Annual Report:

Quantitative Assessment of Zebra Mussels (*Dreissena polymorpha*, Pallas, 1771) in the Lower St. Croix River at Native Mussels Beds.

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Photos: All photos by the author, except where noted. Cover photo shows all 180 samples before processing

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Introduction

The St. Croix National Scenic Riverway was one of the first wild and scenic river units of the National Park System, established in 1968. The Riverway is considered a nationally significant resource for its richness and abundance of native freshwater mussels (~40 species, the greatest in the Upper Mississippi watershed) and is recognized for its outstanding recreational and biological assets (Hove and Hornbach 2002, Doolittle, et al. 1995). Two federally endangered mussel species—Higgins eye pearl mussel (*Lampsilis higginsii*) and winged mapleleaf (*Quadrula fragosa*)—as well as many species listed for protection in Minnesota and Wisconsin, occur in the St. Croix River. The diversity of native mussels within the Riverway is well documented and numerous threats to this diversity have been identified (Hornbach 2001). Although not apparent yet, this faunal group may be severely impacted if zebra mussels reach high densities such as has been reported in the Upper Mississippi River below Lake Pepin in Pool 4 (USFWS 2000). Freshwater mollusks are a keystone faunal group of freshwater systems and their potential loss is unacceptable. Baseline data and future monitoring of zebra mussel density and distribution in the lower St. Croix River is crucial in order to identify future trends of infestation and aid in the prevention and control of the species.

In order to understand the invasion and spread of zebra mussels into the St. Croix River, quantitative measurements of density were taken within the known infestation zone (the lower 23 miles of the river) at areas where native mussels are known to occur. Evidence from the Upper Mississippi River and elsewhere suggests zebra mussel colonization predominates on native mussel beds, especially when substrates are less favorable for recruitment (e.g., sand, silt) (McMahon 1991, USFWS 2000). This evidence, coupled with an interest in understanding the potential impacts to native mussels, provided rationale for choosing sample locations based on native mussel bed survey work previously conducted by the Minnesota DNR and funded by the Corps' St. Paul District (Kelner and Davis, 2002). Six locations were identified from Stillwater, MN, to Prescott, WI, reflecting the range of habitats and hydrology found in the infestation zone. Thirty 1/8-meter quadrate samples were collected by divers within 3 sub-sites (10/each) at each of the locations. These samples were processed off river, frozen and examined under magnification. Data collected will aid managers who are creating policy based on the spread and intensity of the invasion.

Methods and Materials

Study Area

The sampling area included the reach of the St. Croix River where zebra mussels have previously been found on substrate other than boats. This includes the river from the Stillwater Lift Bridge at mile 23.3, to the launch at St. Croix Bluffs Regional Park (mile 4.2). Intensive qualitative searches upstream of the lift bridge during 2004 and in years past have not yielded a confirmed positive find.

The lower 25 miles of the St. Croix River (see Appendix B) are composed of a series of pools created by a naturally occurring riverine impoundment (augmented by Lock and Dam #3 on the Mississippi River). The upstream most pool (Bayport Pool), from Stillwater to North Hudson, WI, is approximately six and a half miles long and ends at a mile-long narrows running along the cities of Hudson, WI and Lakeland/West Lakeland, MN. The next pool (Lake St. Croix Beach Pool) is about four and a half miles, beginning roughly at the I-94 Bridge and ending at the bend in the river creating Catfish Bar. The third pool (Afton/Black Bass Bar Pool) starts at the bend and ends at the narrows created by the Kinnickinnic River Delta (about 5 miles). Finally, the Kinnickinnic/Prescott Pool stretches the last six miles to the Mississippi.

The original study area, as defined by the Corps, includes two permanent locations. One is within the no-wake zone in Prescott, the other is the Hudson Narrows (both Higgins' Eye Essential Habitat Areas). As proposed, a single location previously delineated by Kelner and Davis 2002, should also be included (we included six, see below). The 2002 report highlighted 27 locations from just upstream of the Stillwater Lift Bridge to Prescott which the authors had determined contained native mussels in densities considered a "bed." These beds are useful locations to survey, as information from the

Mississippi River and elsewhere suggest recruitment of settling zebra mussels is higher in native beds than surrounding substrate. This may be more apparent in areas of soft river bottom. While zebra mussels have been found in the river up through the Bayport Pool, the observed infestation varies widely. Whether due to substrate, or some microhabitat condition or influence, site selection was chosen to help identify effects zebra mussels might have on native mussel populations.

During the 2004 field season, the Corps had contracted studies in the Hudson Narrows and Prescott locations. Data collected included quantitative zebra mussel finds, which will be available in the future. Therefore, two other locations could be and were substituted from the 27 locations mentioned above. A designed third location was joined by an additional three sites, so that samples were taken at six locations within all the pools of Lake St. Croix.[ǂ] The locations were (1) the New Stillwater Bridge mussel relocation site, and (2) across from Anderson Point (both in the Bayport Pool and on the Wisconsin shore). The next location (3) was in the Lake St. Croix Beach Pool north of Catfish Bar, followed by a site in the Black Bass Bar/Afton Pool (4). The final two sites were just above (5) and (6) below the Kinnickinnic Narrows. These six locations and the two Essential habitat areas delineate the infested portion of the St. Croix River and meet the criteria of the study. These same sites will be sampled using the same methods in subsequent years.

Sampling Methods

The protocol for sampling was taken from guidelines established by the funding agency and refined in the field. During three days at the end of August 2004, two crews sampled two locations each day. Two to three divers were assigned to each boat, with one to three persons (two is ideal) topside (Fig. 1). Total daily field time was about six to seven hours shore to shore.

[ǂ] (Park Service and Fish and Wildlife Service staff decided on sites by spreading them among the 27 from Kelner and Davis, 2002, and including each pool.)

Figure 1. Sampling the Bayport Pool

Sites were first explored to determine the native mussel density and distribution, and the feasibility of sampling the location. Within the perimeter of each site, three stations were established with a GPS reading and an anchored boat. The crew then tossed a 1/8-meter metal quadrate arbitrarily within a 15-meter circumference of the boat a total of ten times. The divers were instructed to collect everything within the quadrate, digging down into the substrate a finger's length and placing that material into a five gallon bucket. Samples were returned to the boat and flushed through a plastic bucket containing a series of 3mm holes. All live mussels were counted as such, inspected for zebra mussel settlement and returned to the river. The samples then were logged, labeled, poured into zip lock gallon bags and placed in a cooler.

Processing

Processing took two steps. The 180 samples were first dumped onto a framed sieve and washed through a 6mm mesh, eliminating sand and small particulate matter (Fig. 2). The rinsed material was inspected for zebra mussels, Asian Clams (*Corbicula sp.*), snails, native mussels (including empty shells) and fingernail clams. (Snails were aggregated into each of the six locations, and were be part of a river-wide survey conducted in 2004.) Larger gravel/cobble/rock was carefully examined for settlement or suitability. Material that would be scrutinized later (shells, *Corbicula*, suitable rocks, etc.), was returned to the collection bags—in smaller bags or vials if fragile—and placed in a 5 cubic foot chest freezer. Total step one processing time was approximately 40 hours.

Figure 2. Initial flushing of sand from samples

Figure 3. Detailed examination using magnification

Photo: J. Bourman

The initial reduction of the material had many advantages. All material from the 180 samples that was not preserved in ethanol was frozen in a 5 cubic feet home freezer. This reduces the volume of hazardous waste and subsequent disposal concerns, and improves the handling and examination of the remaining material. Additionally, native mussels were found alive packed in the moist sand two weeks after being pulled from the river. Had the samples been preserved in alcohol when collected, rather than cool-stored until processed, these animals would have been lost. Finally, samples did not need to be rinsed again before being examined under magnification.

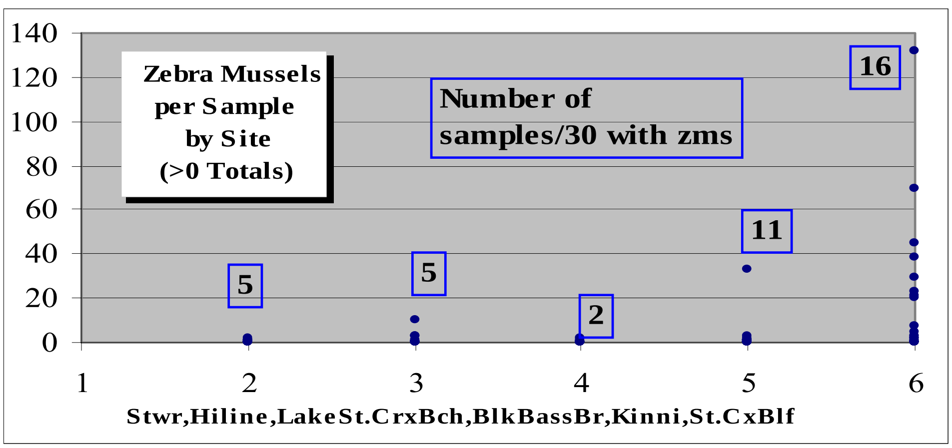
Next, samples were then thawed and placed in an examination tray and inspected under 10x magnification and dissecting scope. The quantity of zebra mussels in these samples was not sufficient to warrant sub-sampling. This may occur in the future and fine processing might require additional breakdown. The amount of fine processing and examination took approximately 30 hours, and 16 hours were used to input the results into a database. Most of the zebra mussels were measured, all were counted, and representives vouchered. *Corbicula* and native mussel data are included in the spreadsheet accompanying this report.

Results

The six sites surveyed by NPS/USFWS were first determined from Kelner and Davis 2002, and identified as suitable once in the field. These were Kelner and Davis' Sites 2 and 6 (Stillwater/Bayport), 12 and 15 (Lake St. Croix Beach and Black Bass Bar), and 18 and 24 (North of St. Croix Bluffs and Kinni Narrows). The data collected from these sites can be found in Appendix A, and full results can be read in the Excel spreadsheet.

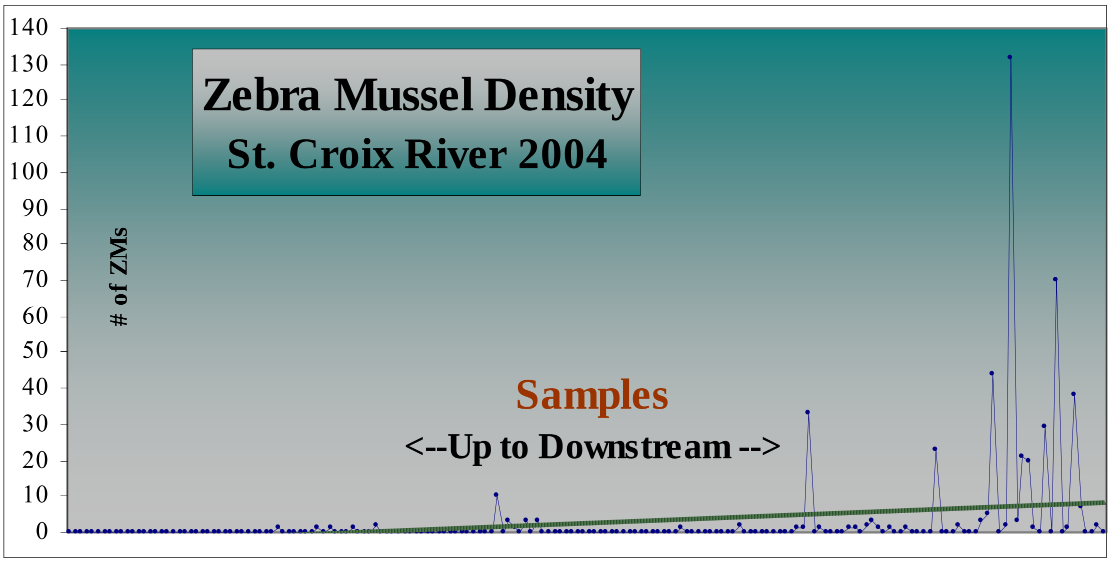
Of the thirty samples collected at each site, no zebra mussels were found in any of the upstream most Site #1 (Kelner 2); five samples contained at least one zebra mussel in the next Sites #2 and #3 (Kelner 6 and 12); the 4th site (Kelner 15) had two samples with a positive find. At the last two downstream Sites #5 and #6 (Kelner 18 and 24), 11 and 16 of each sample set contained zebra mussels (Fig. 4). At Site #2, four of the five sites

Figure 4. The six sites with the number of samples that had zebra mussels and the amount for each sample



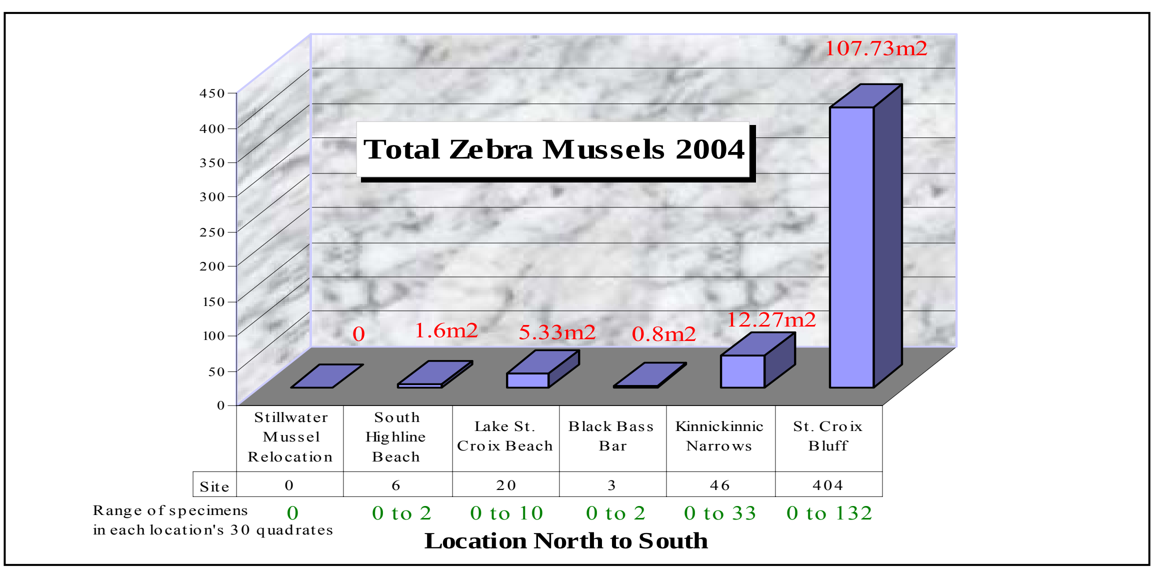
contained only a single specimen, while the fifth contained two. The third site, at Lake St. Croix Beach, had three samples with three mussels, one with one zebra mussel and one sample with 10. Site 4 had a sample with two and one zebra mussel(s). Site 5 had one sample with 33 zebra mussels, but the remaining 10 samples with positive finds had three or fewer. Finally, the sixth site, just upstream from St. Croix Bluffs in the Kinnickinnic/Prescott Pool, had one-half the positive samples with double digit mussels, including one sample with 132 (Fig. 5). These data suggest zebra mussel densities of $0m^2$ at the upstream edge of the Bayport Pool, $1.6m^2$ at midpoint in that pool, $5.33m^2$ at

Figure 5. Zebra mussel totals by each of the 180 samples



mid-Lake St. Croix Beach Pool, $0.8m^2$ in the Black Bass Bar/Afton mid-pool, and $12.27m^2$ and $107.73m^2$ above and below the Kinnickinnic Narrows. In addition, within a single quadrate, zebra mussels at the six sites from north to south were found a minimum of zero at all locations to two, 10, 33, and 132 (Fig. 6).

Figure 6. Total zebra mussels found by location upstream to downstream and m^2 density average (30 x $1/8m^2 = 3.75m^2$ per location). Also includes the range of per quadrate specimens by location.



The Bayport mid-pool location provided only six specimens. These ranged in size from 4.3 to 7.2mm. At the sites below Hudson and Afton, the specimens ranged from 1.4 to 29.9mm and 4.2 to 9mm (the latter with only three specimens). But all three locations had a mean 6.2mm. The downstream-most two sites had slightly lower mean zebra mussel sizes, but the frequency of the smallest mussels was dramatic at Site #6 in the Kinnickinnic/Prescott Pool (Fig. 7.).

For the size distribution, all shells were considered alive. While the overwhelming number of zebra mussels collected was smaller than 15mm—and most of these were less than 10mm—it appears a large number of mussels found in the Kinnickinnic/Prescott Pool are only a few millimeters in size and probably 2004 recruits.

Figure 7a. Histograms/Graphs of the five of six sites where zebra mussels were found. Sites 6, 3 and 5 highlight frequency of sizes. Data includes approximate sizes within narrow ranges (~<10mm) and excludes crushed specimens.

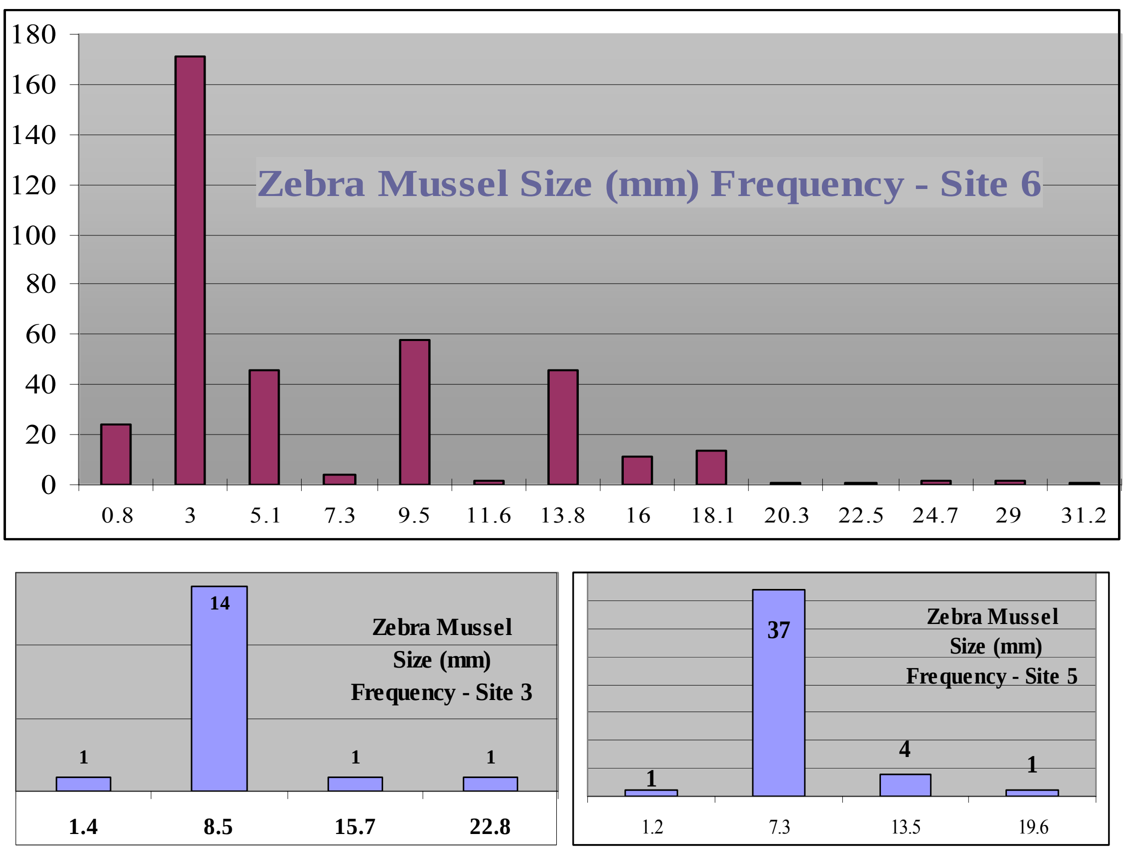
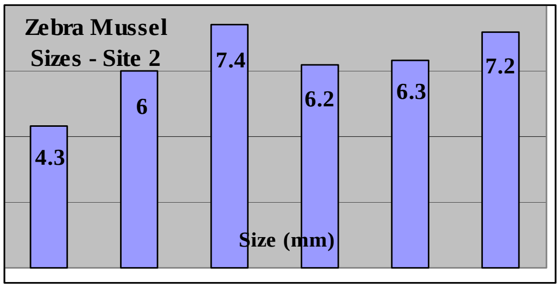
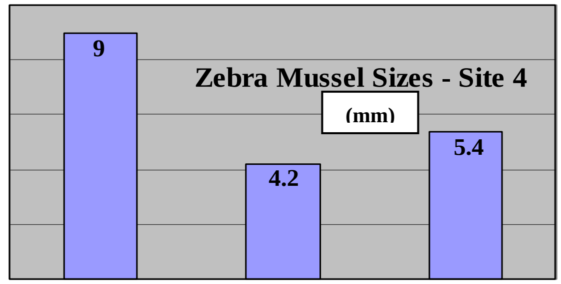


Figure 7b. Shown for Sites 2 and 4 are the sizes of the actual specimens.





Native mussels were collected and counted during the sampling and processing of the substrate material. Though bivalves were not identified below family, live and dead animals were counted, and the number of live attached zebra mussels on live native mussels was tallied (Table 1). Byssal threads were noted on two animals at Site #3 and on one mussel at Site #4. It appeared that only a few zebra mussel attachments per native host occurred on these three animals, but the threads were from mature zebra mussels.

The only physical characteristics noted in the table below highlight the similarity among sites in depth and temperature. Substrate, flow, distance from shore, and other site descriptions can be found in the accompanying spreadsheet, or in the data sheets upon request.

Table 1. Physical site information and bivalves collected

Site	Avg. Depth (ft.)	Water Temp F	Corbicula	Dead Natives	# Live Native Mussels	ZM on live mussels	Total zm
Stillwater Mussel Relocation Site	5	68	18	30	21	0	0
South Highline Beach	5	67	86	29	24	2	6
Lake St. Croix Beach	6	68.35	40	33	11	16	20
Black Bass Bar	5	69	22	7	8	2	3
Kinnickinnic Narrows	6	68	9	10	11	7	46
St. Croix Bluff	6	70	49	46	13	19	404
Avg./Totals	5.9	68.39	224	155	88	46	479

The Unionidae collected at these six sites represent densities that were within the range of what the literature suggests is a viable "bed" (Whitney, 1996). Native mussels were found ranging from $4/m^2$ to $15.7/m^2$ (Table 2.). This might be contrasted with the live/dead ratio of natives at these sites, and zebra mussel infestation on live natives.

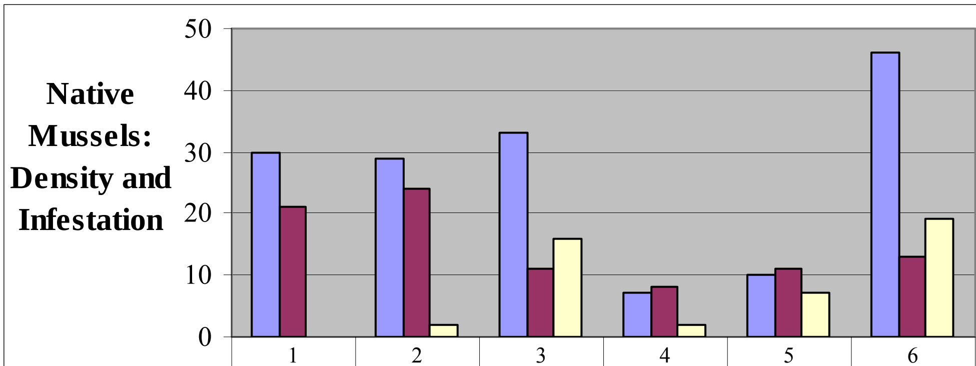
Table 2. Native mussel bed data

Site	Unionidae per m^2	Unionidae Live/Dead Ratio	ZM Infestation Rate
Stw Relocation	**13.6**	**.70**	**0**
HiLine	**14.1**	**.83**	**.08**
Lake St. Croix Beach	**11.7**	**.33**	**1.45**
Black Bass	**4.0**	**1.14**	**.25**
Kinnickinnic	**5.6**	**1.10**	**.64**
St. Croix Buffs	**15.7**	**.28**	**1.46**
Totals	**10.8**	**.73**	**.65**

The rate of infestation was determined by the total number of live mussels found and the number of zebra mussels found attached to live native mussels. The ratio of dead mussels to live mussels found in the samples can be found in Table 2, along with the infestation rate and native mussel densities by location.

Site 6 contained nearly 108 zebra mussels/m^2 with over 400 total individuals collected. At this location, 19 zebra mussels were attached to natives (Fig. 8). The samples at Site 3

Figure 8. Number of Live Mussels, Dead Mussels, and Zebra Mussels by Location



	1	2	3	4	5	6
Dead Native Mussels	30	29	33	7	10	46
Live Native Mussels	21	24	11	8	11	13
ZMs on Natives	0	2	16	2	7	19

contained 16 zebra mussels attached to native mussels. These two sites had the highest number of dead mussels to live mussels of the six locations. Sites 4 and 5 had greater numbers of live to dead native mussels and fewer zebra mussels attached to these natives. The overall numbers of all animals collected at these sites were very low and statistical comparisons were unreliable, however this baseline data may be useful with future results.

Discussion

The sites selected met the study design of sampling over at least marginally dense mussel beds within the known extent of zebra mussels in the St. Croix River. The locations included at least one site in each pool of the lower river. The total area sampled within each site was reasonable at nearly $4m^2$. This area is especially pertinent as the samples were an aggregate of 30 arbitrary 1/8-meter squared quadrates that occurred within the identified beds. The volume of the 180 individual samples was considerable, but lent to a more robust data set for this baseline survey. The results pertaining to zebra mussel densities were largely expected, but interesting information related to other invasives, snails, and native mussels was discovered. What is still unanswered is the source of zebra mussel reproduction.

The positive zebra mussel finds mirror the results of the qualitative sampling that has been done since 2000. The exception was the first signs of juvenile recruitment in the pool directly below the Stillwater Lift Bridge. Small zebra mussels had been found during the June scuba search, when presence/absence and relative abundance data were collected. However, this invasive has always been found highly scattered in small numbers within this pool in the past.

The rate of flow within all of the pools allows for zebra mussel settlement, though the water retention time within any of the pools (Table 3.) is not long enough to allow freshly spawned planktonic zebra mussel veligers the 18+ days to develop (Neumann 1992).

Table 3. Water Retention Times by Pool, Lower St. Croix National Scenic Riverway. Modified from Robertson and Lenz 2002.

Average Water Retention Time (in days) in the Lower St. Croix River		
Pool	Dry Year	Wet Year
Bayport	11.0	5.0
Lake St. Croix Beach	19.4	8.1
Black Bass Bar	11.0	4.3
Kinnickinnic/Prescott	8.1	3.3
Total	50.1	20.0

The qualitative assessments to date have found freshly settled juveniles in every pool in the lower river (Karns 2004). Their presence, resulting from widespread reproduction and not sporadic introductions, suggests some unique hydrological regime. Regardless, as important as answering the question of where they came from is understanding where they are—and in what numbers. This is crucial in assessing zebra mussel impacts and future prevention and control measures.

The size range of zebra mussels found in the study area was 0.8mm to 42.0mm, indicating several sets of cohorts (recent and ongoing recruitment). The histograms show that while the total specimens collected in the upper portion of the study area may have been too few to be significant in determining age class structure, the size average of 6.2-6.3mm represents older sub-adults. However, the size of many of the specimens collected throughout the study area is indicative of recent recruitment, even if the number of specimens per site was small. All zebra mussels 15mm or smaller could be young of the year (Neumann 1992). Of note is how locally abundant zebra mussels have become, four years after the initial stages of colonization.

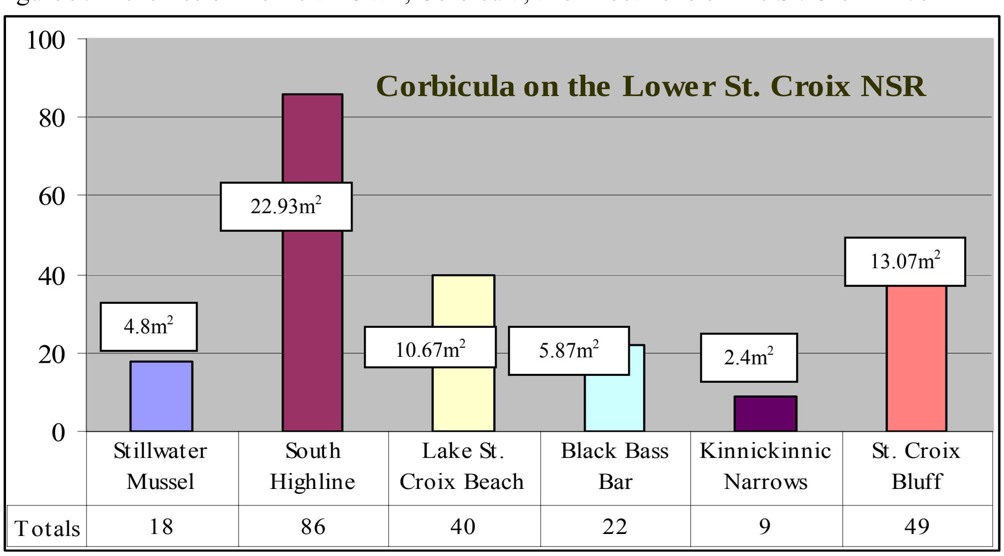
As expected, recruitment was directly related to river reach. The upstream-most sites had no, or low settlement (n=0, 6), while the downstream most sites had many more (n=46, 404). Zebra mussels found on live native mussels were greatest in the Kinnickinnic Pool (n=19, Site 6), but the Lake St. Croix Beach Pool (n=16, Site 3) had the second highest number of specimens on natives and a ratio of live to dead mussels second only to Site 6. Site 3 also had the 3rd greatest density of zebra mussels (5.33m^2), reflecting perhaps surface hydrology (consistent southerly winds), water retention time (dry year=~20 days), or an unidentified upstream source. This site, while directly downstream, is the closest in this study to the Higgins' Eye Essential Habitat in the Hudson Narrows.

Unlike mature populations on the Mississippi River and elsewhere, there are only a few locations on the St. Croix where anecdotal evidence suggests aged zebra mussels are dying at the end of normal life expectancy (Karns 2004). While there were a small number of byssal threads found on living mussels, there was a general lack of evidence of attachment by mature animals, also suggesting a younger/newer zebra mussel population.

Outside the scope of this initial study is the role substrate and other physical characteristics play in recruitment. The attached spreadsheet provides the raw data, and subsequent surveys should incorporate, collect and use this information.

An interesting additional data set collected was the density of *Corbicula* in the lower river. I am not sure if the range of these Asian Clams has been documented on the St. Croix, but the density information presented in Figure 9, suggests the influence of the

Figure 9. Densities of the Asian Clam, Corbicula, at six locations on the St. Croix River



King power plant located across from Site 2. *Corbicula* is a non-native invader which is assumed to be at the northern range of its tolerance, does not appear to be greatly significant in the St. Croix, but is considered a bio-pollutant in warmer parts of the country (McMahon, 1991). This anecdotal evidence indicates the King plant may increase slightly the year-round mean temperature of this part of the St. Croix River.

Conclusion:

The sampling of native mussel beds in the Lower St. Croix National Scenic Riverway for zebra mussel densities appears to support qualitative work to date. The invasive mussel is found in very low numbers north of Bayport, MN, but increases significantly downstream. Population age structure appears to be heavily juvenile, or young of the year mussels. Only a handful of finds of "old" zebra mussels and no empty shells were identified. Dead zebra mussel shells have been detected in the Kinnickinnic Narrows and Prescott areas during past surveys, thus efforts to identify live and dead zebra mussels will occur next season. Infestation may or may not be influencing native mussel die-off, but with monitoring this trend should become clearer over time.

Although quantitative samples in the upper pools where zebra mussels are not abundant appears of no use, baseline data in the potentially early stages of increased density and upstream dispersal are crucial for a long term monitoring approach. The post collection processing is reasonable with the current resources, but may not be in the future if zebra mussel numbers increase dramatically. The value of this baseline information is that it allows managers to hone the scope of the study and change the volume and area as needed. The initial protocols were developed for an already infested site, but modified nicely for the pools of the Lower St. Croix River. This reach of the St. Croix River has relatively low densities compared to areas of the Mississippi river below Lake Pepin.

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Appendix A. Zebra Mussel Density Data from Sample Quadrates within the Lower St. Croix National Scenic Riverway

This table represents an example of data collected during the field event of August 30 to September 1. It includes six locations based on mussel bed site selection from Kelner and Davis, 2001. Identified mussel beds were chosen as likely settling areas for zebra mussels. Within the parameter of each location, 30 samples were randomly selected and collected. Examples of the data collected are provided below, including physical details, live/dead native mussel density, infestations, *Corbicula* numbers, etc. Gastropods were also collected and their densities are available in a different report. Due to the size of the spreadsheet, it is available as a separate file.

St. Croix National Scenic Riverway - 2004 Zebra Mussel Density Data

Site Name	River Mile/Shore	Site	Kelner Site	Sample	Date	GPS - X (Lat)	GPS - Y (Log)	Diver	Note	Offshore (ft)	%Silt	%Sand	%Cobble	%Rock	%Debris	Flow	Depth	Water Temp	Corbicula	Dead Natives	# Live Native Mussels	zm on live mussels	Byssal Threads	Total ZM	ZM Size range
Stillwater Mussel Relocation Site	L23	1	2	1	30-Aug	4988987.82934323	516092.82062494	Team	Fine sand 1-10	70	50	50				none	5	68	1	2	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	2	30-Aug	4988987.82934323	516092.82062494	Team		50	60	50				none	5	68	0	0	1	0		0	
Stillwater Mussel Relocation Site	L23	1	2	3	30-Aug	4988987.82934323	516092.82062494	Team		70	50	50				none	5	68	0	2	1	0		0	
Stillwater Mussel Relocation Site	L23	1	2	4	30-Aug	4988987.82934323	516092.82062494	Team		70	70	30				none	5	68	3	3	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	5	30-Aug	4988987.82934323	516092.82062494	Team		30	40	40			20	none	5	68	0	2	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	6	30-Aug	4988987.82934323	516092.82062494	Team		70	50	50				none	5	68	4	2	3	0		0	
Stillwater Mussel Relocation Site	L23	1	2	7	30-Aug	4988987.82934323	516092.82062494	Team		70	40	40			20	none	5	68	1	1	1	0		0	
Stillwater Mussel Relocation Site	L23	1	2	8	30-Aug	4988987.82934323	516092.82062494	Team		70	70	30				none	5	68	1	4	1	0		0	
Stillwater Mussel Relocation Site	L23	1	2	9	30-Aug	4988987.82934323	516092.82062494	Team		45	70	30				none	5	68	0	1	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	10	30-Aug	4988987.82934323	516092.82062494	Team		70	70	30				none	5	68	3	2	6	0		0	
Stillwater Mussel Relocation Site	L23	1	2	11	30-Aug	4989051.01628574	516033.98036306	Brett		75		80			20	none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	12	30-Aug	4989051.01628574	516033.98036306	Jen		75		90			10	none	5	68	3	2	1	0		0	
Stillwater Mussel Relocation Site	L23	1	2	13	30-Aug	4989051.01628574	516033.98036306	Brett		75	30	60			10	none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	14	30-Aug	4989051.01628574	516033.98036306	Jen		75	20	75			5	none	5	68	1	1	1	0		0	
Stillwater Mussel Relocation Site	L23	1	2	15	30-Aug	4989051.01628574	516033.98036306	Brett		75		60			40	none	5	68	0	1	4	0		0	
Stillwater Mussel Relocation Site	L23	1	2	16	30-Aug	4989051.01628574	516033.98036306	Jen		75	10	85			5	none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	17	30-Aug	4989051.01628574	516033.98036306	Jen		75	30	70				none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	18	30-Aug	4989051.01628574	516033.98036306	Brett		75		70			30	none	5	68	0	3	1	0		0	
Stillwater Mussel Relocation Site	L23	1	2	19	30-Aug	4989051.01628574	516033.98036306	Jen		75	30	60			10	none	5	68	0	1	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	20	30-Aug	4989051.01628574	516033.98036306	Brett		75	25	25			50	none	5	68	0	2	1	0		0	
Stillwater Mussel Relocation Site	L23	1	2	21	30-Aug	N4503.250	W09247.737	Team	More Silty than 1-10	70	60	40				none	5	68	0	1	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	22	30-Aug	N4503.250	W09247.737	Team	Low Viz	70	60	40				none	5	68	1	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	23	30-Aug	N4503.250	W09247.737	Team		70	60	40				none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	24	30-Aug	N4503.250	W09247.737	Team		70	60	30			10	none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	25	30-Aug	N4503.250	W09247.737	Team		50	60	30			10	none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	26	30-Aug	N4503.250	W09247.737	Team		70	40	45	10		5	none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	27	30-Aug	N4503.250	W09247.737	Team		50	60	30			10	none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	28	30-Aug	N4503.250	W09247.737	Team		70	50	50				none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	29	30-Aug	N4503.250	W09247.737	Team		50	60	30			10	none	5	68	0	0	0	0		0	
Stillwater Mussel Relocation Site	L23	1	2	30	30-Aug	N4503.250	W09247.737	Team		45	50	40			10	none	5	68	0	0	0	0		0	
South Highline Beach	L21	2	6	1	30-Aug	N4501.846	W9245.593	Team		60	10	90				none	2	67	4	3	1	0		0	
South Highline Beach	L21	2	6	2	30-Aug	N4501.846	W9245.593	Team		80	10	90				none	3	67	2	0	1	0		0	
South Highline Beach	L21	2	6	3	30-Aug	N4501.846	W9245.593	Team		80	10	90				none	3	67	1	1	0	0		0	
South Highline Beach	L21	2	6	4	30-Aug	N4501.846	W9245.593	Team		80	10	90				none	3	67	2	0	0	0		0	
South Highline Beach	L21	2	6	5	30-Aug	N4501.846	W9245.593	Team		60	10	90				none	2	67	0	0	1	0		0	
South Highline Beach	L21	2	6	6	30-Aug	N4501.846	W9245.593	Team		60	10	90				none	2	67	0	0	0	0		0	
South Highline Beach	L21	2	6	7	30-Aug	N4501.846	W9245.593	Team		80	10	90				none	3	67	3	0	2	1		1	4.3mm
South Highline Beach	L21	2	6	8	30-Aug	N4501.846	W9245.593	Team		60	10	90				none	3	67	0	1	1	0		0	
South Highline Beach	L21	2	6	9	30-Aug	N4501.846	W9245.593	Team		80	10	90				none	3	67	5	1	1	0		0	
South Highline Beach	L21	2	6	10	30-Aug	N4501.846	W9245.593	Team		80	10	90				none	3	67	1	2	2	0		0	
South Highline Beach	L21	2	6	11	30-Aug	4986368.72363527	518917.31752241	Jen		100	30	70				none	3	67	0	0	0	0		0	
South Highline Beach	L21	2	6	12	30-Aug	4986368.72363527	518917.31752241	Brett		100		90			10	none	7	67	1	2	1	0		0	
South Highline Beach	L21	2	6	13	30-Aug	4986368.72363527	518917.31752241	Jen		100	30	70				none	5	67	1	1	0	0		0	
South Highline Beach	L21	2	6	14	30-Aug	4986368.72363527	518917.31752241	Brett		100	5	80			15	none	8	67	1	1	2	0		1	6mm
South Highline Beach	L21	2	6	15	30-Aug	4986368.72363527	518917.31752241	Jen		100	30	70				none	5	67	2	1	1	0		0	
South Highline Beach	L21	2	6	16	30-Aug	4986368.72363527	518917.31752241	Brett		100		90			10	none	7	67	5	2	0	0		1	7.4mm
South Highline Beach	L21	2	6	17	30-Aug	4986368.72363527	518917.31752241	Jen		100	30	70				none	3	67	2	0	0	0		0	
South Highline Beach	L21	2	6	18	30-Aug	4986368.72363527	518917.31752241	Brett		100		90			10	none	4	67	3	1	1	0		0	
South Highline Beach	L21	2	6	19	30-Aug	4986368.72363527	518917.31752241	Jen		100	30	70				none	5	67	1	2	0	0		0	
South Highline Beach	L21	2	6	20	30-Aug	4986368.72363527	518917.31752241	Brett		100		90			10	none	8	67	12	2	3	0		1	6.2mm

Appendix B. Study Area of the Lower St. Croix National Scenic Riverway Includes the six NPS sample locations, determined from previous native mussel bed identification. Also note the two permanent fixed sites, in 2004, sampled by the USACE.