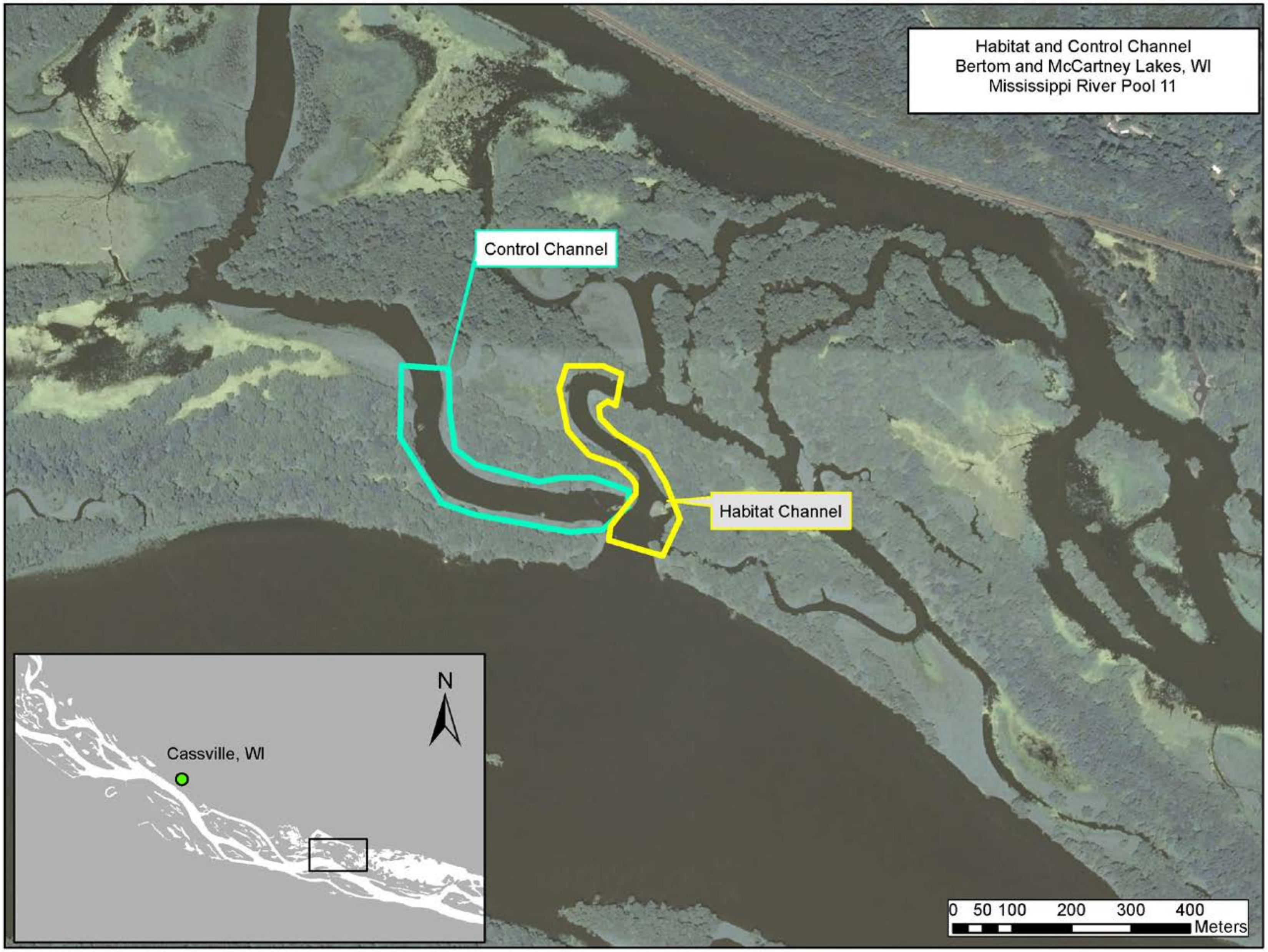


Figure 2. Bertom McCartney HREP fish and mussel enhancement project secondary control and habitat channels.

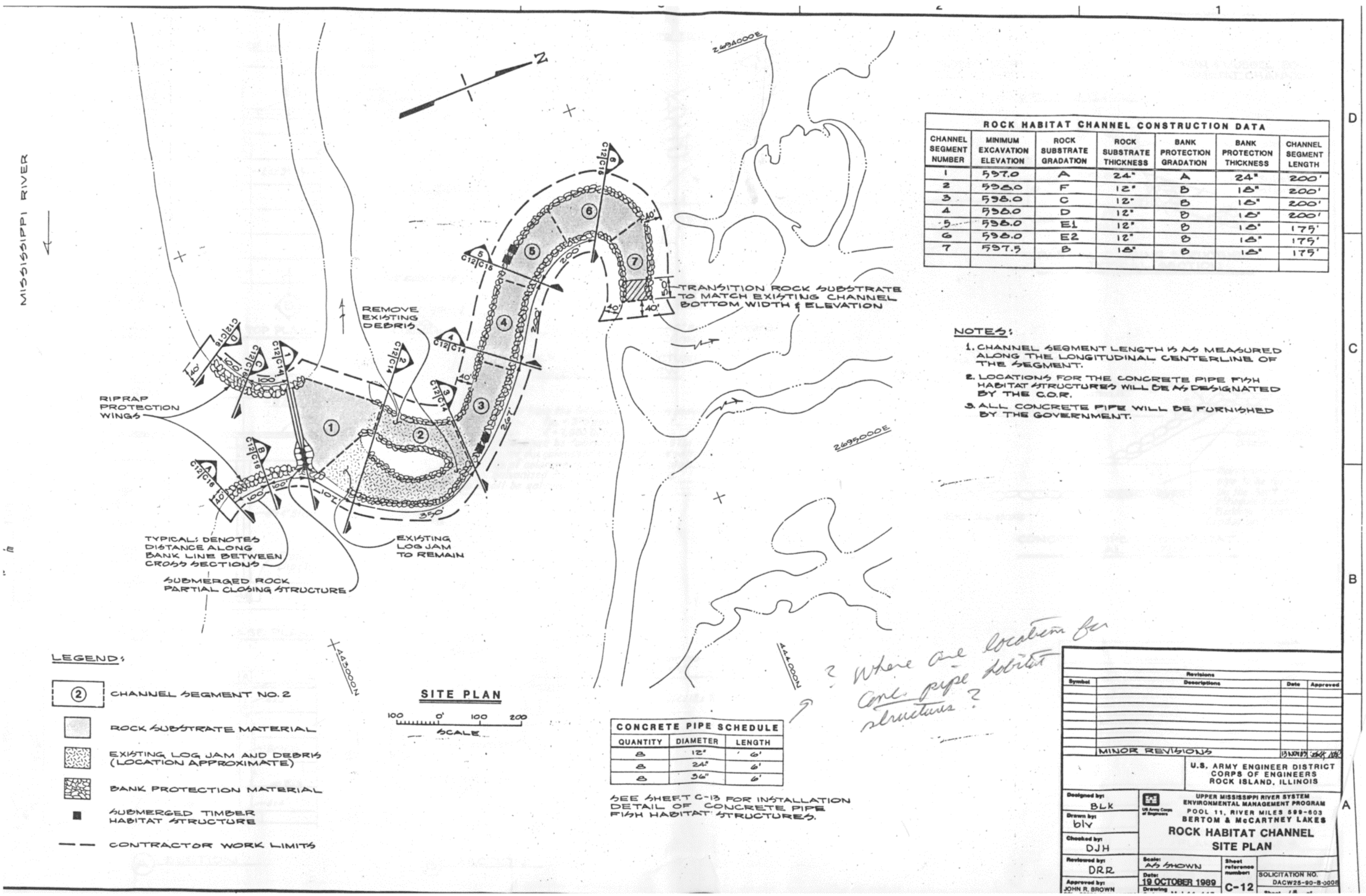
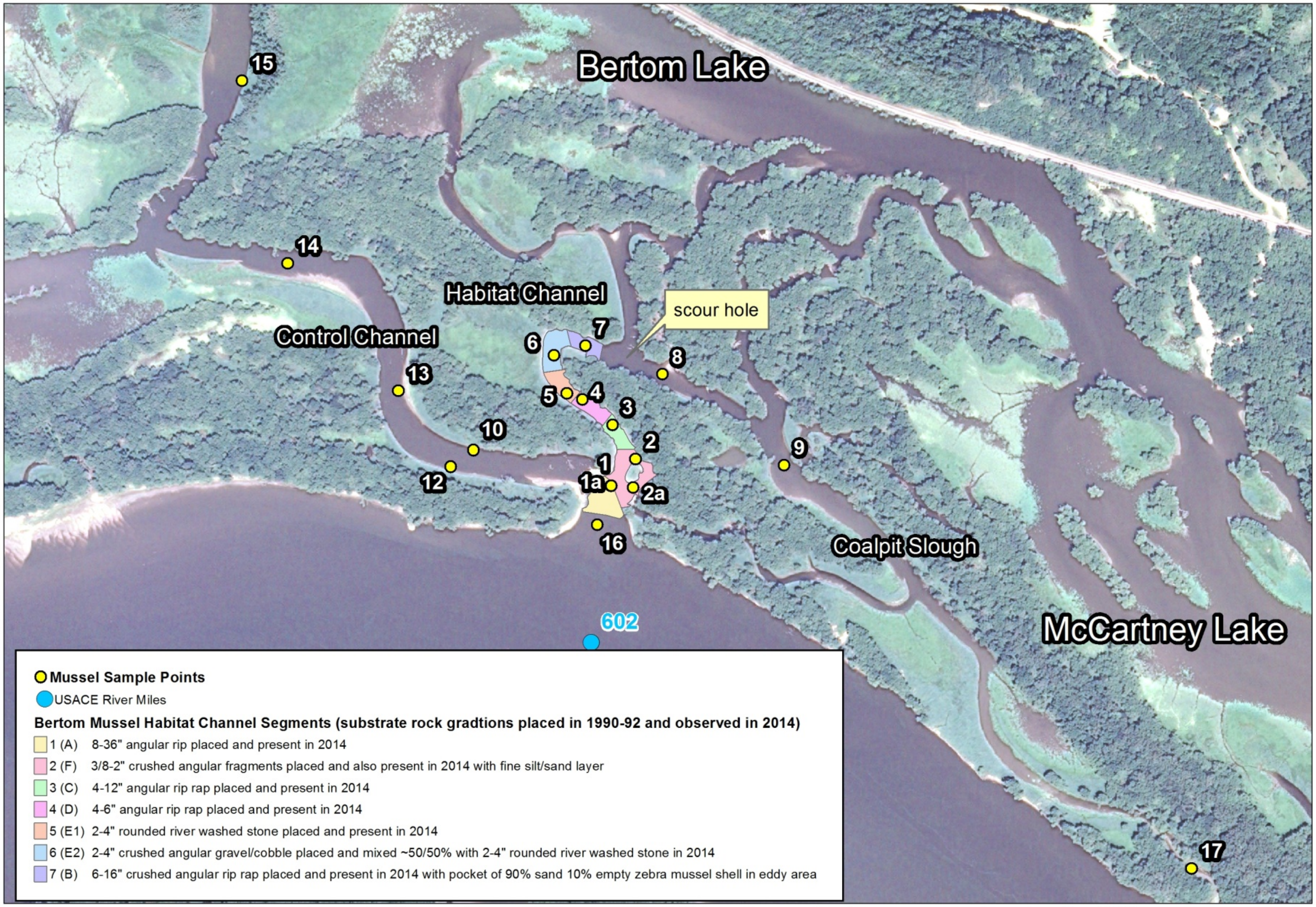


Figure 3. Bertom McCartney HREP fish and mussel enhancement project.



St. Paul District
GIS CENTER
US Army Corps of Engineers®

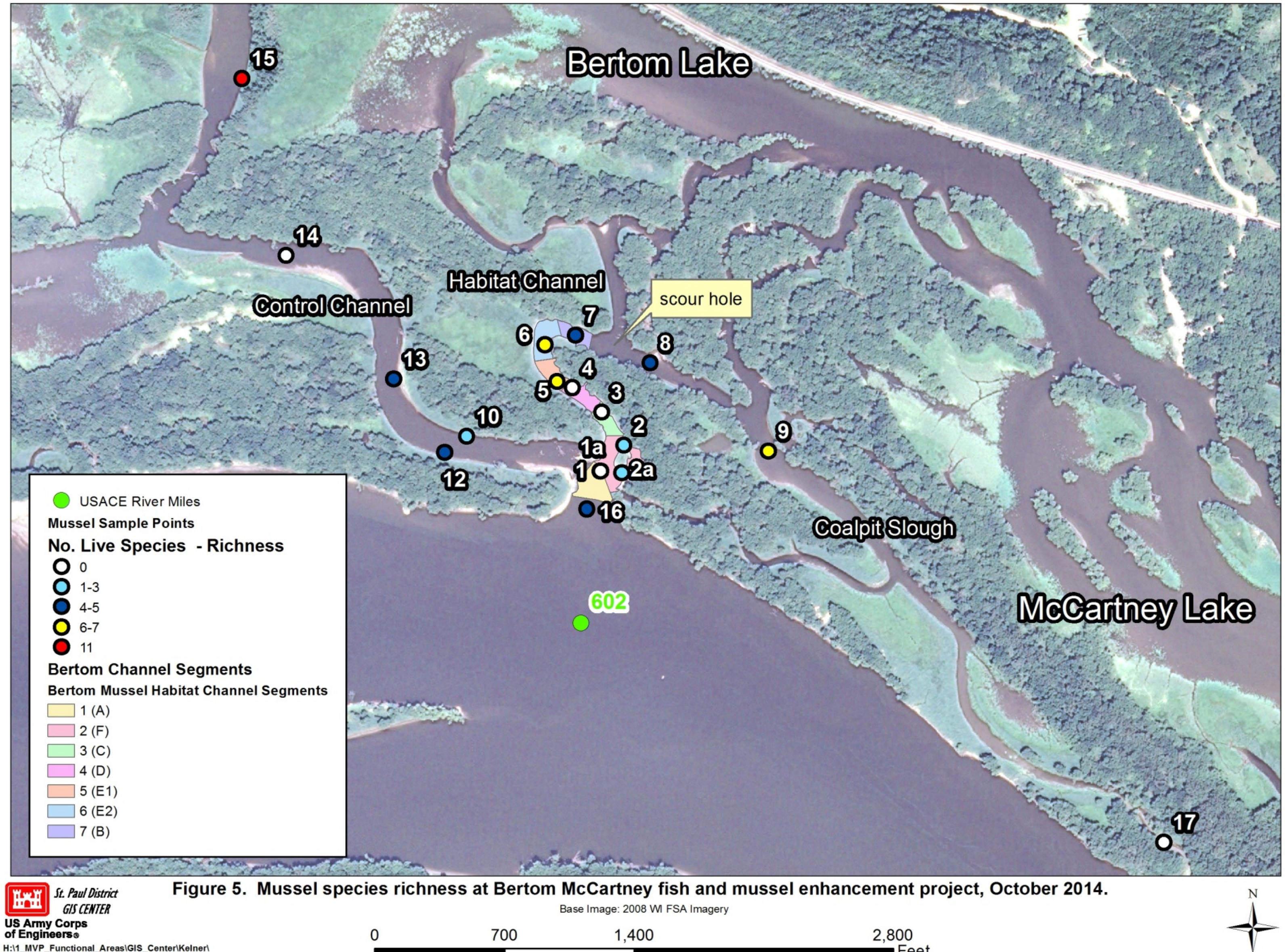
Figure 4. Mussel sample sites at Bertom McCartney HREP fish and mussel enhancement project, October 2014.

Base Image: 2008 WI FSA Imagery

0 700 1,400 2,800 Feet

N

H:\1_MVP_Functional_Areas\GIS_Center\Kelner\Bertom_Mussel_Monitoring_2014 JFW 1-13-15



St. Paul District GIS CENTER
US Army Corps of Engineers®
H:\1_MVP_Functional_Areas\GIS_Center\Kelner\Bertom_Mussel_Monitoring_2014 JFW 1-13-15

Figure 5. Mussel species richness at Bertom McCartney fish and mussel enhancement project, October 2014.

Base Image: 2008 WI FSA Imagery

Table 1. Historical and recent occurrence of native mussels in UMR Pool 11 and at the Bertom McCartney HREP.

				Bertom McCartney Mussel Habitat Area	
Subfamily	Species	Common name	Historically in UMR Pool 11***	Lucchensi and Thiel 1987	This study 2014
Ambleminae	*Amblema plicata*	threeridge	L		L
	*Cyclonaias tuberculata**	purple wartyback	H		
	*Elliptio crassidens**	elephant ear*	H		
	Elliptio dilatata	spike	L		
	*Fusconaia ebena**	ebonyshell*	L		
	Fusconaia flava	Wabash pigtoe	L		L
	Megalonaias nervosa	washboard	L		
	*Plethobasus cyphyus***	sheepnose**	L		
	*Pleurobema sintoxia**	round pigtoe*	L		
	*Quadrula metanevra**	monkeyface*	L		
	*Quadrula nodulata**	wartyback*	L	L	L
	Quadrula pustulosa	pimpleback	L		L
	Quadrula quadrula	mapleleaf	L	L	L
	*Tritogonia verrucosa**	pistolgrip*	H		
Anodontinae	*Alasmidonta marginata*	elktoe	L		
	*Arcidens confragosus**	rock pocketbook*	L		
	Lasmigona complanata	white heelsplitter	L		L
	Pyganodon grandis	giant floater	L		L
	*Strophitus undulatus**	strange floater*	L		D
	Utterbackia imbecillis	paper pondshell	L		L
Lampsilinae	*Actinonaias ligamentina*	mucket	L		
	*Ellipsaria lineolata**	butterfly*	L		
	Lampsilis cardium	plain pocketbook	L	L	L
	*Lampsilis higginsii***	Higgins eye**	L		D
	Lampsilis siliquoidea	fatmucket	L		
	*Lampsilis teres**	yellow sandshell*	L		
	Leptodea fragilis	fragile papershell	L	L	L
	Ligumia recta	black sandshell	L		L
	Obliquaria reflexa	threehorn wartyback	L		L
	Obovaria olivaria	hickorynut	L	L	L
	Potamilus alatus	pink heelsplitter	L	L	
	Potamilus ohiensis	pink papershell	L	L	D
	Toxolasma parvus	lilliput	L	L	D
	*Truncilla donaciformis**	fawnsfoot*	L	L	L
	Truncilla truncata	deertoe	L	L	D
Live species			32	10	14
Total species			35	10	19

L = live H = historic D = Dead

*Iowa or Wisconsin threatened or endangered; **state and federally endangered.

***Historical information of native mussels found in the UMR (Kelner, 2011 unpublished data).

Table 2. Habitat conditions at Bertom and McCartney HREP fish and mussel habitat enhancement project, October 2014.

	Habitat Channel (Sample Site within respective Segment)						
	1	2 & 2a	3	4	5	6	7
Substrate placed rock gradation	A	F	C	D	E1	E2	B
Substrate placed diameter/type	8-36" angular rip rap	3/8 - 2" crushed angular fragments	4-12" angular rip rap	4-6" angular rip rap	2-4" rounded river stone	2-4" crushed angular gravel/cobble	6-16"angular rip rock
Substrate observed in 2014	8-36" angular rip rap	Silt/Sand/ 3/8 - 2" crushed angular fragments	4-12" angular rip rap	4-6" angular rip rap	2-4" rounded river stone	2-4" 50% rounded river stone and 50% crushed angular gravel/cobble	6-16"angular rip rock w/pocket (eddy) of 90% sand/10% empty zebra mussel shells
Water depth (ft.)	8	2-3	6	6-7	6-7	6-7	6-7
~Current Velocity (ft./sec)	>3ft sec	>3ft/sec	>3ft sec	>3ft/sec	>3ft sec	>3ft/sec	1-2ft/sec

	Downstream Habitat Channel (Coalpit Slough Sample Site)			Control Channel (Sample site)				Downstream Control Channel	Main Channel Border
	8	9	17	10	12	13	14	15	16
Substrate observed in 2014	Silt/Sand/Clay	Silt/Sand/Clay	Silt/ Sand	100% Sand Dunes	100% Sand Dunes	100% Sand Dunes	100% Sand Dunes	Silt/Sand compact - stable	100% Sand
Water depth (ft.)	3	3	1	5.5	3-6	3-6	3-6	3.5	8-12
~Current velocity (~ft./sec)	1ft/sec	0.5ft/sec	0 ft/sec	2-3ft/sec	2-3ft/sec	2-3ft/sec	2-3ft/sec	1-2ft/sec	1-2ft/sec

Table 3. Total mussel species richness and relative abundance from qualitative and quantitative samples at Bertom and McCartney HREP fish and mussel habitat enhancement project, October 2014.

	Habitat Channel		**Downstream Habitat Channel (Coalpit Slough)**		**Control Channel**		**Downstream (Control Channel)**		**Main Channel Border**		**Total**	
Species	No.	%	No.	%	No.	%	No.	%	No.	%	No.	%
Ambleminae												
Amblema plicata	10	25.0	13	31.7	3	27.3	42	38.9	3	33.3	71	34.0
Fusconaia flava	1	2.5	3	7.3			5	4.6	2	22.2	11	5.3
*Quadrula nodulata**	1	2.5	1	2.4			8	7.4	1	11.1	5	2.4
Quadrula pustulosa	2	5.0	1	2.4			2	1.9	1	11.1	12	5.7
Quadrula quadrula	2	5.0	1	2.4			2	1.9			5	2.4
Anodontinae												
Lasmigona complanata	2	5.0	2	4.9							4	1.9
Pyganodon grandis	D		1	2.4	2	18.2					3	1.4
*Strophitus undulatus***	D										D	
Utterbackia imbecillis			2	4.9	2	18.2	2	1.9			6	2.9
Lampsilinae												
Lampsilis cardium	3	7.5	D		1	9.1	7	6.5			11	5.3
*Lampsilis higginsii****	D						D				D	
Leptodea fragilis	1	2.5	D		1	9.1	2	1.9			4	1.9
Ligumia recta	3	7.5									3	1.4
Obliquartia reflexa	13	32.5	17	41.5			33	30.6	2	22.2	65	31.1
Obovaria olivaria	2	5.0			2	18.2	1	0.9			5	2.4
Potamilus ohiensis			D								D	
Toxolasma parvus					D						D	
*Truncilla donaciformis**			D				4	3.7			4	1.9
Truncilla truncata			D								D	
No. live	40		41		11		108		9		209	
Live species	11		9		6		11		5		14	
Total species	14		14		7		12		5		19	
No. sites qual. and quant.	8		3		4		1		1		17	

*Wisconsin threatened ; ** Iowa threatened; *** Federally, Iowa, Wisconsin endangered

Table 4. Native mussel abundance at each sample site, Bertom and McCartney HREP fish and mussel habitat enhancement project, October 2014.

	Habitat Channel (Sample Site within respective Segment)											Downstream (Coalpit Slough)				
	1	2	2a		3	4	5		6	7		8		9		17
Species	Qual.	Qual.	Qual.	Quant.	Qual.	Qual.	Qual.	Quant.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Ambleminae																
Amblema plicata		9						1				6		7		
Fusconaia flava									1			1		2		
Quadrula pustulosa								1	1				1			
quadrula nodulata		1												1		
quadrula quadrula								2						1		
Anodontinae																
Lasmigona complanata									1		1	2				
Pyganodon grandis		D								D				1	D	
Strophitus undulatus									D							
Utterbackia imbecillis														2		
Lampsilinae																
Lampsilis cardium									1	2			D			
Lampsilis higginsii								D								
Leptodea fragilis		D		1						D				D		
Ligumia recta							1	1			1					
Obliquaria reflexa		11					D	1	1			8	1	8		
Obovaria olivaria							D			2						
Potamilus ohiensis														D		
Toxolasma parvus																
Truncilla donaciformis														D		
Truncilla truncata													D			
No. Live	0	21	0	1	0	0	1	6	5	4	2	17	2	22	0	0
Live species	0	3	0	1	0	0	1	5	5	2	2	4	2	7	0	0
Total species	0	5	0	1	0	0	3	6	6	4	2	4	4	10	1	0
(n) 0.25m^2 samples				5				5	5		5		5		5	
Density (No. live/m^2) [2SE]				0.8 [1.6]				4.8 [5.9]	4.0 [3.6]		1.6 [2.0]		1.6 [2.0]		0.0 [0.0]	
Estimated population size*	NA			<500	NA	NA		7,050	8,736		<500		NA		NA	

*Approximation - based on density x area. Statistical comparisons on density were not done due to the small sample sizes (5) and variability of the data.

Table 4 (cont). Native mussel abundance at each sampling station, Bertom and McCartney HREP fish and mussel habitat enhancement project, October 2014.

	Control Channel								**Downstream (Control Channel)**		**Main Channel Border**
	10		12		13		14		15		16
Species	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.	Quant.	Qual.
Ambleminae											
Amblema plicata			2		1				40	2	3
Fusconaia flava									5		2
Quadrula pustulosa									8		1
quadrula nodulata									2		1
quadrula quadrula									2		
Anodontinae											
Lasmigona complanata											
Pyganodon grandis			2								
Strophitus undulatus											
Utterbackia imbecillus			1			1				2	
Lampsilinae											
Lampsilis cardium			1						7	D	
Lampsilis higginsii									D		
Leptodea fragilis					1				2	D	
Ligumia recta											
Obliquaria reflexa									31	2	2
Obovaria olivaria		1			1				1		
Toxolasma parvus			D								
Truncilla donaciformis									2	2	
Truncilla truncata											
No. Live	0	1	6	0	3	1	0	0	100	8	9
Live species	0	1	4	0	3	1	0	0	10	4	5
Total species	0	1	5	0	3	1	0	0	11	6	5
(n) 0.25m^2 samples		5		5		5		5		5	
Density (No. live/m^2) [2SE]		0.0 [0.0]		0.0 [0.0]		0.8 [1.6]		0.0 [0.0]		6.4 [7.4]	
Estimated population size		NA				NA				NA	NA

Table 5. Mussel community characteristics from quantitative samples from the Bertom McCartney HREP fish and mussel habitat enhancement project, October 2014.*

		Age - Years (external annuli count)			Length mm (maximum anterior to posterior)		
Species	(n)	Mean	Min.	Max.	Mean	Min.	Max.
Habitat Channel							
Ligumia recta	2	6.5	4	9	115.0	101	129
Leptodea fragilis	1	2.0	2	2	46.0	46	46
*Lampsilis higginsii***	FD	6.0	6	6			
Quadrula quadrula	2	5.5	2	9	36.5	20	53
Quadrula pustulosa	2	8.0	8	8	56.0	56	56
Lampsilis cardium	1	8.0	8	8	105.0	105	105
Obliquaria reflexa	2	4.0	2	6	33.0	20	46
Amblema plicata	1	10.0	10	10	79.0	79	79
Fusconaia flava	1	10.0	10	10	57.0	57	57
Lasmigona complanata	2	9.0	8	10	145.0	140	150
Total	15	6.8	2	10	75.6	20	150
% ≤ 3 years old		21.4					
% ≤ 5 years old		28.6					
% ≤ 30 mm					14.3		
Downstream Habitat Channel							
Obliquaria reflexa	1	7.0	7	7	34.0	34	34
Quadrula pustulosa	1	3.0	3	3	20.0	20	20
Total	2	5.0	3	7	27.0	20	34
% ≤ 3 years old		50.0					
% ≤ 5 years old		50.0					
% ≤ 30 mm					50.0		
Downstream Control Channel*							
Amblema plicata	2	6.0	2	10	48.5	22	75
Obliquaria reflexa	2	4.0	4	4	37.5	35	40
Truncilla donaciformis	2	1.0	1	1	15.5	14	17
Utterbackia imbecillis	2	0	0	0	21.5	20	23
Total	8	3.2	0	10	34.0	14	75
% ≤ 3 years old		75.0					
% ≤ 5 years old		87.5					
% ≤ 30 mm					60.0		

*Only one live *U. imbecillis* was aged and measured from the Control Channel and was not include in table. Individual was 1 year old and 27mm in length
***L. higginsii* (Higgins eye collected was fresh dead and was aged and included (but not measured for length)

Bibliography

Ecological Specialists, Inc. 2014. Final Report. Unionid Mussel Habitat Construction/Creation Summary. Submitted to U.S. Army Corps, St. Louis District, St. Louis, Missouri. 64pp and Appendices.

Hornbach, D.J., M.C. Hove, B. Dickinson, K. MacGregor and J.R. Medland. 2010. Estimating population size and habitat associations of two federally endangered mussels in the St. Croix River, Minnesota and Wisconsin, USA. Aquatic Conservation: Marine and Freshwater Ecosystems 20: 250-260.

Hunter, R.D., and J.F. Bailey. 1992. *Dreissenapolymorpha* (zebra mussel): colonization of soft substrata and some effects on Unionid bivalves. Nautilus 106(2):60-67.

Kelner, D.E. and M. Davis. 2002. Final Report: Mussel (Bivalvia: Unionidae) survey of the Mississippi National River and Recreation Area Corridor, 2000-01. Contract report to the National Park Service Mississippi National River and Recreation Area and the Great Lakes Network Inventory and Monitoring Program. Minnesota Department of Natural Resources, Division of Ecological Services, St. Paul, MN 43pp. with appendices.

Lucchesi D. and P. Thiel. 1988. Pre-project limnological investigation and fishery survey of Bertom and McCartney Lakes, Pool 11. Wisconsin Department of Natural Resources, LaCrosse, Wisconsin.

Matthaei, C. D., U. Uehlinger, E. I. Meyer, and A. Frutiger. 1996. Recolonization by benthic invertebrates after experimental disturbance in a Swiss prealpine river. Freshwater Biology 35:233-248.

MacKay, R. J. 1992. Colonization by lotic macroinvertebrates: a review of processes and patterns. Canadian Journal of Fisheries and Aquatic Sciences 49:617-628

Neves, R. J. 1993. A state-of-the-unionids address. p. 1-10 *in* K. S. Cummings, A. C. Buchanan, and L. M. Koch (eds.). Conservation and management of freshwater mussels. Proc. Upper Mississippi Riv. Conserv. Comm. Symp., Rock Island, IL.

Peterson, J. T. and P. B. Bayley. 1993. Colonization rates of fishes in experimentally defaunated warmwater streams. Transactions of the American Fisheries Society 122:199-207.

Sheldon, A. L., and G. K. Meffe. 1994. Short-term recolonization by fishes of experimentally defaunated pools of a coastal plain stream. Copeia 1994:828-837.

Sietman, B.E., Whitney, S.D., Kelner, D.E., Blodgett, K.D. Dunn, H.L. 2001. Post-estirpation recovery of the freshwater mussel (Bivalvia: Unionidae). Fauna in the upper Illinois River. Journal of Freshwater Ecology 16, 271-281.

Appendix

GPS Photo Documentation

Site 16. Main Channel Border facing Habitat Channel. 100% sand.

W 90° 55' 01"
N 42° 41' 12"

10/9/2014
11:50:10 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 2 - facing northwest downstream of Island looking downstream into Habitat Channel. Segment 2.

W 90° 54' 58"
N 42° 41' 15"

10/8/2014
10:10:40 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

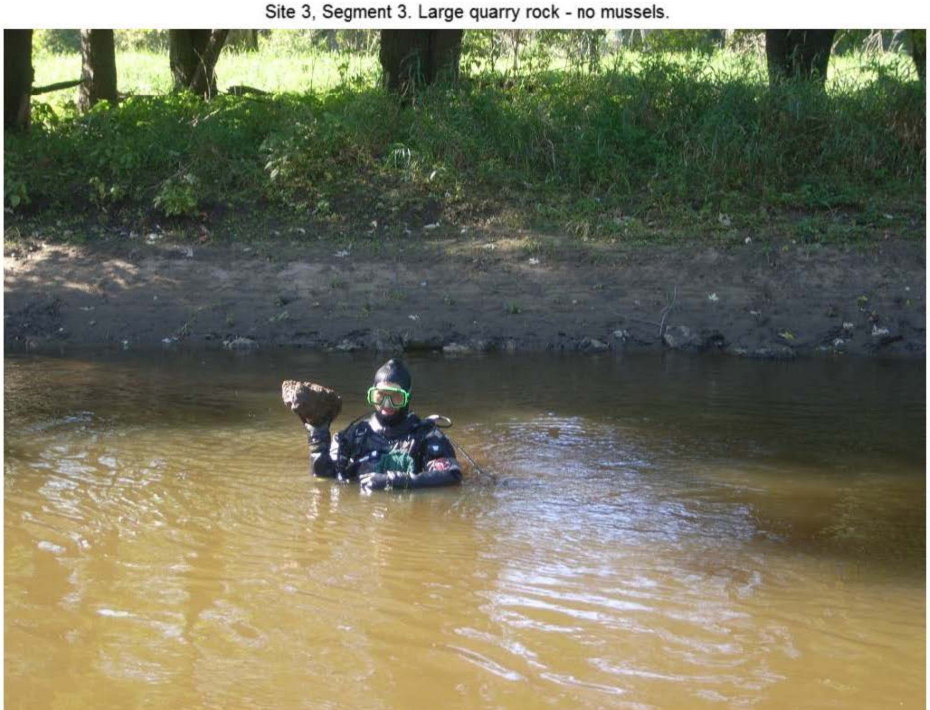
At head of Control Channel facing Site 1 a 2a on n left between head of island and log jam).
Main Channel on right.

W 90° 55' 02"
N 42° 41' 14"

10/9/2014
11:04:55 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 3, Segment 3. Large quarry rock - no mussels.



W 90° 54' 60"
N 42° 41' 17"

10/8/2014
10:31:17 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 2a Crushed quarry gravel near log jam at head of island. no mussels - poor habitat.

W 90° 54' 58"
N 42° 41' 14"

10/8/2014
3:07:54 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 5 Segment 5. Clean river washed gravel - excellent mussel subtrate.

W 90° 55' 03"
N 42° 41' 19"

10/8/2014
11:01:52 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 5 Segment 5. Higgins eye 1/2 shell semi-fresh <3years ago. Six when it died.

W 90° 55' 03"
N 42° 41' 19"

10/8/2014
10:54:33 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 5 , Segment 5. Mike Davis (MNDNR).

W 90° 55' 02"
N 42° 41' 19"

10/8/2014
10:54:20 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 5

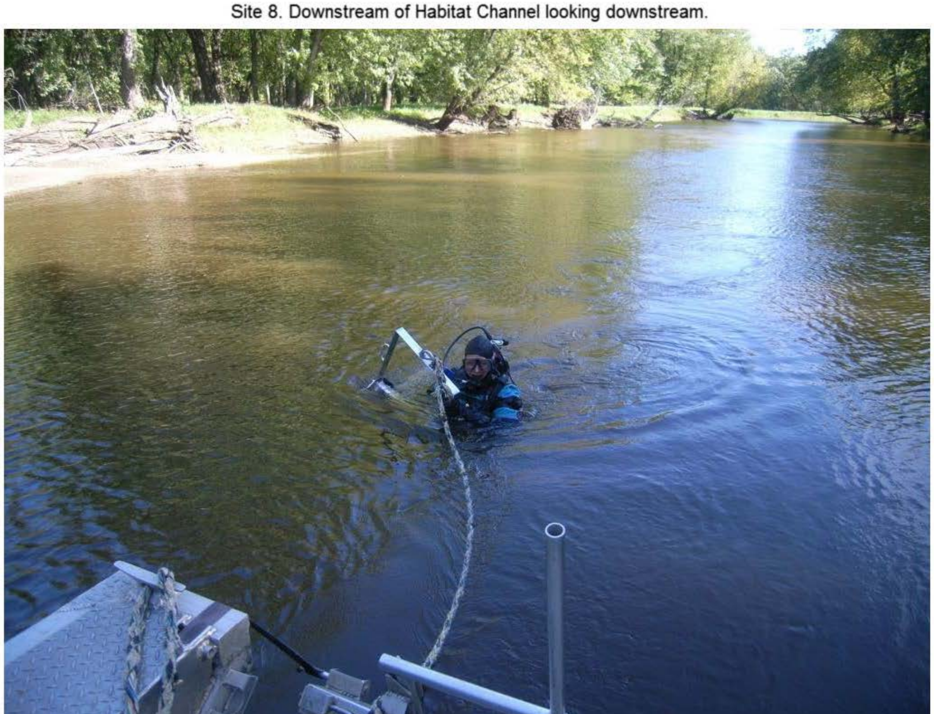
Segment 5. River washed gravel/cobble with some crushed quarry rock. 2-6" diameter rock.
Ligumia recta (black sandshell)

W 90° 55' 03"
N 42° 41' 19"

10/8/2014
10:47:12 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 8. Downstream of Habitat Channel looking downstream.



W 90° 54' 55"
N 42° 41' 20"

10/8/2014
1:17:48 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 8 facing west. Downstream of Habitat Channel facing upstream. Deep scour hole immediately downstream of Habitat Channel
Depositional area at Site 8, ~2.5 ft. deep, ~100% sand a few mussels.

W 90° 54' 56"
N 42° 41' 20"
10/8/2014
1:16:38 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 9. Below Habitat Channel. Facing north. 3ft deep, silt, sand some mussels. no flow.

W 90° 54' 47"
N 42° 41' 15"
10/8/2014
2:02:38 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 9. Below Habitat Channel. Facing south. 3ft deep, silt, sand some mussels. no flow.

W 90° 54' 47"
N 42° 41' 15"

10/8/2014
2:02:38 PM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 17 downstream of Habitat Channel near outlet to Main Channel
Flow actually coming in from main channel flowing towards McCartney.

W 90° 54' 20"
N 42° 40' 54"

10/9/2014
11:20:35 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 17 downstream of Habitat Channel near outlet to Main Channel
Flow actually coming in from main channel flowing towards McCartney.

W 90° 54' 19"
N 42° 40' 54"
10/9/2014
11:20:20 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Sand Bar at head of Control Channel facing downstream.

W 90° 55' 04"
N 42° 41' 15"
10/9/2014
11:03:04 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Sand Bar at head of Control Channel facing Habitat Channel.

W 90° 55' 04"
N 42° 41' 15"

10/9/2014
11:02:57 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 12. Control Channel. Facing downstream. Eroding shoreline, loose shifting sand dune substrate.

W 90° 55' 15"
N 42° 41' 19"

10/9/2014
9:37:45 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Site 12. Control Channel. Facing downstream. Eroding shoreline, loose shifting sand dune substrate.

W 90° 55' 11"
N 42° 41' 15"
10/9/2014
9:29:19 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Control Channel immediately downstream backwater lake.

W 90° 55' 30"
N 42° 41' 29"
10/9/2014
10:14:41 AM

Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Downstream of Control Channel Site 15 Facing downstream. Site on right bank. Loose shifting sand mid-channel - poor. f mussels along bank.

W 90° 55' 25"
N 42° 41' 36"
10/9/2014
10:35:31 AM
Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR

Downstream of Control Channel Site 15 Directly on site facing upstream. Mussels along bank.

W 90° 55' 25"
N 42° 41' 35"
10/9/2014
10:35:51 AM
Bertom Mussel Habitat Channel Survey 2014: Corps - St. Paul District, Minnesota DNR