Preliminary Report on the Effects of the 2005 Pool 5, Mississippi River Drawdown on Shallow-water Native Mussels.

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20 February 2006

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ACKNOWLEDGEMENTS

The St. Paul District of the U. S. Army Corps of Engineers supported this work. Various staff from the Minnesota Department of Natural Resources, U. S. Fish and Wildlife Service, Region 3, U. S. Army Corps of Engineers and the Wisconsin Department of Natural Resources contributed significant in-kind work.

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INTRODUCTION

This document reports results of an investigation into the effects of the 2005 Navigation Pool 5, Mississippi River drawdown on shallow-water native mussels. This investigation's purpose was to determine the effect and fate of shallow-water mussels from this pool-wide surface water elevation drawdown.

Pool 5, created in 1936, is located between river miles 738.2 and 752.8 and is bounded on the downstream end by Lock and Dam 5 and on the upstream end by Lock and Dam 4 (Figure 1). The downstream

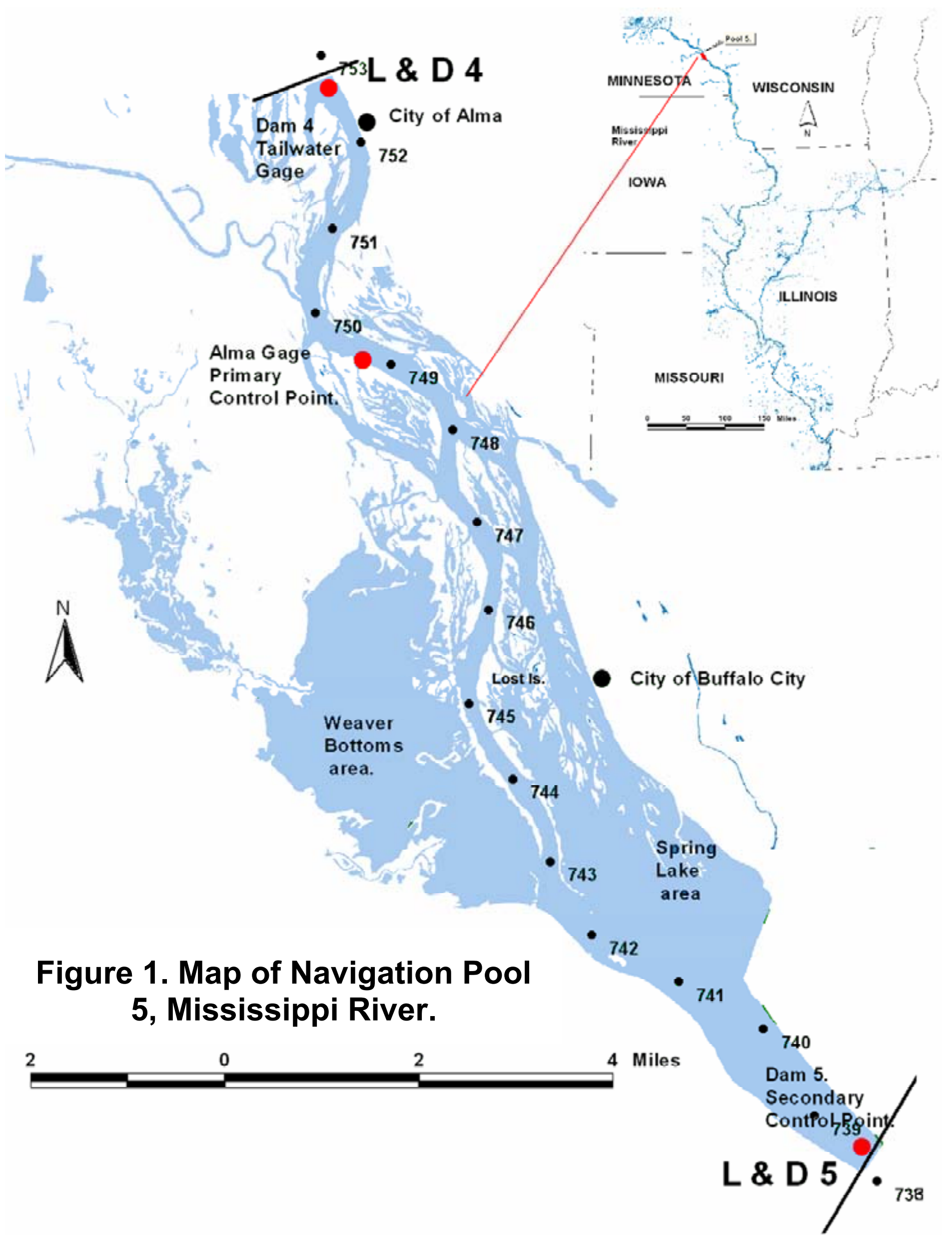


Figure 1. Map of Navigation Pool 5, Mississippi River.

two-thirds of the Pool 5 floodplain is dominated by shallow open water. Significant open water complexes include Weaver Bottoms, Lost Island and Spring Lake. The remaining parts of the floodplain contain a mosaic of bottomland forests, marshes, grasslands, backwaters, secondary and tertiary channels.

In the past several years, upper Mississippi River management agencies have planned and executed water level reductions during the plant growing seasons in select navigation pools. During the summer of 1995, water surface elevations in Navigation Pool 25 near St. Louis, Missouri were held 1 to 2 ft lower than normal, exposing about 3000 ac. Similarly, during the summers of 2001 and 2002, a demonstration pool-scale drawdown was done in Pool 8 when about 1954 ac was dewatered, representing about 8.5% of the pool.

During 2005, Pool 5 was drawn down June 13 to September 26. The target elevation reduction was 1.5ft at Lock and Dam 5. The normal target elevation at the dam is 659.5 ft above mean sea level, so the drawdown target elevation was 658.0. Pool 5 drawdown objectives included: the increased production, extent, and diversity of aquatic vegetation, particularly, emergent plants, to increase fish and wildlife habitat; the continued operation and maintenance of 9-foot Navigation Channel; the minimization of adverse effects on river resources and uses; and the increase in knowledge of upper Mississippi River drawdowns (U.S. Army Corps of Engineer, St. Paul District. 2005).

During 2005, a number of potential impacts were monitored. These included aquatic vegetation, hydrology, hydrodynamics, sediment transport, water quality, river use, cultural resources, weather, freshwater mussels, other macroinvertebrates, birds, amphibians and recreation.

METHODS

Water Elevations

Water elevation data was taken from the St. Paul District, U. S. Army Corps of Engineers Water Control Center database (www.mvp-wc.usace.army.mil/imagemaps/Miss.shtml). Spatial areas dewatered were provided by the USGS, Upper Midwest Environmental Sciences Center – La Crosse, Wisconsin from aerial photographs of most of Pool 5 flown on July 15, 2005 and August 13, 2004. These photographs were digitized and compared to baseline photographs made prior to the drawdown. We calculated dewatered area for the lower pool based on the July 15 photograph and added any additional area from upper pool based on the August 13 photograph. We subtracted any overlap between these time periods and areas.

Three different methods were used to assess the impact of the drawdown on shallow-water freshwater mussels. These included stationary quadrates, transects in dewatered locations, and a visual survey.

Stationary Quadrates

Stationary quadrates containing previously captured and marked mussels were used to determine experimentally the impacts of the drawdown at various locations. These quadrates were placed when elevations at the dam were at 659.5ft above mean sea level, the target operating elevation. Therefore, all water depths measured at each stationary quadrate reflected the “normal” pool elevation at the dam, which the drawdown was based on. On June 6 and 7, 2005, six to seven days prior to the start of the drawdown, we placed a total of twenty quadrates in the river, ten in Pool 5 and ten in Pool 4, a reference pool that was not drawn down (Figure 2). Each quadrate consisted of four 1m-long one-inch diameter PVC pipes (Figure 3). Pipes were placed vertically in the substrate marking the corners of the quadrate. While sampling or placing marked mussels, we used a lead line connected to the four PVC pipe corner posts to delineate the perimeter of each of the quadrates.

We placed in each pool one 3m by 4m quadrate at approximately 1ft of water depth under normal pool elevation at a location where the river bottom was level for at least 50m in all directions (Figure 4). We placed 120 marked mussels within each of these two quadrates. These were designated for analysis as the “flat sites”.

The dimensions of the remaining 18 quadrates were 1m by 4m. We placed a total of 40 marked mussels in each. Of these 18 quadrates, 9 were placed at three noticeably sloped locations in each pool. These quadrates were spatially placed in groups of three, one each at approximately 1ft, 2ft and 3ft water depths under normal pool elevations (Figure 5). These 9 groups of three quadrates were designated as “sloped sites”.

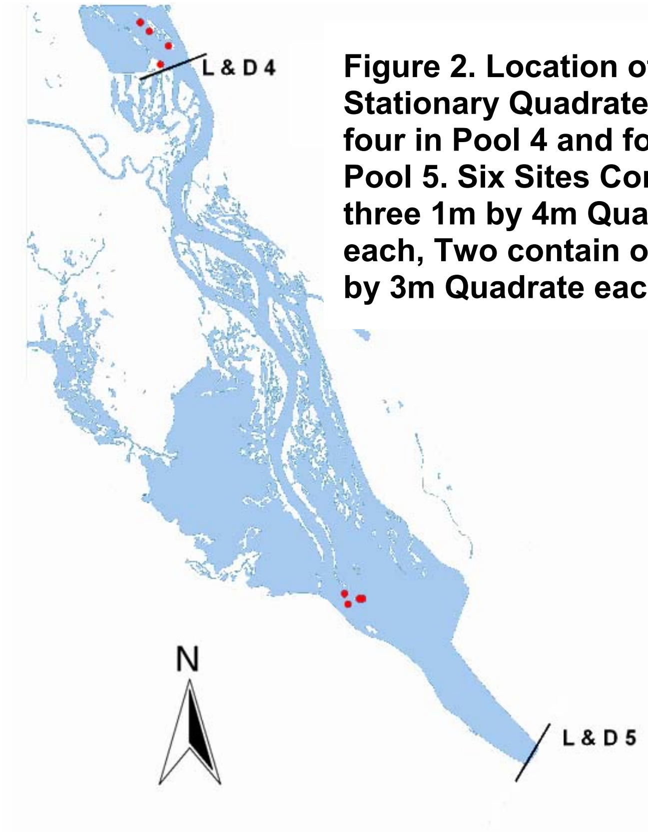


Figure 2. Location of Eight Stationary Quadrate Sites, four in Pool 4 and four in Pool 5. Six Sites Contain three 1m by 4m Quadrates each, Two contain one 4m by 3m Quadrate each.

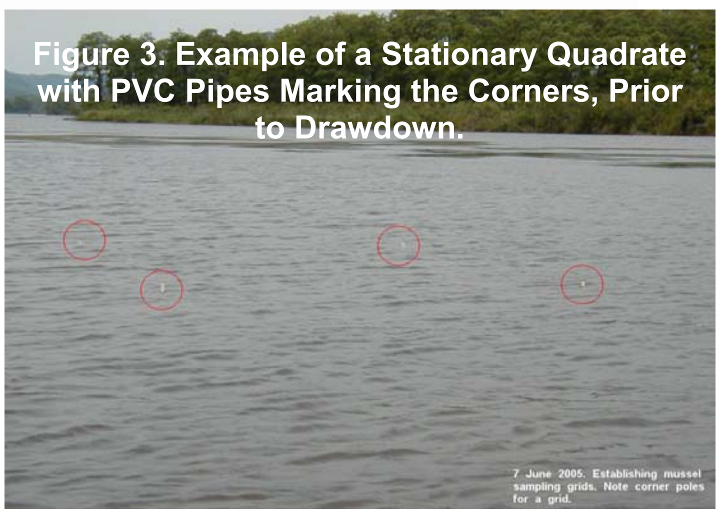


Figure 3. Example of a Stationary Quadrate with PVC Pipes Marking the Corners, Prior to Drawdown.

Mussels were collected from shallow water within 50m of the site, identified to species and measured for total length. We then marked them by etching an identifier on each valve and placed them in quadrates. Each identifier corresponded to the depth the mussel was placed. For example, the one ft quadrates has mussels marked with a “1”. Ones placed in two ft were marked with a “2” etc. Mussels in flat sites were marked with an “F”.

We inspected marked mussels in both pools either using SCUBA or snorkeling when quadrate sites were covered by water. Quadrate sites were inspected visually and tactilely when not covered by water. We inspected quadrates three times in each pool: June 9 (two days after placement), July 7, and August 24-25. During the first

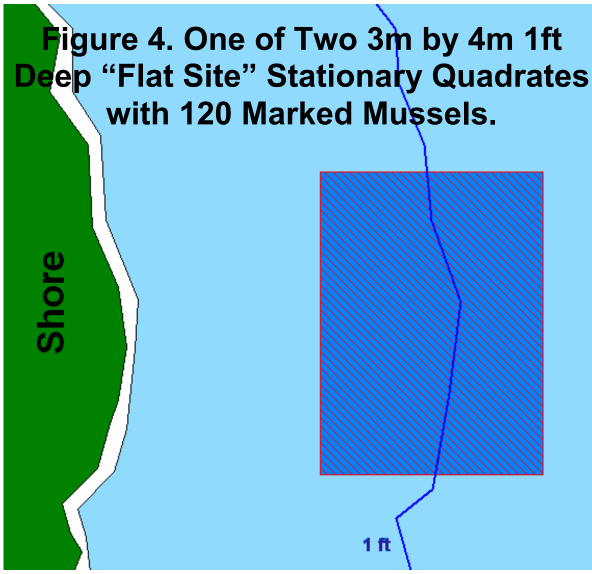


Figure 4. One of Two 3m by 4m 1ft Deep “Flat Site” Stationary Quadrates with 120 Marked Mussels.

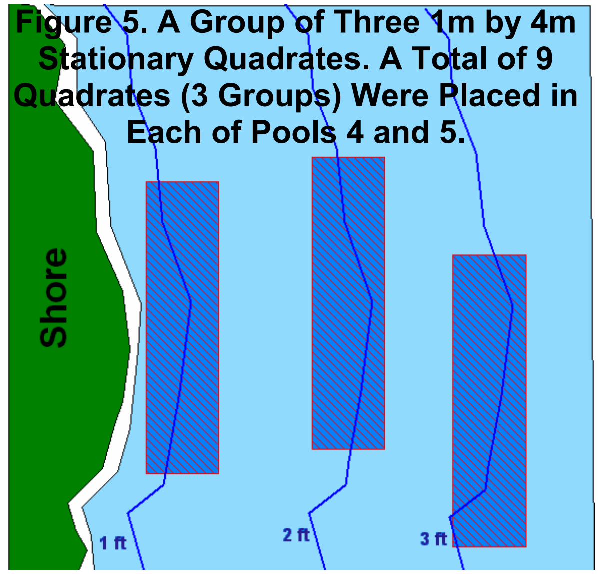


Figure 5. A Group of Three 1m by 4m Stationary Quadrates. A Total of 9 Quadrates (3 Groups) Were Placed in Each of Pools 4 and 5.

two inspection events, all live mussels found were briefly removed from the substrate to verify the presence or absence of marked mussels. No submerged mussel was out of the water more than a few seconds and was immediately replaced to the exact location it was found. Dead mussels were recorded and removed from the site. During the last sampling event, all mussels were permanently removed.

We hand-searched the top 2-4cm of sediment for both live and dead mussels within each quadrate during all three inspection events (Figure 6). During the second, we also hand-searched a 3m buffer outside of

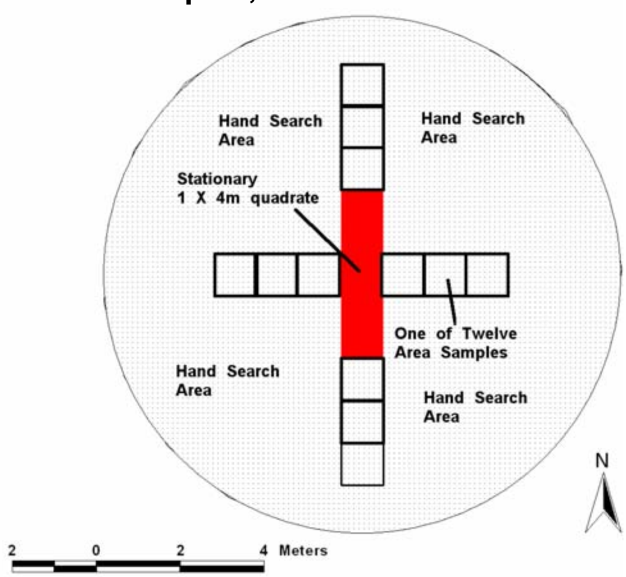
Figure 6. Example of a Hand-Searched, Dewatered Quadrate.

each quadrate. During the third event, at dewatered sites, we also dug with shovels to a depth of about 30cm in twelve 1m² area-samples. Of these twelve area-samples, three were in each of the four cardinal directions around every one of the 7 dewatered stationary quadrates (Figures 7 & 8). Also at dewatered sites, we dug or hand-searched all remaining un-sampled areas to a depth of about 8cm within 4m of each stationary quadrate. Recapture rates were calculated as (number of live marked recaptured + dead marked recaptured during and previous to sampling event) / (total number marked potentially remaining in or near the stationary quadrate).

Survival was calculated as 1-(number of live marked recaptured in Aug. / (number of live marked recaptured in Aug. + dead marked recaptured throughout the summer)).

Figure 7. Example of August 24 - 25 area-samples, three in each of the four cardinal directions around each of the 7 dewatered quadrates.

Figure 8. Example of Areas sampled during the Last Sampling Event (August 24, 25). Included the Stationary Quadrate, then the Twelve Area-Samples, then the Hand-Search Area.



Prior to the drawdown, at each of the sloped sites, we placed a HOBO® automated temperature recorder, encased in a white PVC pipe, at a 1.5ft depth. One temperature logger was placed on each of the two flat sites, at a depth of 1ft.

Transects

On July 14, 31 days after the start of the drawdown and 15days after maximum drawdown was achieved, a total of 32 transects were sampled at various dewatered locations, primarily in the downstream half of the pool (Figure 9). Each transect contained 15 1m² quadrates spaced randomly (Figure 10). In each quadrate,

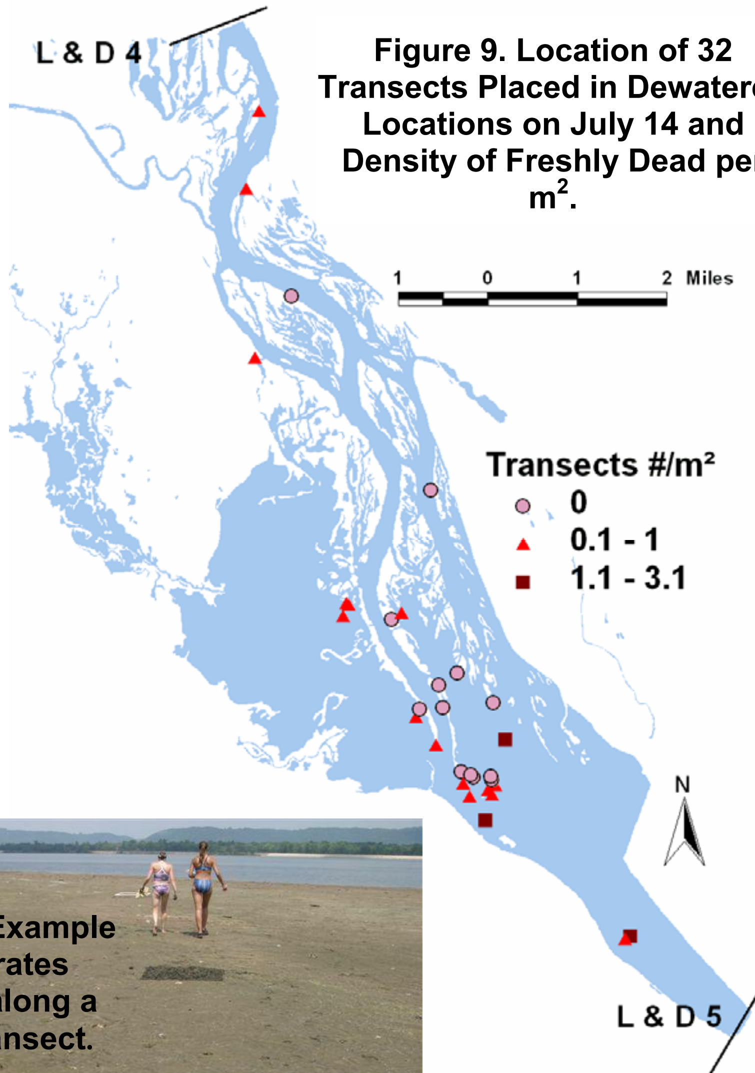


Figure 9. Location of 32 Transects Placed in Dewatered Locations on July 14 and Density of Freshly Dead per m².

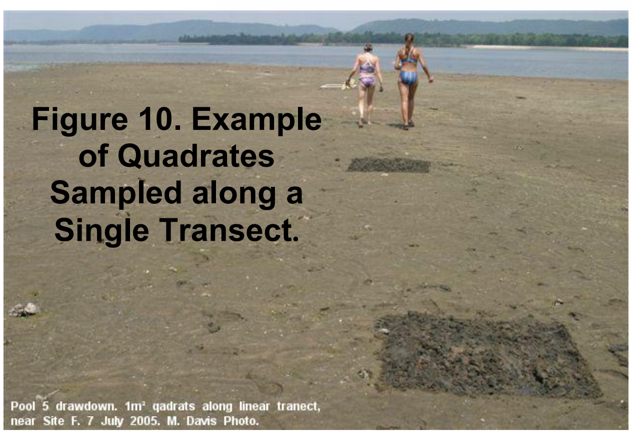


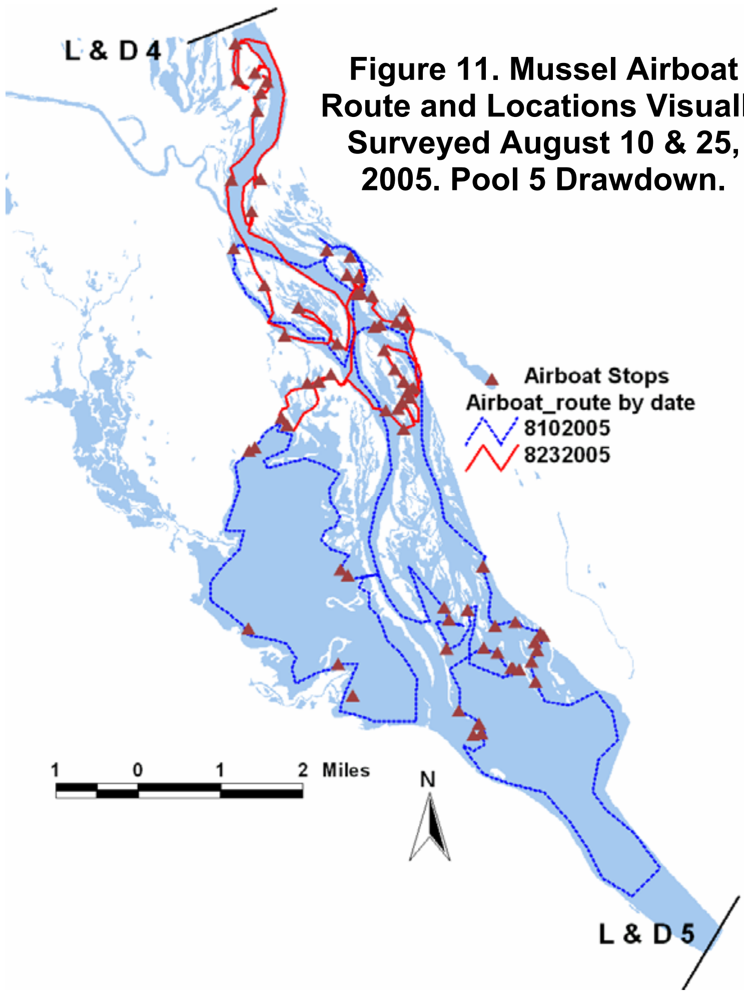
Figure 10. Example of Quadrates Sampled along a Single Transect.

we searched to a depth of about 8cm. We enumerated species and classified them as live or dead. Dead were classified as either "old dead" or "fresh dead". "Fresh dead" were dead animals having any one of the following characteristics 1) absence of attached zebra mussels or zebra mussel shells on the inside of the native shell, and having articulated valves, and having shiny nacre with lack of invertebrate or plant colonization, 2) containing dead tissue or tissue remnants.

Placement of transects was not truly random. We instructed samplers to choose dewatered locations regardless of the presence of mussels and not to bias placement choice. In most cases samplers arbitrarily identified an area along the shoreline at a distance from the boat. Once ashore, they began sampling from that point. We attempted to place a person on each of the six teams who could identify mussel species.

Visual Survey

A roving, visual survey using an airboat was done on August 10 and 23. We visually surveyed all accessible shorelines searching for significantly large dewatered areas. Areas that appeared to be less than about 300m² were not recorded. Also, long and narrow locations, for example channel shorelines, were not recorded. At each of the 72 locations noted (Figure 11), we visually estimated the population density of freshly dead



mussels, and the length and width of the dewatered area. We defined dewatered areas based on substrate characteristics and vegetation including dead or dying vegetation remnants. At several locations with tall vegetation or high population densities of mussels, we exited the airboat to better estimate density and to enumerate species.

RESULTS

Water Elevations

Pool 4 had normal operations and elevations during the study period. The downstream portion of Pool 4 only deviated about 0.1ft from the target elevation. In Pool 5, water surface elevations were measured at three points. These points from upstream to downstream include Lock and Dam 4 Tailwater, Alma Primary Control Point, and Lock and Dam 5 Pool, which is the secondary control point (Figure 1).

The Water Control Center uses different pool control points depending upon inflow. When inflows are less than 20,000 cfs, regulation of the pool is at the Alma Gage and the pool is in “primary control”. At higher flows, the pool is regulated at the secondary control point, which is immediately upstream of Lock and Dam 5. During the summer of 2005, lower Pool 5 achieved its lowest elevations early in the summer. Later in the summer, the lower pool rose, while elevations in the upper pool dropped with the primary control point serving as the fulcrum point.

Table 1. List of Important Dates during the 2005 Summer Pool 5 Drawdown.

DATE	EVENT
June 7, 2005	Completed mussel stationary quadrate establishment.
June 9, 2005	Sampled mussel stationary quadrates, Pools 4 and 5.
June 13, 2005	Start drawdown, 0.088ft/day (planned 0.2ft/day).
June 30, 2005	Drawdown achieved maximum level at Lock & Dam 5, maintained until 31 July.
July 7, 2005	Sampled mussel stationary quadrates, Pools 4 and 5.
July 14, 2005	Sampled mussel transects in Pool 5.
July 15, 2005	Switched to Alma Primary control point control, on or about.
July 31, 2005	Drawdown at Lock & Dam 5 decreased to 0.5-1.0 rather than 1.5ft. Maintained until 9/15/05. Alma Primary Control Point reaches maximum drawdown elevation, maintained until 09/26/05.
Aug. 10, 2005	Did roving, visual survey using an airboat in lower Pool 5.
Aug. 23, 2005	Did roving, visual survey using an airboat in upper Pool 5.
Aug. 25, 2005	Completed final mussel stationary quadrate sampling, Pools 4 and 5
Sept. 15, 2005	Refill of Pool 5 initiated.
Sept. 26, 2005	Refill completed, pool in normal pool regulation.

A list of key water level and sampling events is given in Table 1. The drawdown was initiated on June 13 and continued at a mean rate of 0.088ft/day at Lock and Dam 5 until June 30 (Figure 12). These lower elevations continued until September 14 when refill was initiated. Twelve days later, on September 26, the pool was completely refilled and resumed normal operations.

At Lock and Dam 5, the 2005 mean daily pool elevation deviation was -1.25ft from the 1995-2004 daily mean during the June 30 to September 14 period (maximum = -1.86ft, minimum =- 0.79ft) (Figure 13). At the Alma gage, the mean deviation was –1.33ft (maximum = -2.06ft, minimum = -0.31ft) during this time period. In Lock and Dam 4 tailwater, it was –1.58ft lower (maximum = -2.50ft, minimum = -0.16ft) than the 1995-2004 daily mean.

From July 1 to July 30, the pool was reflecting elevations of modified “secondary control”, where the lower half of the pool was at its lowest, on average, and had the greatest deviation among the three gages. At the dam, the mean daily deviation from 1995-2004 was -1.53ft (maximum = -1.86, minimum = -1.04). At the Alma gage, during this same time period, the mean daily deviation was -1.28ft (maximum = -1.89, minimum = -0.31),

Figure 12. Summer 2005 Pool 5 Elevations.

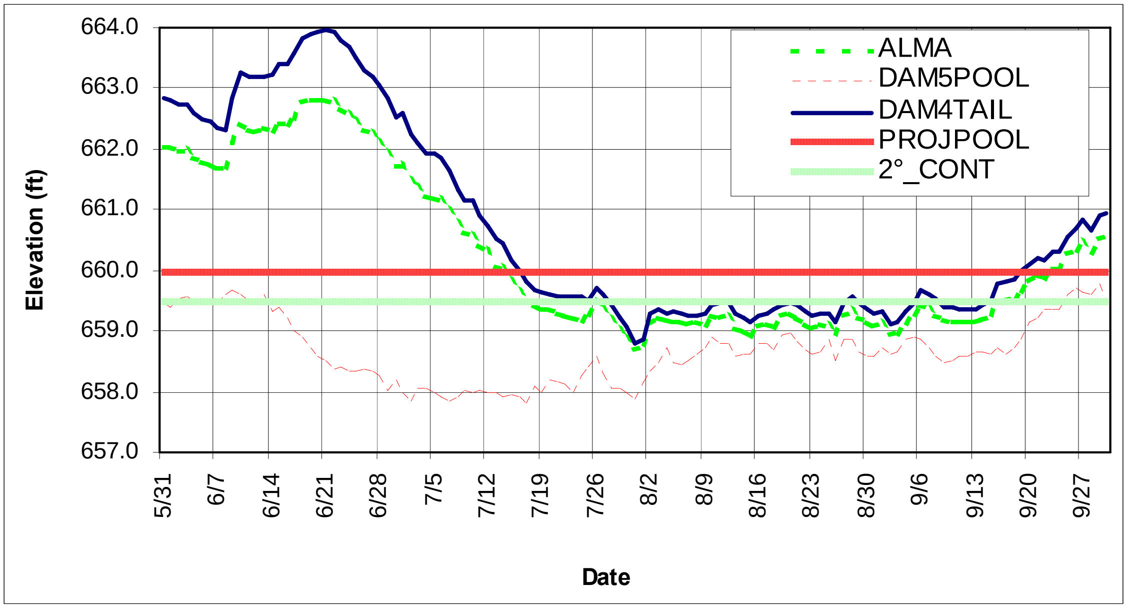
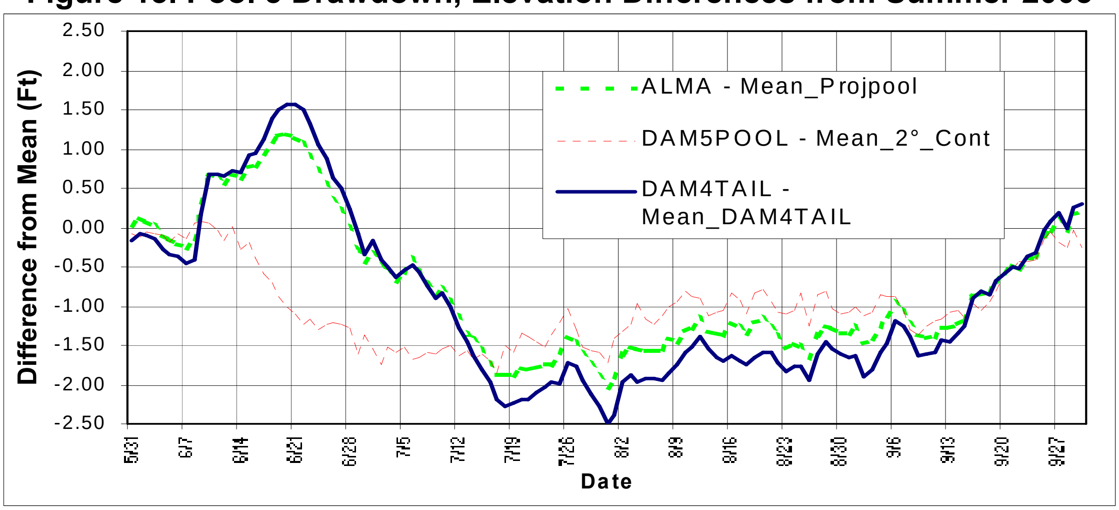


Figure 13. Pool 5 Drawdown, Elevation Differences from Summer 2005



0.25ft less than the lower pool. At the Lock and Dam 4 Tailwater gage, during this same time period, the mean daily deviation was -1.46ft (maximum = -2.27, minimum = -0.16), 0.07ft less than the lower pool.

From July 31 to September 14, the pool was reflecting elevations of modified "primary control" where the upstream half of the pool was at its lowest. At the dam, the mean daily deviation from 1995-2004 was -1.06ft (maximum = -1.72, minimum = -0.79). This was nearly 0.5ft higher than earlier in the summer. At the Alma gage, the mean daily deviation was -1.38ft (maximum = -2.06, minimum = -0.96), 0.32ft greater than the lower pool. Mean deviation at the Alma gage was only 0.1ft higher than July. At the Lock and Dam 4 Tailwater gage, the mean daily deviation was -1.69ft (maximum = -2.50, minimum = -1.19), 0.63ft greater than the lower pool. Mean deviation at the Lock and Dam 4 Tailwater gage was 0.23ft greater than July.

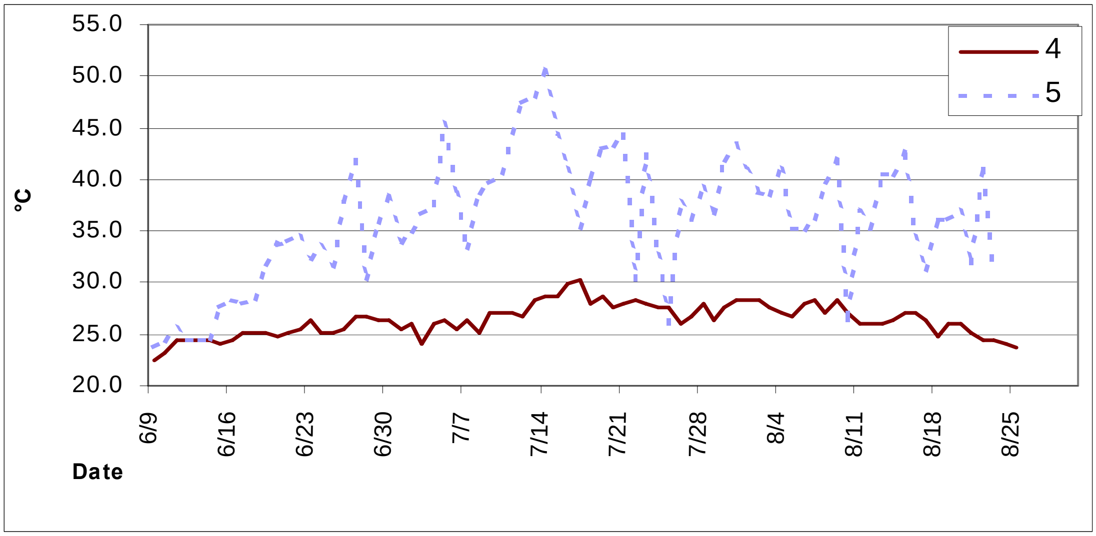
During our July 7 event, about half of each of the 2ft quadrates were dewatered while the gage reading was 1.67ft below normal. The 1ft quadrates were fully dewatered. During the late August sampling event, no part of the 2ft quadrates were dewatered and all of the 1ft quadrates were dewatered. The Lock and Dam 5 gage was 1ft below normal at this time.

The total dewatered area in Pool 5 was an estimated 1101ac. Of this, 1002 acres was in the lower pool while 99ac was in the upper.

Water and Air Temperatures at Stationary Quadrates

During the summer, the temperature logger maximum daily temperatures were 20.4°C higher in Pool 5 than in Pool 4 (Figure 14). Pool 5 maximum temperatures began to rise a few days after the drawdown was initiated and reached as high as 50.7°C.

Figure 14. Daily Maximum Temperatures from Stationary Loggers. Pools 4 & 5, June 9 - Aug. 25, 2005.



Stationary Quadrates

A list of mussel species found in Pool 5 while doing the stationary quadrate work is given in Table 2. We found live representatives of 15 species. On a pool-wide basis, at the end of the study period we recaptured, either live or dead, 91.3% of marked mussels in Pool 4 and 63.8% in Pool 5 (Figure 15).

Through time, recapture rates increased in Pool 4 and tended to decline in Pool 5. During June, we recaptured 65.2% and 76.3% of the marked mussels within the quadrates in Pool 4 and 5, respectively (Figure 16). During July and August, Pool 4 recaptures were higher, at 80.3% and 91.3%. Recapture rates in Pool 5 declined from June to July and August. These were 76.3%, 50.7% and 54.7%, respectively. Within Pool 5 stationary quadrates, excluding sampling outside of quadrates, recapture rates steadily declined throughout the summer (76.3%, 36.6%, and 24.1%).

Total survival was greater in Pool 4 than Pool 5 for all stations, depths and slopes. The total survival in Pool 4 was 100% (n = 438 recaptures) (Figure 17) and was 71.9% in Pool 5 (n = 306 recaptures).

Table 2. List of Species Found in Pool 5 during 2005.

Species	Stationary Quadrates		Transects		Visual Survey	
	Live	Dead	Live	Dead	live	Dead
A. l. carinata MT**			0	2	X	X
A. marginata MT, WS			0	0		X
A. plicata	X	X	152	102	X	X
C. fluminea			0	6	X	X
D. polymorpha	X	X	X	X	X	X
E. dilatata MS			0	0	X	X
F. flava	X	X	61	53	X	X
L. cardium	X	X	10	64	X	X
L. complanata	X	X	0	7	X	X
L. fragilis	X		7	20	X	X
L. recta MS	X		0	1	X	X
L. siliquoidea	X	X	3	4	X	X
L. teres f. *teres* ME, WE			0	0		X
O. olivaria	X		0	0		X
O. reflexa	X	X	25	9	X	X
P. alatus	X	X	0	1	X	X
P. cyphyus ME, WE			0	0		X
P. grandis	X	X	4	6	X	X
P. ohiensis	X	X	4	1	X	X
P. sintoxia MT, WS	X	X	2	2	X	X
Q. metanevra MT, WT		X	1	1	X	X
Q. pustulosa	X	X	1	1	X	X
S. u. undulatus			0	2		X
T. donaciformis			0	1		
T. truncata	X		0	1	X	X
U. imbecillis			3	4	X	X
unidentified			3	4		
Total			276	292		

** ME = Minnesota State Endangered
MT = Minnesota State Threatened.
MS = Minnesota State Special Concern
WE = Wisconsin State Endangered
WT = Wisconsin State Threatened
WS = Wisconsin State Special Concern

Depth appeared to make a significant difference in Pool 5 survival rates. For initial depths of 1, 2 and 3ft, survival was 30.1%, 88.1% and 98.0%, respectively for both sloped and flat sites (Figure 18) and 40.6%, 88.1% and 98.0% for sloped sites only. Pool 5 mussel mortality was at least 5 times higher in the quadrates that had an initial depth of 1ft than those at 2ft and was 6 times higher at 2ft compared to 3ft.

Slope seemed to make a significant difference in Pool 5 survival rates. The flat site had a survival rate of 12.8% while sloped sites at the same depth had 40.6% survival. On July 7, we observed very high mussel

Figure 15. Percent Recaptures of Marked Living and Dead Mussels from within Stationary Quadrates by Pool. June - August, 2005. All Depths Combined.

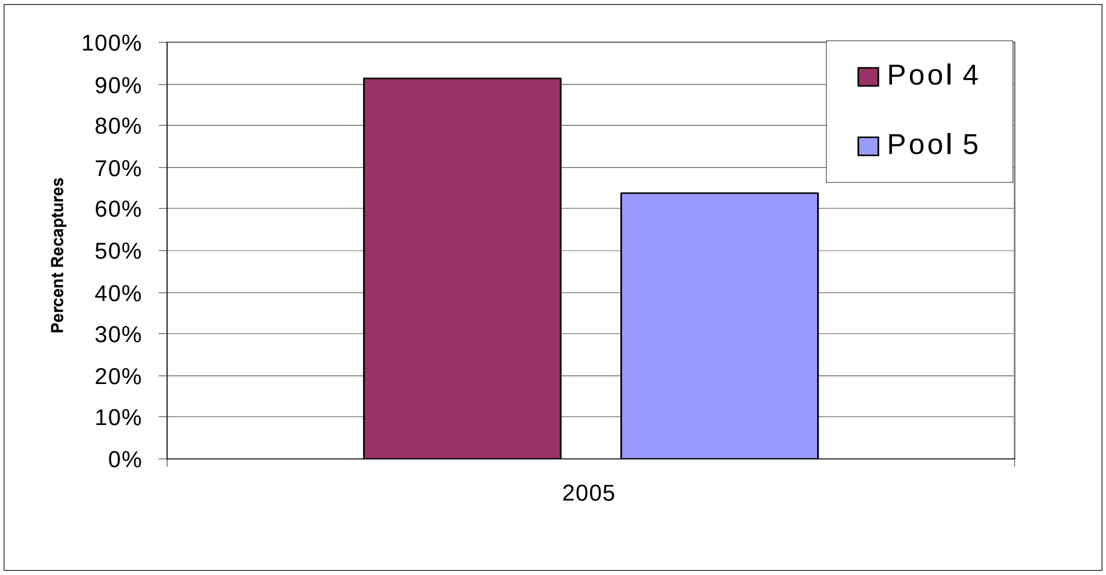
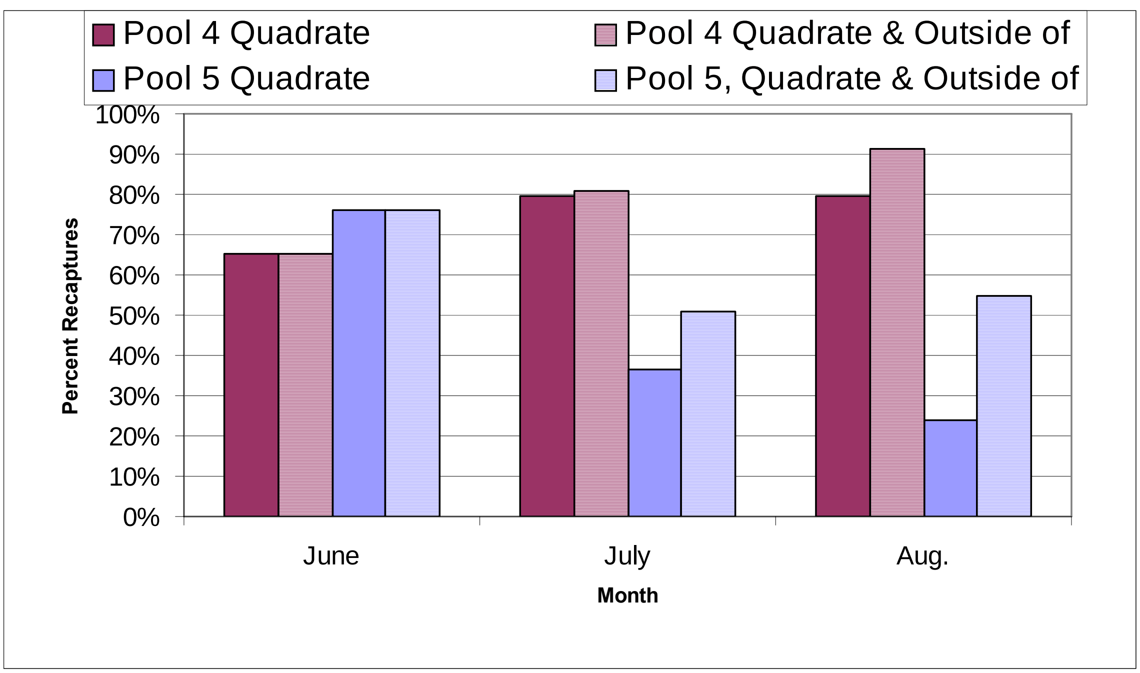
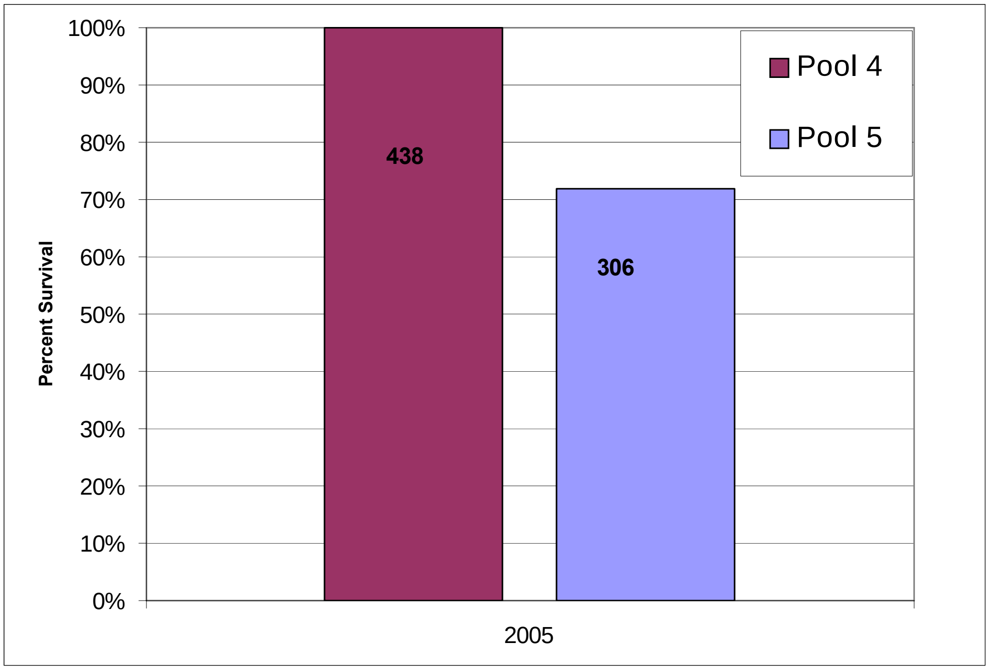


Figure 16. Percent Recaptures of Marked Living and Dead Mussels from within and Outside of Stationary Quadrates, by Pool, Month. June - August, 2005. All Depths Combined.



population densities near the water's edge, much higher than adjacent deeper water. These were likely actively retreating mussels from the adjacent dewatered area. At flat sites, we did not see this. Mussels that remained at the surface, seemed to move in random horizontal directions, and sometimes moved downward into the substrate.

Figure 17. Total Percent Survival of Recaptures at Stationary Quadrates, by Pool. June – Aug. 2005 (N = number of recaptures).



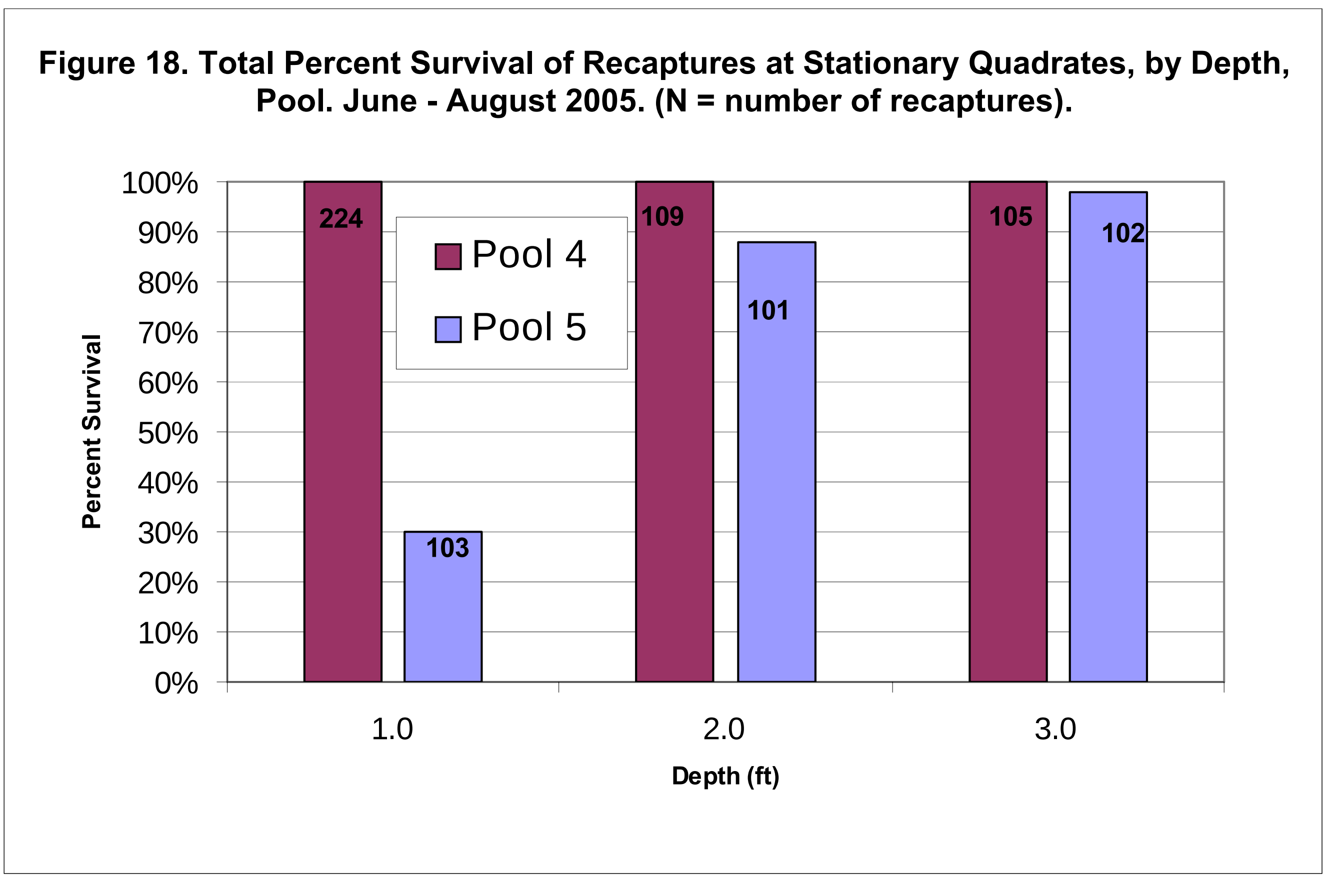


Figure 19. Total Percent Survival of Recaptures, Pool 5, by Species, for those Species with Original N's ≥10. June-Aug. 2005 (N= number originally placed).

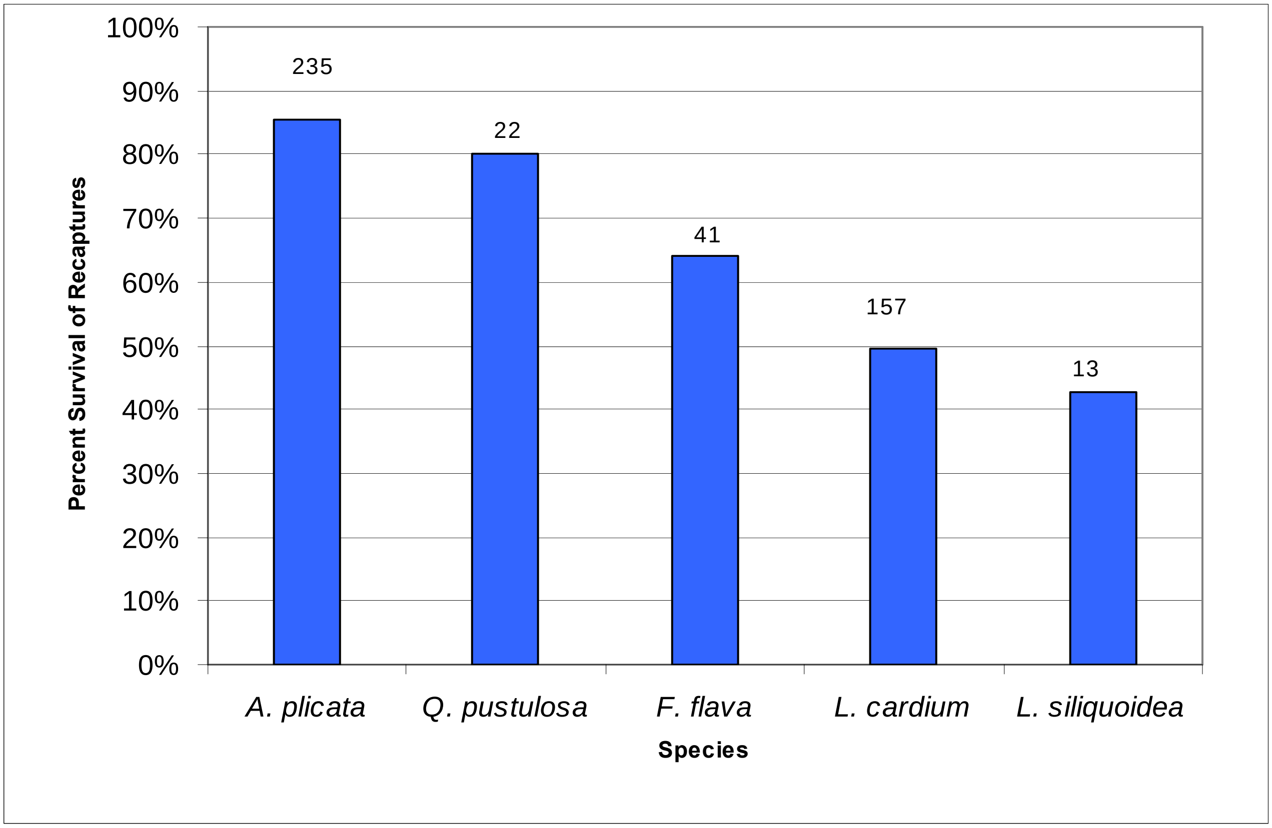
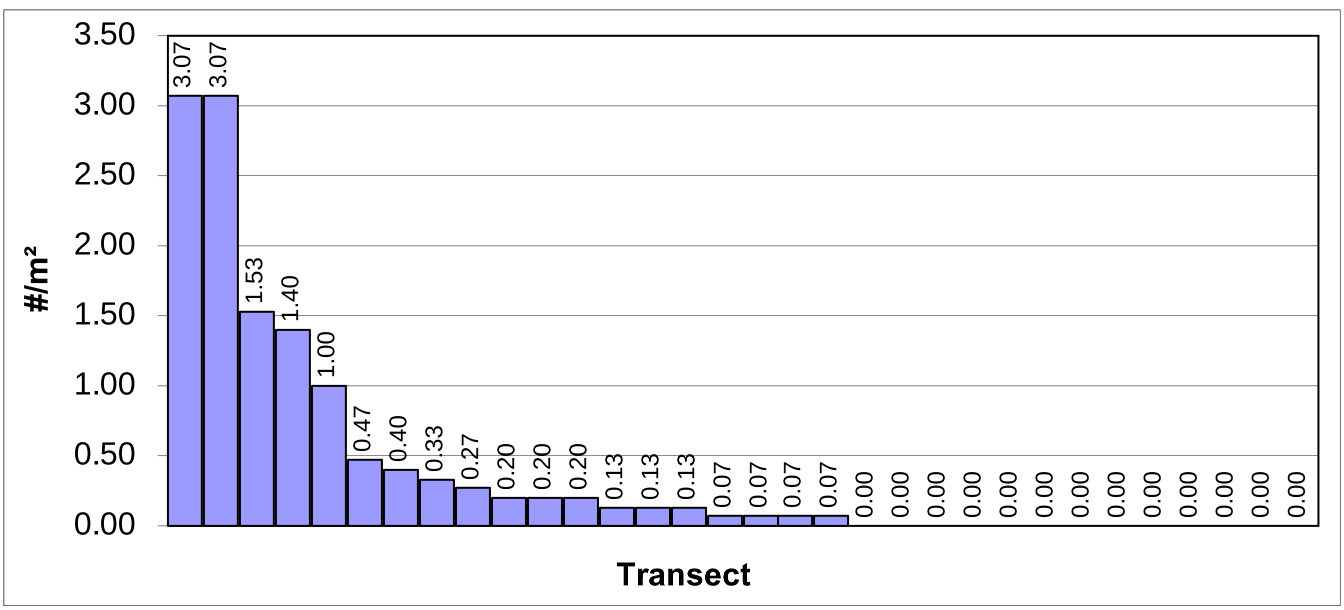


Figure 20. Distribution of Fresh Dead Population Densities, from 14 July 2005 Transects, Pool 5. Mean=0.4/m². N=32.



We investigated survival among species for those that had 10 or more individuals placed in stationary quadrates in Pool 5. For all depths and months combined, survival by species was variable, no two species survived at the same rate (Figure 19). *Lampsilis cardium* and *L. siliquoidea*, the only two members of the subfamily Lampsilinae, had the lowest survival rates at 49.5% and 42.9%, respectively. The remaining three species, *Amblema plicata, Quadrula pustulosa, Fusconaia flava,* are members of the subfamily Ambleminae. These had higher survival rates of 85.5%, 80.0% and 64.0%, respectively. At the flat site in Pool 5, a total of 5 marked mussels of the 120 placed, were recaptured living in August. All were *A. plicata*. Four of these were buried in the sediment about 25cm, where temperatures were lower and sediments were damp or wet. Only one was found on the surface and had apparently emerged sometime during the previous 47 days, since it was not noticed during our July 7 sampling.

Transects

During transect sampling, we did not count all mussels in the quadrates. Like June – July stationary quadrate sampling, transect sampling counted only mussels at or near the surface, not deeply buried ones. We did not excavate quadrates along transects to a 30cm depth.

A list of mussel species found in Pool 5 found during the transect work is given in Table 2. We found live representatives of 11 species and an additional 9 species represented by dead individuals. A total of 276 mussels were found alive and 292 were dead. Of the 292 found dead, 192 were freshly dead.

The July 14 transects were done 15 days after lower Pool 5 reached its maximum low and 31 days after initiation of the drawdown. Surface water elevation in the lower pool was 1.67ft below normal. Therefore, all transects were done at locations that were normally inundated up to 1.67ft. These population density estimates of total mussels represent mortality and survival for the period of June 13 to July 14, not the entire duration of the drawdown. Mean population density of freshly dead mussels was 0.40/m² (N=32, Std = 0.798) (Figure 20). The 90% confidence interval is 0.1679 - 0.6321 freshly dead mussels per m². Mean population density of live was 0.57/m² (N=32, Std = 1.026). The 90% confidence interval is 0.2746 - 0.8712. About 41% of the mussels remaining in dewatered locations at the surface died recently. This 59% transect survival rate compares to a combined 59.1% survival rate for flat, 1ft and 2ft stationary quadrates in June – August, although this stationary quadrate survival rate may be high. It included the 2ft stationary quadrate, which had a mean depth of 2ft, but also included portions that were below the elevation of the drawdown. The population density of freshly dead mussels found along transects is given in Figure 9.

A more equitable comparison is between the July transect survival rate and July Pool 5 flat stationary quadrate. The June – July flat, stationary quadrate combined survival rate was 70.7%, 12 percentage points higher than transect survival rate. We were not able to adequately estimate the mean population density of freshly dead state listed mussel species since these rarely appeared in the transect samples.

We estimated the total number of freshly dead mussels found on transects in the Minneiska – Weaver Bottoms sub-area (Figure 21), a location where transects were concentrated. Spatial areas dewatered were provided by the USGS, Upper Midwest Environmental Sciences Center – La Crosse, Wisconsin from aerial photographs of lower Pool 5 flown on July 15, 2005 and August 13, 2004. The following estimate of total mortality are based only on the density of fresh dead mussel found in transects.

In the Minneiska – Weaver Bottoms sub-area, which was 11% of the pool surface area, we estimated a total of 448,590 (± 315,692) freshly dead mussels. In this sub-area there was a total of 275.3ac exposed and the mean density of freshly dead mussels was 0.403/m² and included 25 of the 32 transects. The population density of live mussels was slightly higher at 0.480/m². The population estimate for these was 534,743 (±313,049).

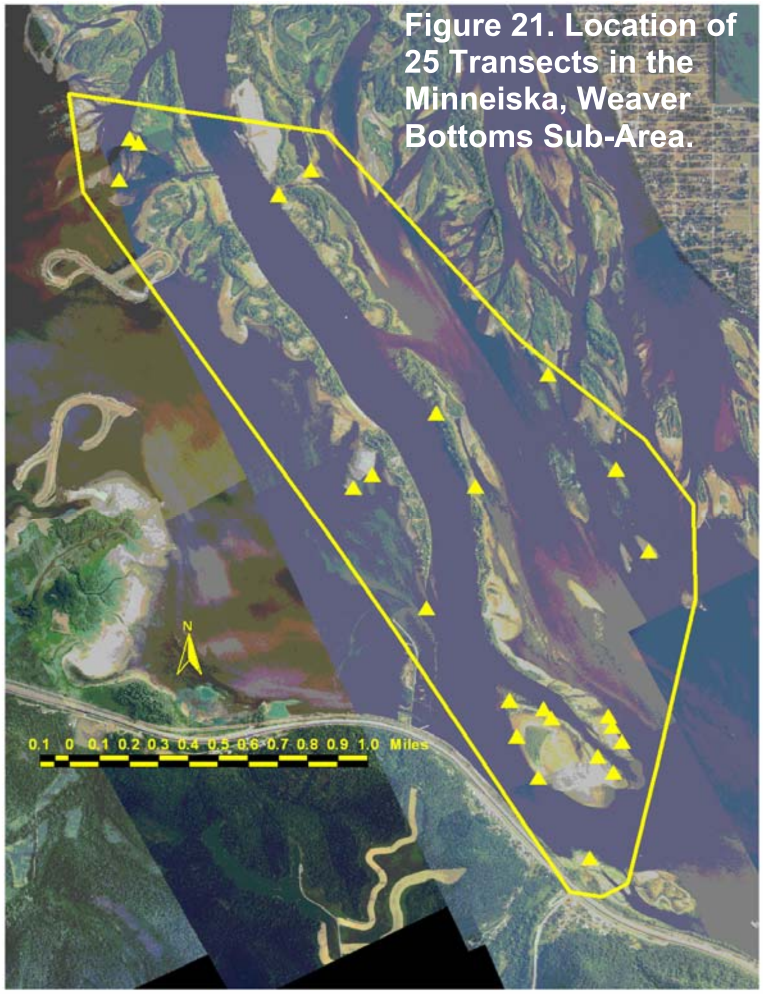
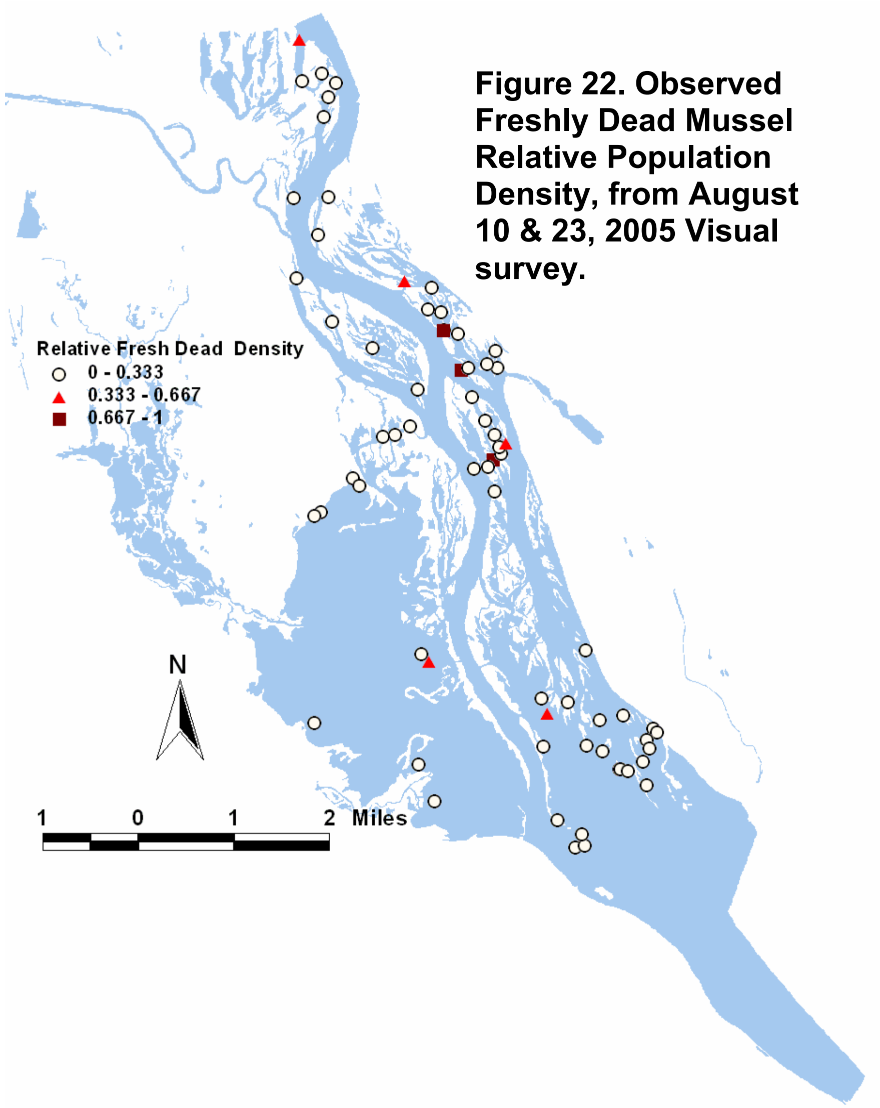


Figure 21. Location of 25 Transects in the Minneiska, Weaver Bottoms Sub-Area.

Visual Survey

Although our visual estimates of freshly dead population density and surface area are surely not accurate because they were "eyeball" observations, they do have relative use. In the upper and middle thirds of the pool, mean densities were identical (0.26/m², n = 31 and 26 locations, respectively). In the lower third, estimated density was 0.81 of the rest of the pool (0.21/m², n = 12 locations) (Figure 22). The lower two-thirds of the pool had 80.1% of the estimated dewatered area throughout the entire pool. The upper third contained an estimated 19.9% of the dewatered area.

A list of mussel species found in Pool 5 found during the visual survey is given in Table 2. We found live representatives of 19 species and an additional 3 species represented by dead individuals. In addition to visually estimating mussel densities, we also enumerated species at four locations (Figure 23) that contained a relatively rich fauna including rare species. These locations include a gravel bar immediately downstream of the dam, the downstream end of a mostly obstructed, short slough that enters "Wiggle-Waggle Slough" from the main channel, a gravel bar located in West Newton Chute, a gravel bar in the upstream end of Belvidere Slough (Pomme de Terre Slough), and a narrow strip of shoreline along Buffalo City. These four locations had



relatively high population densities and contained nearly all of the specimens of all eight rare species found during the entire investigation. In addition to these eight rare species, we found one freshly dead suspected *Lampsilis higginsii*, a federally endangered species. We and other malacologists are not certain of this mussel's identification. It has characteristics of both *L. higginsii* and *L. cardium (*Figure 24*)*. Certainly, it is not a typical *L. higginsii*.

DISCUSSION

Surprisingly, gage readings in upstream part of the pool deviated from normal more than downstream measurements. We predicted that the downstream portion of the pool would have deviated the most. In fact, the extreme upstream end deviated most, followed by the middle then the extreme downstream end (Figure 13). In a sense, the drawdown was greatest in the upstream part of the pool and least in the downstream part of the pool, and was consistently so from about July 14 to September 15. This is also the period of time the pool was in modified "primary control". Apparently the geometry of Pool 5 lends itself to this occurrence.

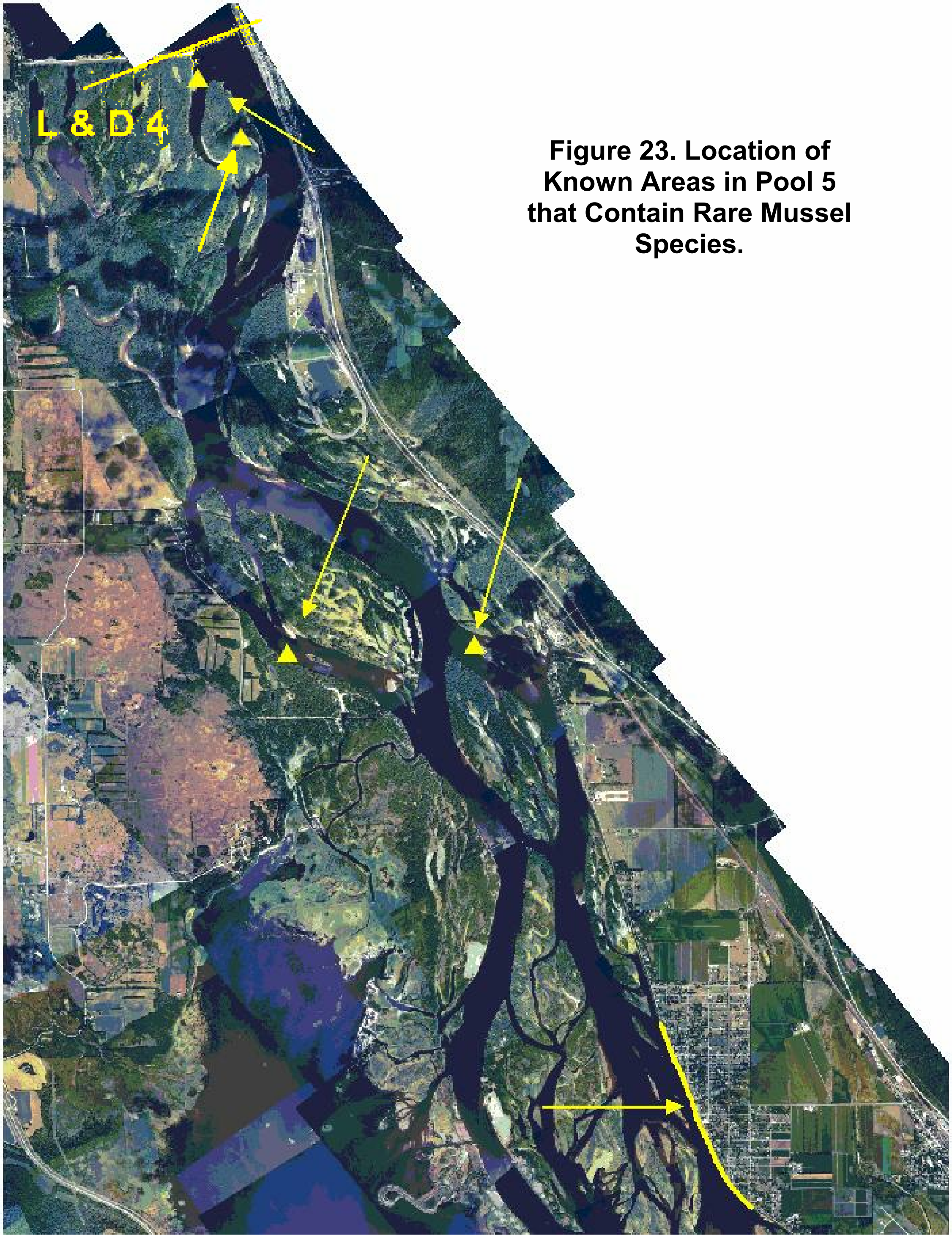


Figure 23. Location of Known Areas in Pool 5 that Contain Rare Mussel Species.

Water elevations at the stationary quadrates were consistent with Lock and Dam 5 gage deviations during all three of our sampling events. This suggests that elevations at the nearest gage were reflective of elevations at the stationary quadrates. The 1101ac exposed was not dewatered all at once. During the early part of the study period, the lower Pool reached its maximum drawdown. During the later part of the study period, the upper pool achieved its maximum drawdown.

Figure 24. Suspected *L. higginsii* from Pool 5. 2005.

Temperature logger data reflects most accurately locations that were initially shallower than 1.1ft, since the loggers were placed in about 1.25ft of water prior to the drawdown. Therefore, these higher Pool 5 values reflect temperatures of the encased logger from aerial exposure and dry substrate temperatures, not water temperature. Some dewatered mussels buried themselves into the exposed substrate where, presumably, it was cooler than the air or exposed substrate surface. We did not measure substratum temperatures. It is unknown what the thermal tolerances are of species most commonly found in pools 4 and 5, but some unionids have lethal tolerances of around 39°C (Afanasjev, et. al, 1997), at which they die within 5 hours. Clearly, mussels exposed or partially exposed to the air, were subject to lethal temperatures for an extended time period. This suggests that high temperature contributed to observed mussel mortalities.

The Pool 4 stationary quadrate recapture rate was similar to other studies where 83 to 91% of mussels were recaptured under similar conditions (Waller et. al, 1995; Neils and Neves, 1996). The increase through time of Pool 4 recapture rates is probably due to additional sampling outside of the stationary quadrates. The Pool 5 recapture rates were less were less than Pool 4, probably due to dispersion of mussels in response to the drawdown. Mussels were seen attempting to avoid lowering or lower water levels. The Pool 5 August recapture rate was higher than July probably due to even more extensive sampling within and outside of the quadrates.

The drawdown clearly influenced Pool 5 shallow-water mussel survival rates in stationary quadrates. The overall Pool 5 survival rate (71.9%) was substantially lower than Pool 4 (100%) and results of other investigations. To put this in perspective, for moderately long-lived species, like threeridge, which was also the most abundant species used in this study, total annual natural survival rates are about 97% (Hart, Grier, Miller & Davis (2001). For other species, total annual survival rates are about 90-100%. Dunn and Gardner (1997) determined that 100% of several mussel species survived relocation after one year. Ecological Specialists, Inc. (1996) found 98.2% annual survival (minimum 94%, maximum 100%) for relocated mussels, which was similar to background levels. Ecological Specialists, Inc. (1998) found 95% survival of relocated mussels after one year on the Wolf River, Wisconsin. Mussel mortalities from drawdowns have been reported by others. Samad and Stanely (1986) recorded nearly total mortality from a drawdown in Maine. Howells (2000) reported higher mortality from drawdowns and adverse temperatures in a Texas Reservoir. Our conclusion that the drawdown influenced Pool 5 mussel survival is also supported by the sharp correlation between initial depth and survival rate.

One may ask why there was any mortality at the 2ft and 3ft initial depths in Pool 5 when the drawdown was planned for and averaged only 1.5ft and there was no observed mortality at any depth in Pool 4. In reality, the maximum drawdown was 1.86ft at the dam, over four inches more than planned. This was enough to unexpectedly expose about half of the 2ft stationary quadrates, evidently resulting in some mortalities at this initial depth. In addition, those submersed mussels remaining may have moved more than usual in response to falling water levels. Some of these movements were shoreward and resulted in mortalities. Samad and Stanely (1986) also reported multidirectional near random movements in response to a drawdown.

Slope of a stationary quadrate location influenced survival rate. Sloped sites had three times the survival rate of the flat site. It is likely that mussels are able to access deeper water more easily at sloped rather than flat sites. Howells (2000) also noticed the positive relationship between slope and survival rate.

Higher species specific survival for the amblemines may be due to their shell geometry. Amblemines in general, have the ability to close their valves tightly, sealing water in. Lampsilines, on the other hand, have a noticeable gape anteriorly. This gape exposes tissues to water loss. It could be that amblimines had higher survival rates because they are able to conserve water better.

All survival rates calculated from stationary quadrates are maximum estimates. It is likely that real survival was lower. Quadrate sites were last sampled on August 25, 32 days prior to refilling the pool. Therefore, there was an additional 32 days of dewatering (30% of entire drawdown period) during which we did not estimate mortality. Transect and stationary quadrate survival rates were reasonably close to each other. This suggests that the less rigorous transect survival rate of 59% is valid.

Population densities estimates calculated from transects need to be interpreted cautiously. Because real-time aerial photography of dewatered areas was absent, transect locations were not truly random. Their selection may have been biased. Transects were not done throughout the pool, but rather clustered within one of the middle quarters of the pool. Therefore, transect data does not represent the entire pool. Also, execution of transect sampling was not tightly controlled. The coefficient of variation of fresh dead density was within usual ranges for living mussels at 200%. The average coefficient of variation of living mussels from 10 sampling events on the St. Croix and Wisconsin rivers ranged from 87% to 291% and averaged 128% (WDNR, UWFWS, USNPS, 2004; Heath, 2003).

Transects density estimates are probably lower than the actual values. We only counted mussels that were visible on or near the surface. We did not dig beneath the surface to locate live or dead mussels. From the August sampling of the stationary quadrates, we know that only 31.6% freshly dead and live mussels were found at or near the surface. A total of 68.42% were buried deep enough that only sampling by digging with tools would reveal them. If we adjust the Minneiska – Weaver Bottoms sub-area mortality estimate for this, a total of 1,419,589 mussels died from the drawdown in this area. Also, transect sites were sampled on July 14, 74 days prior to refilling the pool. Therefore, there was an additional 74 days (70% of entire drawdown period) of dewatering during which we did not estimate mortality from these transects. It is very likely that there were additional mortalities during this time period. The combined dead and living population densities are within shallow-water ranges seen in this pool and other Mississippi River Pools (Wisconsin Department of Natural Resources, Unpub. Data).

Results from the visual survey suggested that densities of freshly dead mussels were similar throughout the pool. If anything, densities were slightly lower in the lower third of the pool where one-third of the transects were placed. Based on this, transect results may represent the entire pool in spite of not being randomly selected.

SUMMARY

In summary, Pool 5 elevations during 2005 were an average of 1.5ft and 1.4ft lower at the dam and Alma gage, respectively, than they were normally. Mean daily temperatures were 20.4°C higher on dewatered areas in Pool 5 compared with watered areas in Pool 4. Estimated area exposed from the drawdown was 1101ac. Mussel survival in Pool 5 was related to depth; 30.1% of mussels placed in 1ft of water survived while 98% survived when placed in 3ft of water. Mussels at sloped sites had three times the survival than those at flat sites suggesting that escape routes are important. Members of the subfamily Ambleminae had over 1.6 times the survival rate as members of the subfamily Lampsilinae. This may be related to their ability to close their valves tightly, thus retaining a larger proportion of water.

The mean density of freshly dead mussels at sampled dewatered locations in lower half of the pool was 0.40/m² compared to 0.57/m² for living mussels. Although the transect density and mortality estimates are rather crude, at least 132,000 mussels died as a result of the drawdown. We were not able to estimate the mortality of state listed species, although we know that at least 8 representatives of these species occur in the pool and were killed by the drawdown. Freshly dead population densities seemed fairly uniform throughout the pool.

MANAGEMENT IMPLICATIONS AND ADDITIONAL RESEARCH NEEDS

These results were surprising. Prior to this investigation, no one estimated the magnitude of mussel mortalities we saw. The possible loss of 0.4 mussels/m^2 over 4.5 million exposed m^2 is considerable. Considering the dire continental conservation status of native freshwater mussels, serious consideration needs to be given to mortalities caused by upper Mississippi River natural resource management drawdowns. Although we do not know the numerical proportion of pre-drawdown Pool 5 mussels killed, and hence can't judge the loss to these populations, losses of this potential magnitude raise some environmental and regulatory questions.

Can this imperiled animal group sustain periodic losses like this in the upper Mississippi River? Most mussels are long-lived and have very low reproductive rates and hence have slow recovery rates. An additional loss of one or two percent annually could, over time, reduce total numbers. Should we be doing anything that contributes to the dire continental conservation status of freshwater mussels? One could argue that any significant sources of mortality that natural resource agencies can control should not be permitted. Are there any benefits to mussel populations from drawdowns? We could find no evidence in the literature that there is, although research is lacking. How do natural resource agencies respond to their regulated public when they support this kind of take by one entity, yet restrict or deny activities to another that could affect a much smaller fraction of a mussel community? Natural resource agencies are frequently criticized for inconsistently and unfairly applying regulations.

Upper Mississippi River states have continued to restrict or entirely close down commercial mussel harvest for harvest magnitudes much less than mortalities seen here. These harvest restrictions and closures were based on studies that demonstrated unsustainable over-harvest. Is the periodic exposure of 9.2% of this pool's water area, resulting in even smaller total area meeting the management goal of emergent macrophytes establishment, worth this loss of mussels? Potential mortality minimization and mitigation are outlined in Appendix 1.

Clearly additional investigation is needed to verify and refine estimates given here. It would be beneficial to repeat our stationary quadrate protocol to verify these findings and refine factors that contribute to drawdown mussel mortalities. Most importantly, a more rigorous investigation to determine total mortality on a pool-wide scale and its effect on pool-wide populations needs to be done before upper Mississippi River drawdowns become programmatic and routine. Lastly, all the negative effects of drawdowns need to be compared and weighed against the known benefits of drawdowns and this natural resource management tool needs to be evaluated against all other available tools.

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APPENDIX 1

MUSSELS AND DRAWDOWNS. IDEAS TO MITIGATE AND STUDY EFFECTS OF UPPER MISSISSIPPI RIVER DRAWDOWNS.

In Response to a Request to the Mussel ad-hoc team (Davis, Heath, Sietman, Kelner, Wege) of the Water Level Management Task Force. 17 Nov. 2005 Meeting.

2006 POOL 5

Question: *What mitigation measures could be taken if a Pool 5 drawdown is repeated in 2006?*

Answer: Assuming a 2006 drawdown of 1.5 ft, which was the 2005 target, mussel mortalities will likely be measurably less than in 2005. We guess there will be mortalities to mussels that may recolonize previously dewatered areas, or from the small numbers that survived in areas dewatered in 2005. The magnitude of mortality from this second drawdown is unknown. During the 2005 investigation, we observed movements where up to 50% of the mussels out of the stationary quadrates sometime during the summer. This suggests that mussels will move and may move into previously dewatered areas.

There are a number of mitigation actions that could be taken to reduce mussel exposure and mortality.

A) A full-scale "rescue" could be attempted. Volunteers could be assembled and assigned locations to return stranded mussels to deeper water. Timing would be important, and a rescue should be done very soon after the maximum drawdown or could potentially be done while elevations are lowering. Due to the likelihood of large number of stranded mussels and their large spatial extent, it is unlikely that most could practically be relocated.

B) A smaller-scale "rescue" could be attempted in locations containing rarer species, high population densities or high species richness of stranded mussels. Based on the 2005 investigation results, these locations must include all the exposed gravel bars in the pool. Due to the much smaller spatial area of these specific locations, most mussels could be practically relocated. In 2005 we discovered a total of three exposed gravel bars, all of which were relatively small. Additional searches of gravel bars may be needed either during the 2006 drawdown or prior to it.

C) Moderation of rate of drawdown. An additional mitigation measure may include dropping water levels more slowly than 0.09ft/day, which was the 2005 rate over 17 days. There may be operational constraints to drawing the pool down in increments finer than 0.09ft/day; dam operators may not be able to more finely tune the drawdown on a daily basis due to fluctuations in inflow and seiches. Drawing the pool down at a slower rate would necessitate starting the drawdown earlier to achieve benefits to emergent vegetation. An earlier start, say as soon as flows can be re-controlled in the pool after the spring flood, may also reduce mussel colonization and re-colonization in areas dewatered in 2005. It is unknown if this would occur since we have only poor information of when and where mussels move during high water. Initiating a slower drawdown earlier may have implications on the completion, effectiveness and immediacy of bathimetric surveys and dredging. Also, a drawdown started earlier may have some biological implications, such as mortality to fish larvae or eggs.

D) Direct compensatory mitigation is another option to mitigate the effects on mussels from a 2006 drawdown. Specifically, at least the state-listed and special concern species could be artificially propagated and released into deep waters of Pool 5. There are local expertise and facilities to do this. Costs would likely be in the tens of thousands of dollars, and we would not know how may mussels would have to be replaced, since we have no good mortality estimate on state listed species from the 2005 Pool 5 drawdown. In addition, completion of this task could take several years due to logistics. Also, host fishes are unknown for three of the nine rare mussels. These three include *A. marginata*, *E. dilatata* and *Q. metanevra*. Although at least one laboratory verified host is known for the remaining six species, these hosts may not be the ones used in the wild – which can have some conservation implications. In addition, some host fishes may be difficult to secure or propagate. Assuming that all nine mussels species could not be propagated at once, the rarest ones should be propagated first with the least rare (state special concern) propagated last. Direct compensatory mitigation could also set a precedent that could potentially apply to other Corps of Engineers activities as well as add substantially to the cost of drawdowns. This approach would also have some long-term funding issues since completion may take 5 or 6 years. It could also send a message that mussel impact solutions are simple – just raise some more. This is not fit into the long-term mussel management strategy since it depends on steady funding and an ongoing effort and is still experimental in nature with unknown long-term implications for mussel genetics and evolutionary processes.

E) Reducing the depth of the drawdown in 2006 will reduce the mortality rate. From our 2005 preliminary findings, there was 2%, 12% and 70% mortality at pre-drawdown depths of 3ft, 2ft and 1ft, respectively. Therefore, it is likely there would be lower mortality rate from a drawdown of lower magnitude. Doing a 1ft nominal drawdown instead of a 1.5ft nominal drawdown at the dam may reduce drawdown-induced mortality by about 30%.

Question: *Are there any additional bureaucratic measures that must be taken during the 2006 drawdown because of the 2005 mussel findings?*

Answer: **No. *A Wisconsin endangered species incidental take approval and permit will not be needed for the 2006 drawdown and a retroactive one will not be needed for the 2005 drawdown. Although the states and other bodies are involved in the decision-making process,***

they are not actually doing the direct actions that deliver a drawdown. The Corps of Engineers is. The authority and administrative rules for this approval and permit are contained in Wisconsin State Statute 29.604 and Administrative Code 27.07 and applied to entities that fund, conduct or approve actions that may take state listed species. It is unclear how and where Minnesota rules and statutes apply.

There is one potential public relations problem with this scenario. While technically legal, the public may view the application of Wisconsin rules in this case as duplicitous. The public may view this as exempting the CoE to procedures and regulation that an ordinary citizen or private corporation may be compelled to abide by. One solution to this, is to request that the CoE informally go through Wisconsin's incidental take process. The process includes a determination that taking incidental to an otherwise legal activity is likely; the CoE will minimize the impacts to these species and is not likely to jeopardize the continued existence and recovery of the state population of these or the whole plant-animal community of which they are a part; and has benefit to the public health, safety or welfare that justifies the action. These determinations may already be documented in the EA as a matter of process.

Based on the 2005 findings, no federally listed mussels are present in the pool. Although we did find one suspected **L. higginsii*****, its identification is in question and is not a verified specimen. We did locate some*** **P. cyphyus*****, a species being considered for federal listing. Since this species is not at present federally listed, it does not fall under the protections of the Federal Endangered Species Act.***

Question: **What effect did mortality from the 2005 drawdown have on the Pool 5 mussel population as a whole?**

Answer: Unknown. Requires some sort of population estimate of living, which could be expensive and time-consuming. In addition, a better, more comprehensive population mortality estimate is needed. A PE may not need to be pool-wide, but could include subareas or representative areas. After verification, some subareas (e.g. navigation channel) could be dropped. Some considerations include the proportion and species composition of the population in shallow water, as has been observed in other zebra mussel infested pools. May be able to stratify sampling by mussel habitat type (e.g. Side channel, near shore, gravel bars, flats, depth category etc.).

GENERAL DRAWDOWN

Question: *Should there be any long-term monitoring of the effects of the drawdown?*

Answer: Long-term monitoring of Pool 5 mussel populations may provide information on the effects of the 2005 and 2006 drawdown. Monitoring may also answer the question of whether or not mussels recolonize formerly dewatered sites. To determine the effect of a drawdown on the mussels in an entire pool, a reference pool would also have to be established and monitored.

Question: *Should the 2005 transects be revisited?*

Answer: Revisiting the 2005 transects may provide useful information on recolonization rates and survival of burrowed in mussels in formerly dewatered areas. Another option is to sample areas dewatered in 2001 and 2002 in Pool 8. Methods surrounding 2006 sampling of dewatered areas needs additional discussion.

Question: *Could there be other effects of a pool drawdown on mussels that were not estimated in 2005?*

Answer: Yes. Very little is known about the effects of water elevation fluctuations in riverine systems on mussels. Some previously speculated positive effects include:
1. Improvement of water quality
2. Improvement of filterable food quality and quantity.
3. The cleaning of substrates of fine material through scouring.
4. Gradation riverbed material to form and maintain gravel bar habitat.
5. Improvement overall productivity.
6. Improvement conditions for host fish species.
7. The concentration of mussels into dense beds and fish into narrower channels where they are more likely to be infected with glochidia.
8. The increased recruitment into channel habitat due to fish host concentration.
9. Reducing mussel recruitment/colonization in areas that are vulnerable to winterkill and/or low water events.

Some potential negative effects could include:
1. The reduction of long-term recruitment via stranding and loss of reproductive age adults.
2. The elimination of shallow habitats, which are less affected by zebra mussels.
3. The destabilization of substrates, it is widely recognized that substrate instability is inimical to mussels.
4. Increasing vulnerability to predators.
5. Other unknown changes to habitat.

Pool 5 drawdown. Buried & dead mussels. 24 Aug. 2005. M. Davis photo.

Pool 5 drawdown. Buried mussel. 24 Aug. 2005. M. Davis photo.

Pool 5 drawdown. Stranded mussels. 14 July 2005. M. Davis photo.

Pool 5 drawdown. Stranded mussels. 14 July 2005. M. Davis photo.

Alma dam tailwater, RDB. Pool 5 drawdown. 23 Aug. 2005. WDNR photo.

Pool 5 drawdown. Stranded mussels. 14 July 2005. M. Davis photo.

Pool 5 drawdown. near Site F. 7 July 2005. M. Davis Photo.