Upper Mississippi River

Pool 5, 6 and 8 Drawdown Results

A summary of the research and monitoring results from the drawdowns of Pools 5,6,and 8.

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DRAFT

River Resources Forum-Water Level Management Task Force

Monitoring and research reports were compiled and summarized by Ruth Nissen, Wisconsin Department of Natural Resources.

Full length versions of final reports that were summarized for this document are listed in an appendix.

Executive Summary

Water level management on the Mississippi River has been a process based on scientific analysis as well as adaptive management through a series of demonstration projects and experimental drawdowns under the guidance of the Water Level Management Task Force (WLMTF), a technical advisory group to the River Resources Forum (RRF). The River Resources Forum is an advisory body to the U.S. Army Corps of Engineers-St. Paul District, and was formed to offer recommendations and coordination of river-related issues. The WLMTF representatives from federal and state agencies, and others, include:

- U.S Army Corps of Engineers- St. Paul District,
- U.S. Fish and Wildlife Service,
- U.S. Geological Survey,
- U. S. Coast Guard,
- Iowa Department of Natural Resources (DNR),
- Minnesota DNR and Department of Transportation (DOT),
- Wisconsin DNR and DOT,
- representatives from the commercial navigation industry,
- non-governmental organizations (NGOs),
- citizen groups.

In 1995 the WLMTF began to evaluate the potential for water level management in the northern reaches of the Upper Mississippi River with funding and technical support from the U.S. Army Corps of Engineers-St. Paul District. After successfully conducting several small-scale drawdowns, a demonstration large scale drawdown of a navigation pool was planned. After a lengthy selection process, Pool 8 was chosen for the first pilot large-scale drawdown.

The drawdown was initially scheduled for the summer of 2000; however it was postponed due to projections of summer river discharges not conducive to implementing the drawdown. A drawdown of Pool 8 (1.5- feet at the lock and dam,) was conducted in the summer of 2001 and then repeated in the summer of 2002.

A similar drawdown of Pool 5 was conducted in 2005. An attempt was made to repeat the drawdown in 2006 but due to low flow conditions the drawdown was discontinued several days after reaching the target level.

An experimental minor drawdown (a drawdown of only 1-foot at the lock and dam) was scheduled for Pool 6 in 2003, 2004, 2008, and 2009, but river conditions were not conducive to a drawdown. A drawdown of Pool 6 was conducted in 2010.

A brief summary of the monitoring results for each of the pools follows.

Dredging and Sediment Transport

Pool 8

Data suggests;

- Large scale drawdowns, such as the 1.5-foot drawdown in Pool 8, increase main channel water discharge and sediment transport.
- The high main channel dredging volumes that are needed in advance of a drawdown resulted in reduced future dredging.
- The lack of change in the main channel bed elevations in the study reach may be due to the fact that while the sediment transport rate increased, inputs balanced outputs. This is a desirable condition, since normally the study reach would be aggrading until dredging was needed.

Pool 5

During the drawdown, a greater percentage of the total river flow was conveyed in the main channel, and main channel flow velocity increased. This caused increased bed sediment transport in the main channel. During the drawdown, the percentage of the total river discharge conveyed in the main channel increased because in secondary channels the cross section area is decreased and roughness is increased as the water surface is lowered. Similar results were found in Pool 8 during the 2001 - 02 drawdown.

Vegetation Response

Pool 8

More than 50 species of moist soil, perennial emergent and submersed aquatic species of plants were found on the exposed areas. The plant response to the drawdown was very similar to the results of a seedbank study designed to quantify the availability of seed. Plant density, plant diversity, moist soil seed, and arrowhead tuber production were largely related to the duration of substrate exposure. A shift was observed from a plant community dominated by annuals the first year of the drawdown to one dominated by perennials the second year. Growth of perennial emergent vegetation was robust. Arrowhead tuber production increased 16-fold across transects examined. Submersed aquatic plants were not negatively impacted by two summer drawdowns. Following the drawdowns, a substantial expansion of aquatic plant communities in the lower third of the pool was recorded, as well as a comparable reduction in open water habitat. The perennial plants grown on the sand and mudflats during the drawdowns persisted for at least five years in some areas.

Pool 5

More than 70 plant species were identified on the exposed substrate. Similar to Pool 8, there was a predominance of annual plants the first year, followed by a shift to more perennial species the second year. Submersed vegetation was not negatively impacted and increased in some areas.

Changes in vegetation from 2005-2009 were also monitored. A number of desirable plant species that were established on exposed substrates during the 2005 drawdown persisted, and in some cases flourished, through 2009. A general pattern of increase was observed in submersed aquatic plant species and a decrease in moist soil and terrestrial species in 2009 compared to the vegetation composition of the same area in 2005-2007. The pattern in emergent aquatic vegetation varied by species. Changes noted include:

- Large increases were noted in the occurrence of frequency of sessilefruit arrowhead and broadfruit bur-reed.
- Frequency of occurrence of common arrowhead, soft-stem bulrush, American lotus, rice cutgrass, and reed canary grass generally declined over the same time period.
- Several terrestrial/moist soil species that were prevalent in 2005 including willows, were not detected among sample sites in 2009.
- Much of the emergent vegetation that occurred within the sampling area (substrates exposed in 2005) was likely established with the 2005 drawdown. Emergent species, such as arrowhead, that arose from seed where suitable conditions were created during the 2005 drawdown were small in stature but produced small tubers or rhizomes. Plants arising from these structures in the subsequent growing season tended to be much more robust.

Pool 6

Sixty- six plant species were identified on exposed substrates. Growth of broadfruit bur-reed, barnyard grass, chufa flatsedge, redroot flatsedge, and rice cutgrass was robust in some areas. A comparison of frequency of occurrence of plant species observed during the Pool 6 drawdown to that occurring during the 2005 drawdown on Pool 5 indicate some notable differences. Moist soil species were not as prevalent, common arrowhead and soft-stem bulrush occurred less frequently, and submersed aquatic species were generally more widespread among Pool 6 sample sites compared to Pool 5 sites. This pattern was most likely related to the reinundation of much of the exposed area of Pool 6 due to the bounce in the elevation (and river discharge) during mid-August. Terrestrial/moist soil plants that are intolerant to flooding (especially small plants) may not have persisted. Also, wave action and fish activity may have dislodged susceptible plants.

Fish Response

Pool 8

Overall, there were no negative short-term trends or differences in fish catch rates that could be attributed to the drawdown. An increase was observed in catch rates for the forage fish group surrounding the drawdown period which may warrant further investigation during a future drawdown. No fish kills were observed in the backwaters.

Pool 5

Even though there was a decrease in the bluegill young of the year abundance in Pool 5 the year of the drawdown there was no detectable effect from the drawdown on the 2005 year class by 2006. This data suggests that any negative impact on spawning success the year of the drawdown is outweighed by improved survival of the young of the year. The large increase in bluegill abundance which occurred in both Pool 5 and 8 two years post drawdown suggests the drawdown had a positive effect on habitat.

Freshwater Mussels

Pool 8

While large scale monitoring of the effect of the drawdowns on freshwater mussels was not conducted, a pre-drawdown survey conducted in 1999 indicated that limited numbers of mussels were in the drawdown zone. An informal survey was conducted during a volunteer mussel rescue effort in July 2001 which indicated more mussels than expected on exposed sites, possibly due to the effects of the extended flood in spring 2001.

Pool 5
Monitoring of the effects of the drawdown on freshwater mussels in shallow water indicated mussel survival differed by species and was related to the initial water depth and the slope of the site. Mussels impacted the most included those located in one foot of water or those located on flat sites. Mussel mortality on the exposed areas was greater than was anticipated, however, this sampling effort was not designed to estimate pool-wide mussel mortality during the drawdown. To better estimate the significance of mussel mortality, a comprehensive survey of mussel populations was completed in Pool 5 in 2006 to determine a statistically accurate estimate of the pool-wide mussel population.

The study estimated 189 million mussels in Pool 5 (95% CI range = 152 - 221million), with a relative error of less than 20%. Of this total, 2.3 million mussels were estimated in the shallow dewatered zone (95% CI range = 1.0 - 3.6 million). The estimate in the shallow zone had a relative error much greater than 20%. No mussels were collected in 2006 at depths less than 10 inches (0.25-meter) possibly due to a combination of increased aquatic vegetation in the shallow dewatered zone and mortality of mussels during the 2005 drawdown.

Pool 6
The survey objective was to estimate total live mussels within Pool 6 of the Mississippi River to estimate the proportion of the total population that could be impacted by dewatering. The study estimated 60,530,422 mussels in Pool 6 (95% CI range = 45,551,530 – 75,509,313). Given that the systematic design did not produce acceptable estimates in the dewatered area during the Pool 5 survey a different design was tested in Pool 6. A one-stage cluster double sampling design was selected for surveying mussel populations in shallow areas. Using the total population estimates in dewatered area from the quantitative sampling (total = 333,278; 95% upper confidence limit = 535,839), the percent of mussels that were in the predicted dewatered area was about 0.55% (95% upper confidence limit of 1.19%).

Mortality, movement and behavior of two different species of mussels in response to lowering of the water levels was studied. All mussels generally moved perpendicular to shore into deeper water regardless of the year, treatment or slope. However, without the ability to move to deeper water most mussels perished.

Shorebird Response

Pool 8
The data suggests that the water level reduction in Pool 8 created important feeding habitat for migrating shorebirds as indicated by the number of shorebirds and the number of different species observed. In 2002, the number of shorebirds observed during weekly monitoring surveys nearly doubled from the 2001 season. The increase over 2001 numbers was primarily due to observations during surveys in ate August and early September, a time period when the drawdown technically had ended in 2001 due to low flow conditions in the river. The data suggests the importance of maintaining a drawdown the full time period if feasible to provide habitat for shorebird migration during late August and September.

Pool 5
Temporary feeding areas created by the drawdown were quickly found by locally breeding shorebirds. Although the surveys did not detect a significant increase in migrating shorebirds this is probably due to both the lack of a weekly survey and an inability to get close enough to the exposed flats using the Go-Devil in 2005 and the premature end of the drawdown in 2006 in late July.

Waterfowl Response

Pool 8
There was a positive response by waterfowl, including dabbling ducks, and tundra swans to the improved habitat which resulted from the drawdowns, Tundra swan use increased substantially in response to the development of arrowhead beds in the Wisconsin Islands Closed Area. Diving duck use days also increased steadily after the drawdowns but the increase was most likely not related to effects from the drawdowns.

Pool 5
Use by dabbling and diving ducks and tundra swans in Pool 5 during 2006 (post drawdown) was the highest recorded in 10 years.

Water Quality

Pool 8
In general total suspended solids and turbidity were not significantly greater during the summer of 2001 when the pool was drawn

down 1.5 feet as compared to 1999 when accounting for changes in river flow between the monitoring periods. Wind induced effects on sediment resuspension explained less of the variation in total suspended solids, turbidity or light penetration than river flow. As a result, it can not be concluded that wind-induced effects on sediment resuspension were greater during the drawdown based on these data. There were no obvious changes in water quality parameters that could be directly attributed to the drawdowns. Most parameters were within the normal range of variability and followed the same patterns or trends as previous years.

Pool 5

There was no response in Pool 5 water quality that could be directly attributed to the drawdown in the two years following at either backwater or main channel sites. Although summer turbidity levels at the Pool 5 backwater site were at record lows following the drawdown, similar results were observed in lower Pool 4 over the same time period. The low turbidity in 2006 and 2007 is likely the result of increased aquatic vegetation in these backwaters and the low discharge that occurred during this period.

Contaminants

The bioavailability of contaminants did not appear to increase as a result of the drawdown.

Sediment Consolidation

Pool 8

Limited consolidation of sediments was expected because most of the drawdown zone was silty-sand with low organic content. Data collected in Lawrence Lake showed increases in available nitrogen, which coupled with consolidation of loose organic sediments suggested that desiccation of sediment in Lawrence Lake or other areas with high organic content would likely result in improved conditions for submersed aquatic plant growth including: reduction in sediment resuspension potential, and improvement of rooting medium (i.e. nutrients and sediment texture) for submersed aquatic plant growth.

Nitrogen Cycling

Results indicate that water level drawdowns are probably not an effective means of removing nitrogen from the Upper Mississippi River.

Commercial Navigation

All three pools were described in the tow boat pilot survey as being tougher to navigate during the drawdown.

Recreation

Pool 8

Monitoring, including several aerial surveys, indicated there was no reduction in recreational boating activity as a result of the drawdowns. There does not appear to have been any major fluctuation in recreational boat activity in Pools 7, 8 or 9 other than the general decrease in boating activity during 2001 which occurred in all pools in the study area.

Pool 5

An extensive effort was made to minimize recreational boating impacts resulting from the Pool 5 drawdown, including formation of a Citizens' Advisory Committee and dredging to provide "reasonable" recreational access. All sites identified and the three sites later dredged were channels used to access the main channel from a public boat ramp. Results from the recreation boating study indicates no major fluctuation in boating activity in the immediate or adjacent pools as a result of the drawdown.

Pool 6

The WLMTF provided assistance to marina owners including: signage, maps , buoys, dredging permit assistance, etc. Recreational access dredging was provided for one site.

Cultural Resources

Cultural resources monitoring focused on known archeological sites located on the shoreline portion of Pool 8 and later Pool 5. Known sites were monitored during the drawdowns or impacts from shoreline erosion or looting, Previously unrecorded sites exposed during the drawdown were identified. Fifteen of 33 sites on Pool 8 had a high probability of impact from shoreline erosion or looting. Two of five sites on Pool 5 had a high probability of impact from erosion and looting.

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WATER LEVEL MANAGEMENT ON THE UPPER MISSISSIPPI RIVER

Introduction

The Upper Mississippi River has been modified for navigation and other purposes for over 100 years. The first channel modification of 4-feet was authorized in 1824, a 4.5-ft channel was authorized in 1878, followed by a 6-ft in 1907. Modifications included removing snags, dredging, constructing wing dams and closing dams to create the necessary depth. Congress authorized the 9-ft channel project in 1930 which resulted in the construction of 26 locks and dams between St. Paul, Minnesota and St. Louis, Missouri. The dams created a series of shallow impoundments or navigation pools which provide higher and relatively stable water levels during non flood periods to maintain the Nine-Foot Navigation Channel.

Over the years, the amount of allowable fluctuation at the locks and dams was periodically reduced, primarily to reduce navigation channel dredging requirements, but the public also favored higher and stable water levels. For example: the allowable fluctuation at Lock and Dam 8 in 1937 was 3.5 feet. It was reduced to 2 feet in 1945, to 1.5 feet in 1964, and the current 1 foot in 1972. The minimum water surface elevation at the primary control point in La Crosse has always remained at 631.0 (4.7 on the La Crosse gage.)

Impounding the Upper Mississippi River had numerous effects including:

- sediment and nutrient accumulations reduced the depth of deep water channels, sloughs and backwaters;
- erosion of the islands in the lower portion of the pools reduced habitat diversity and quality;
- loss of aquatic vegetation reduced water clarity;
- less species diversity in the ecosystem (Figure1).

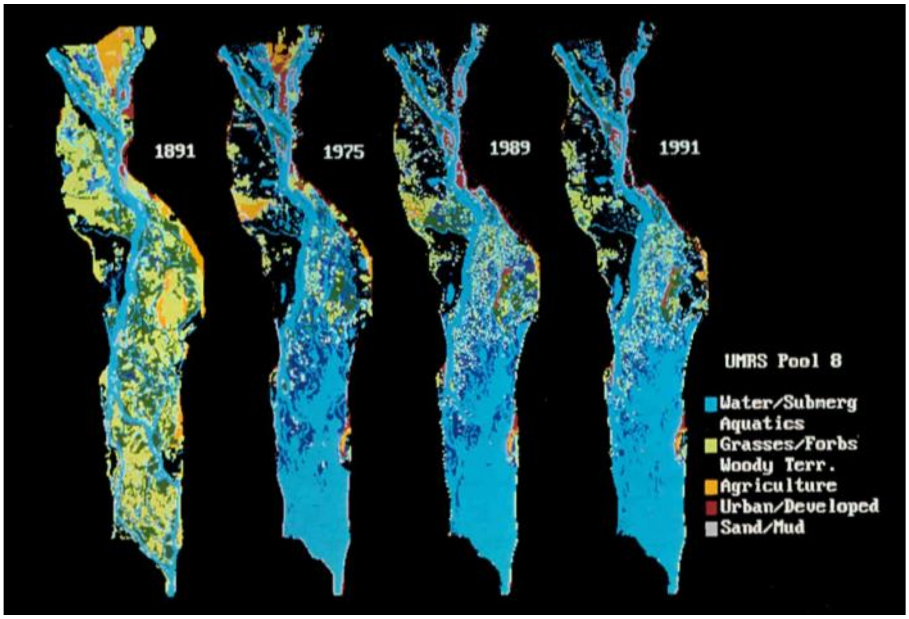


Figure 1. Landcover and vegetation changes in lower Pool 8 as a result of impoundment.

River managers began rebuilding islands, as well as restoring channels and deep-water habitat through funding from the Upper Mississippi River System-Environmental Management Program, established through the Water Resources Development Act in 1986.

The habitat projects produced conditions beneficial to submersed aquatic vegetation, but emergent aquatic plants were slower to respond. Emergent aquatic plants depend on a seasonal fluctuation in water levels for their long term survival and the generation of new plants. The natural seasonal low water levels during the summer growing season, especially in the lower portion of the pools, had been eliminated as a result of impoundment. Water level reductions or drawdowns offered a way to restore the natural seasonal fluctuation in water levels to benefit the emergent aquatic plant component.

In 1995 the WLMTF began to evaluate the potential for water level management in the northern reaches of the Upper Mississippi River with funding and technical support from the U.S. Army Corps of Engineers-St. Paul District. After successfully conducting several small-scale drawdowns, a demonstration large scale drawdown of a navigation pool was planned. After a lengthy selection process, Pool 8 was chosen for the first pilot large-scale drawdown.

Drawdowns Summaries

Experimental drawdowns of 1.5 feet at the dam were conducted on Pool 8 in 2001 and 2002, and on Pool 5 in 2005 and 2006. An experimental minor drawdown of 1-foot at the lock and dam was conducted in Pool 6 in 2010.

Drawdowns were initiated in mid-June, and water levels were lowered approximately 2 inches per day until the desired elevation was reached. If flows were suitable to maintain the drawdown, the water level reduction continued until mid-September when the level was gradually increased to full pool level by 30 September. The Pool 5 drawdown in 2006 ended three days after the 1.5-foot water level reduction was achieved on 26 June because of low flows.

The estimated extent of exposed substrates was based on geographical information system (GIS) coverage generated from true color aerial photography collected after the full drawdown was achieved. The extent of the exposed substances for each drawdown was:

- Pool 8 - 1,954 acres exposed both in 2001 and 2002.
- Pool 5 - 1003 acres exposed in 2005. The 2006 drawdown was discontinued.
- Pool 6 -133 acres exposed.

The extent and location of exposed substrates was variable depending on flows and pool operation. For example, during the 2001 drawdown of Pool 8 water levels were increased in the lower portion of the pool in mid August while reduced water levels persisted throughout the mid portion of the pool through 15 September. In 2002 the extent of area exposed was similar but was concentrated in the lower portion of the pool, which more closely approximated the anticipated results of a drawdown (Figure 2.) In contrast to 2001, the mid-pool area experienced only a limited effect from the drawdown.

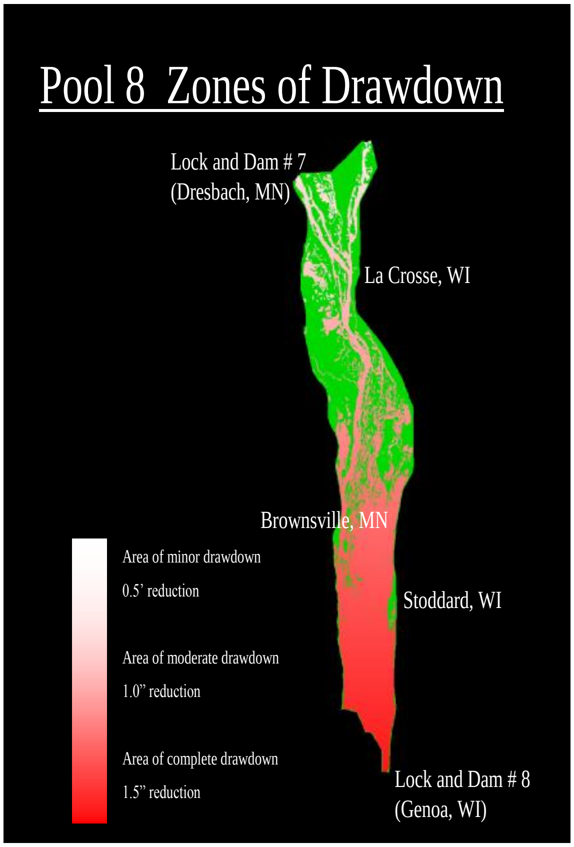


Figure 2. Estimated zones of impact due to drawdown of 1.5 foot water level reduction at the Pool 8 dam.

As river flow rates dropped, the minimum pool elevation at the La Crosse gage could no longer be maintained and pool levels at the dam had to be increased to maintain the water levels at the La Crosse gage. From 16 August to 15 September, the pool level at L&D 8 was only about three-tenths of a foot below normal. However, due to the slope of the pool, reduced water levels persisted throughout the mid-portion of the pool through 15 September (Figure 3).

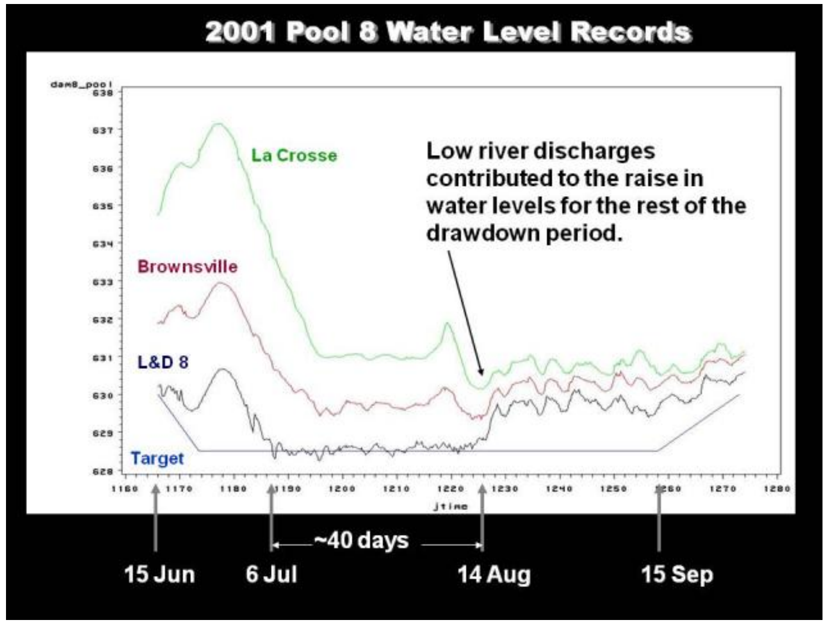


Figure 3. Upper Mississippi River Pool 8 water elevation (feet msl) at Lock & Dam 8, Brownsville and La Crosse gages, June through September 2001. The Brownsville water level represents the mid portion of the pool. USACOE

2002 Drawdown

The target reduction of 1.5-ft. at Lock and Dam 8 was reached on 03 July. Flows in the Mississippi River were high for much of the summer, therefore it was possible to maintain the maximum target drawdown level of 1.5-ft at the lower end of the pool while minimizing the impact upstream. The mid pool area around Lawrence Lake and Goose Island experienced a limited effect from the drawdown. Maximum extent of the drawdown in 2002 was similar to that of 2001. However, because river discharge rates were generally higher in 2002, area exposed at any given time during 2002 was generally less than that of 2001. The drawdown was in effect in the lower portion of Pool 8 for the prescribed time frame of 85-90 days. (Figure 4) . Refilling of the pool began on 16 September, reaching full pool level by 24 September.

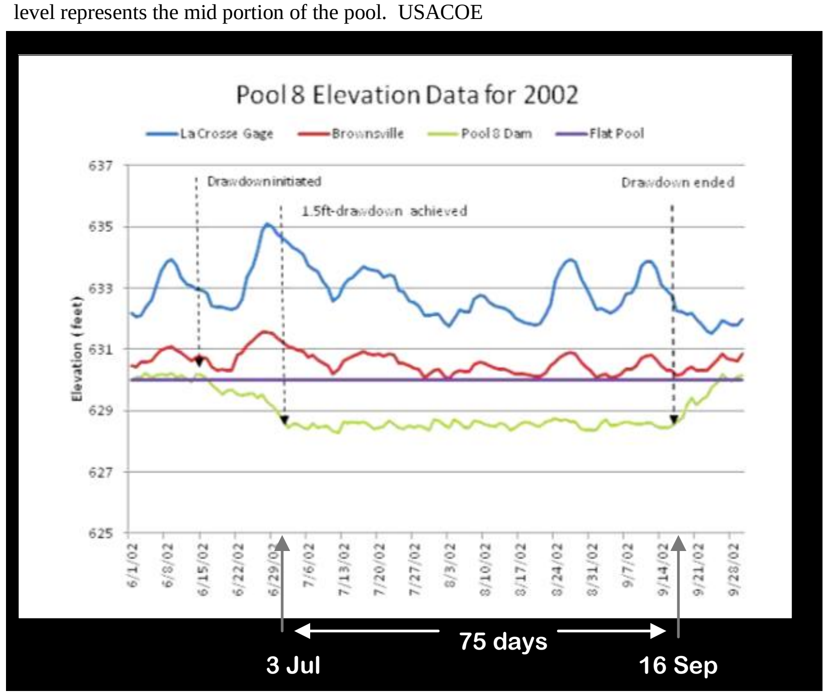


Figure 4 . Upper Mississippi River Pool 8 water elevation (feet msl) at Lock & Dam 8, Brownsville and La Crosse gages, June through September 2002. WDNR

Pool 5 Drawdown

The target water level reduction of 1.5 foot at the dam was achieved on 29 June, 2005. During June and most of July, river flows were higher than normal, consequently the 1.5-ft at LD 5 was maintained until about 25 July. An estimated 1000 acres of substrate was exposed. In late July and through September, low flows in the river necessitated water levels be increased at Lock and Dam 5 to maintain commercial navigation (Figure 5) .The shift in pool operations after 01 August exposed a different 1,000 acres in the middle and upper end of Pool 5 for the remainder of the drawdown, while previously exposed substrates in the lower pool were re-flooded in late August and early September. The pool elevation in Pool 5 was raised starting on 15 September and the pool was in normal pool regulation by 30 September.

Similar to Pool 8, a second drawdown was scheduled for 2006. The drawdown was initiated on 12 June 2006.and the target level of 1.5 ft. at the Lock and Dam 5 was reached on 26 June. However due to low flows in the river and the inability to maintain adequate depth for commercial navigation the drawdown was discontinued after three days and the pool was back to operation levels by 09 July.

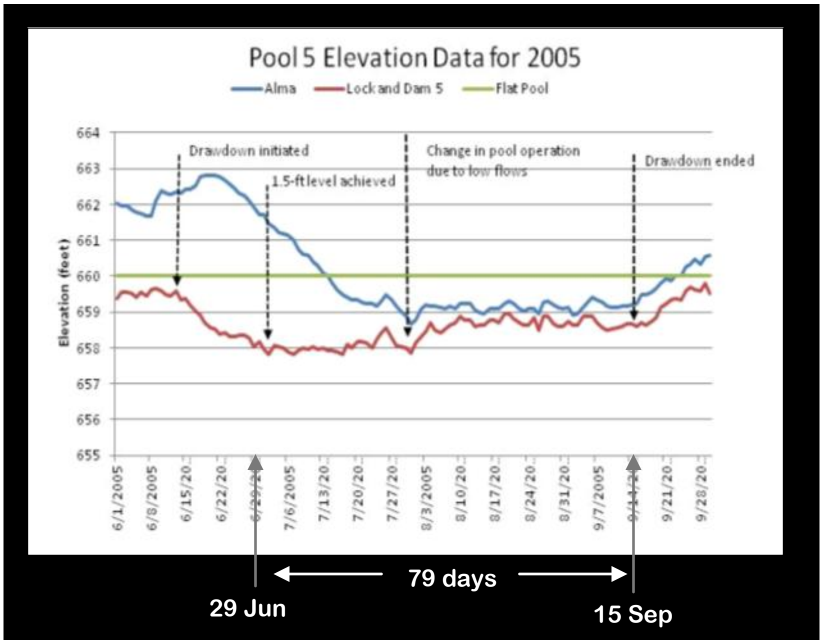


Figure 5 . Upper Mississippi River Navigation Pool 5 water elevation (feet msl) at Lock & Dam 5 and Alma gages, during June through September 2005. WIDNR

Pool 6 Drawdown

After four cancellations in 2003, 2004, 2008, and 2009, the Pool 6 drawdown was initiated on 18 June 2010. The target level of 1-foot drawdown at Lock and Dam 6 was reached on 01 July, and was maintained through 09 August when low flows necessitated an increase in water levels at the dam. Mid August rains increased discharge and by 20 August, the drawdown was again in effect. The drawdown was maintained through 26 August when the pool was gradually raised to normal operating levels by 03 September. Due to high summer flows only the lower portion of the pool (below Winona, MN) experienced the effects of the drawdown (Figure 6).

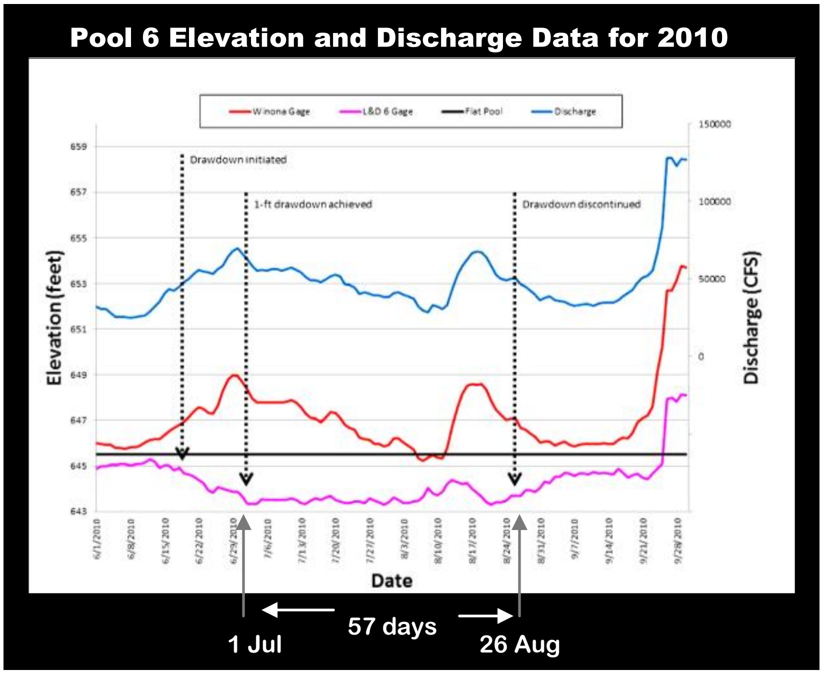


Figure 6. Upper Mississippi River Navigation Pool 6 water elevation (feet msl) at Lock & Dam 6 and Winona gages,) during June through September 2010. USGS

The drawdown ended early due to unusual river conditions combined with low flows in the river. Favorable conditions in spring contributed to an abundance of submersed aquatic vegetation throughout the Upper Mississippi River system. The heavy rains in mid August increased the discharge and raised water levels, which uprooted large quantities of aquatic vegetation. Large floating mats of vegetation floated downstream and were pushed in backwater areas causing recreational access and boating problems for the two marinas in lower Pool 6. On 25 August inadequate flows to maintain the drawdown were projected for the next several weeks. This combined with the recreational access problems led to the decision to end the drawdown by Labor Day.

MONITORING RESULTS

MAINTENANCE OF THE NAVIGATION CHANNEL

Dredging Summary NOT COMPLETED

Pool 8 Dredging Summary 2001 to 2003

The large quantity of dredging that was done in 2001 in advance of the drawdown resulted in reduced dredging in the following 2 years (Table 1.) The average dredging for the three years was 83,500 cubic yards which is 11 percent higher than the long term value of 75,000 cubic yards based on long term trend analysis. District wide dredging for the years 2001 to 2003 averaged 883,000 cubic yards, which is close to the projected long term value of 900,000 cubic yards.

Table 1. Dredging amounts in Pool 8 for the years 2001 to 2006.

Year	**Dredging** (thousands of cubic yards)	**Long term average**
2001	208900 (208.9)*	
2002	3700 3.7	
2003	3800 3.8	
	Average 2001-2003 = 83500	75,000
2004	94700	
2005	45900	
2006	16500	
	Average 2001-2006 = 67,900	

Dredging volumes from 2004 to 2006 were 94,700, 45,900 and 16,500 cubic yards of sand respectively. It appears that the advance dredging reduced dredging volumes until 2003, but not beyond. The lower dredging volumes in 2005/06 are probably related to lower flow conditions on the Mississippi and Root Rivers. The average dredging volume between 2001 and 2006 was 67,900 cubic yards.

** Note: The spring of 2001 saw the second highest flood of record on the Upper Mississippi River. The flood of 2001 had the longest period of extended river discharge following the flood peak of any of the major spring floods, even longer than the flood of 1965.Estimates in the After action report estimate without the drawdown 88,800 cubic yards dredged, estimate was 208,800 total and difference in quantity was 120,000 for the drawdown. Dredged from 6 dredge cuts ata cost of $37,000*

Similar results would be expected to occur in other pools where large quantities of dredging are required prior to the drawdown. However caution is urged. The discharge on the Root River was well below average in both 2002 and 2003. The Root River supplies over 50 percent of the bed material that result in dredging in Pool 8 so it is likely that the amount of sand entering the pool was below average in 2002 and 2003. Discharge on the Mississippi River was above average in 2002 and below average in 2003 which probably resulted in a fairly typical bed material supply from Pool 7 for the two years.

Pool 5 Dredging Summary

Pool 6 Dredging Summary 2010

Since the Pool 6 drawdown was a minor drawdown (1-foot at the dam) no dredging was scheduled for the drawdown to take place. In June , 2010 normal dredging was needed at two sites Below Winona RR Bridge and Gravel Point. Under normal dredging the Homer and Blacksmith Slough areas would not require dredging however with the drawdown in effect channel conditions were anticipated to be poor unless channel scouring occurred when the water level dropped. If feedback from the navigation industry regarding difficulties transiting the area indicated that conditions weren't safe for the navigation industry the water level would be brought back up to normal levels.

Sediment Transport System

Pool 8 Sediment Transport System including Hydrodynamics, Bathymetry, and Tributary Degradation

Jon S. Hendrickson, Marvin Hrdlicka - *U. S. Army Corps of Engineers-St. Paul District*

Hydraulic and sediment transport data collected during the Pool 8 drawdown included:

- Discharge measurements which were compared to discharge measurements without a drawdown.
- Bedload transport, which was measured using the ISDOT (Integrated Surface Difference Over Time) method. This method was developed by personnel from the Engineering Research and Development Center (Abraham and Pratt, 2002), and was used for the first time in Pool 8.
- Hydrographic surveys were collected and compared to pre-drawdown surveys collected during 1998 and 1999 to assess bathymetry changes.

Cross sections were obtained on Coon Creek and the Root River before and after the drawdown in 2001 to assess changes due to the drawdown. The objectives of these surveys were to obtain measurements of changes in hydrodynamics, sediment transport, and bottom configuration in the Mississippi River main channel and on tributaries that enter Pool 8.

Hydrodynamic and sediment transport related hypothesis that were analyzed included:

1. Due to decreased cross sectional area and greater effects of boundary roughness during a drawdown, the flow through secondary channels will be decreased so that a greater percent of the total river discharge is conveyed in the main channel.

2. The onset of drawdown will mobilize bed sediments and result in greater rates of sediment transport in the main channel in Pool 8, possibly causing degradation of the main channel in the reaches where dredging is usually done.

3. Tributary degradation could occur due to the lowered water levels in Pool 8, introducing additional sediment to the main channel in Pool 8.

4. The high main channel dredging volumes that are needed prior to a drawdown so that commercial navigation can continue will result in reduced dredging volumes in future years.

The navigation channel study reach selected for this study extends from river mile 686 to 691 located near Brownsville, Minnesota. This is a highly divided reach with many secondary channels. The main channel discharge decreases from 74-percent to 25-percent of the total river discharge from the upstream to the downstream end of the reach, due to flow through the secondary channels to backwater areas. Because of the decrease in main channel discharge, a large amount of dredging is needed annually in this reach.

Hydrodynamic Monitoring

Discharge measurements were collected during the drawdown and compared to discharge conditions without a drawdown to examine changes in the flow of water in the river. Data collected indicated the percentage of water conveyed in the main channel at river mile 688.9 increased from 60 to 73 percent of the total river discharge, which was due to decreased flow in secondary channels. These factors caused the average main channel velocity to increase from 1.83 to 2.35 fps.

Additional flow measurements were collected in the main channel and secondary channels throughout Pool 8 and compared to the data collected in previous years during normal water levels. These measurements indicated that secondary channels with entrances located further upstream in Pool 8 (e.g. the sloughs flowing past Goose Island) were not affected significantly by the drawdown, while discharge was reduced in secondary channels further down in the pool. The flow through Crosby Slough was almost cut in half from 8.3- to 4.8-percent of the total river flow, while the flow in Wigwam Slough was not affected. Crosby Slough is located further downstream in Pool 8 and flows through a shallow delta into a backwater area, while Wigwam Slough is located further upstream in Pool 8 and is relatively deep along its length. It is also possible that drawdown conditions increased the effectiveness of the closing dam at the entrance to Crosby Slough thereby affecting flow conditions in the slough.

Sediment Transport

Sediment transport is strongly influenced by river flow and channel velocity. Maximum channel velocities typically occur at the bankfull discharge condition (about the 1.5-year flood.) The flow rate at bankful conditions is about 85,000 cubic feet per second (cfs) at Lock and Dam 8. If flows during the drawdown were between 50,000 cfs and 80,000 cfs it was speculated that the combination of flow and drawdown could result in velocities high enough to significantly increase sediment transport.

In 2001, flows were less than 50,000 cfs for 75 of the 84 days during which the pool was drawn down. A discharge of 60,000 cfs was exceeded for 7 days at the start of the drawdown; however the pool wasn't completely drawn down at this point. In 2002, flows were in the lower portion of the drawdown range (less than 50,000 cfs) for 52 of the 101 days during which the pool was drawn down. A discharge of 60,000 cfs was exceeded for 29 days at several different times during the drawdown, and the pool was drawn down 1.5-foot for all but 6 of these 29 days.

Measurements of sand wave movement using the Integrated Surface Difference over Time Method (Abraham et al. 2003) indicated an increase in sediment transport during the drawdown in 2001. The potential for increased sediment transport was much greater during the 2002 drawdown because of the higher flows; however sediment measurements weren't taken during this time period

Bathymetry Changes in the Main Channel

Hydrographic surveys were conducted in Pool 8 during the drawdowns for comparison to pre-drawdown surveys completed during 1998 and 1999 to determine whether any changes in the bottom contours in the main channel were induced by the drawdown. The results were used to determine if greater sediment transport rates in the main channel would cause main channel degradation in the reaches where dredging is usually done.

A comparison of the surveys between river miles 686 and 691 indicated both deposition and erosion between 2001 and 2003; however some of the observed changes may have been due to normal sand waves moving through this reach. On an annual basis this reach normally aggrades to the point where main channel dredging is needed, however the high dredging volumes during 2001 maintained adequate navigation channel dimensions and resulted in a reduction in dredging in 2002 and 2003.

Tributary Degradation

Due to the lowered water levels in Pool 8, a high flow event on a tributary creek or river during the drawdown could potentially have caused down-cutting of the tributary introducing additional sediment to the main channel in Pool 8. Cross sections were obtained on Coon Creek, located in lower Pool 8, and the Root River, located in upper Pool 8, before and after the drawdown in 2001 to assess changes due to the drawdown. The drawdown should have had a greater influence on Coon Creek since it is located in lower Pool 8.

A comparison of cross sections before and after the 2001 drawdown on Coon Creek indicates degradation of less than 0.5 feet. A comparison of cross sections before and after the 2001 drawdown on the Root River indicates net aggradation exceeding 1 foot in the lower Root River; however degradation by as much as 2 feet occurred along the upper cross section. The Root River results are not consistent with those expected from a water level drawdown. If anything, bed degradation was expected at the downstream cross sections, with less degradation at upstream cross sections that are less influenced by the drawdown. Most likely these results are due to flow conditions on the Root River.

Conclusion

The results of this monitoring suggest:

- Large scale drawdowns, such as the 1.5-foot drawdown in Pool 8, increase main channel water discharge and sediment transport.
- Degradation occurred on Coon Creek; however it was generally less than 0.5 feet in the lower portion of this tributary.
- The high main channel dredging volumes that are needed in advance of a drawdown result in reduced future dredging.
- The lack of change in the main channel bed elevations in the study reach may be due to the fact that while the sediment transport rate increased, inputs balanced outputs. This is a desirable condition, since normally

the study reach would be aggrading until dredging was needed.

Pool 5 Main Channel Bed Material Sediment Transport Analysis

Jon Hendrickson, Regional Technical Specialist Hydraulic Engineering, *St Paul District U.S. Army Corps of Engineers*

Discharge and sediment data, collected in 2005, was analyzed to determine the effects of the drawdown on bed material transport in the main channel. A tool for estimating the sediment transport capacity in the main channel based on measured physical parameters was developed as part of this effort.

Monitoring data collected in Pool 5 in 2005 included:

- Flow velocity and distribution and training structure hydrodynamics
- Discharge measurements at two separate Main Channel cross sections during pre and during drawdown conditions. (Put in map)
- Total sediment load measurement suspended sediment, bed material size, suspended sediment size
- Sediment budget

Discharge Distribution

Both measurement sites saw a significant increase in the percentage of the total flow being carried in the main channel (i.e. less flow in the backwaters) during the drawdown compared to normal/pre-drawdown conditions.

Velocities

The average velocity is naturally higher in the upstream cross section. In the St Paul District, a decrease in velocity is typical downstream of a significant breakout flow.

Higher average velocities were expected in the Main Channel during the drawdown due to lower water surface elevations and increased flow in the main channel. This was verified by the data collected during 2005. The effect was more dramatic in the downstream cross section.

Bottom Material/Grain Size Distributions

The data showed that finer material exists at the downstream cross section than the upstream cross section. Also, the downstream cross section showed a consistent trend of finer material on the right side of the channel compared to the left. There was basically no gravel in the bottom material, as the material is classified as medium to coarse sand.

Shear Stress

The boundary shear stress is the parameter that directly relates to the ability of the river to move bed material (i.e. sand.) Calculated shear stresses for the 2005 measurements & estimated high flow conditions were analyzed to show the critical conditions for bed load movement and suspended load entrainment. Results indicated the river is beyond the critical condition for bed load movement through the range of flows considered. Also evident is that the smaller particles (fine sand) are beyond the critical condition for significant suspension through the water column, but the larger particles (coarse sand) are not.

Sediment Transport Calculator

A spreadsheet type calculator was developed that estimates the boundary shear stresses and sediment transport rates. This calculator was used to calculate theoretical suspended load & bed load for each of the 2005 measurements. It was also used to estimate the sediment transport conditions at L/D 5 discharges of 95,000 cfs & 150,000 cfs.

The calculator uses specific relationships for bed load & suspended load transport, however the structure allows for fairly easy modification to other relationships that may be of interest in the future.

Suspended Sediment Load:

The measured concentration of suspended sediment was generally dominated by the wash load (silt & clay) rather than the bed material (sand). This wash load is influenced by flows on the Zumbro River. The concentration of suspended sediment is generally much higher on the Zumbro than the Mississippi, and thus high flow events on the Zumbro contribute to high concentrations of suspended sediment in Pool 5.

Total Bed Material Load:

The data showed a significant increase in total bed material load during drawdown conditions. The sand load is increased by about 75-125% for the flow rates measured. It is important to remember that this represents only instantaneous sand transport, and does not represent an annual sand load. However, this analysis shows that the effect of a pool-wide drawdown on annual sand transport in the main channel is significant.

Analysis of the data shows that the majority of the bed material load (ie. sand load) moves through the system as bed load. The percent of sand moving as bed load is on the order of 90% for average flows, but is somewhat lower for larger flows. This indicates that in order to understand the sediment transport regimes in the Upper Mississippi River, bed load measurements are necessary to go along with the traditional suspended load measurements.

Conclusion:

During the drawdown, a greater percentage of the total river flow was conveyed in the main channel, and main channel flow velocity increased. This caused increased bed sediment transport in the main channel. During the drawdown, the percentage of the total river discharge conveyed in the main channel increased. This is due to the fact that in secondary channels, cross section area is decreased and roughness is increased as the water surface is lowered. Similar results were found in Pool 8 during the 2001-02 drawdown.

<u>One-Dimensional Sediment Modeling:</u> The hydraulic model HEC-RAS was used in conjunction with ArcMap 8.0, geographic imaging software to model sediment transport in Pool 5. Using this calibrated model along with grain size distribution data of sediment (St. Paul District Data), the HEC-RAS hydraulic design function was used to determine sediment transport capacity for each cross-section. The sediment yield in each reach was determined by integrating the sediment capacity curves and flow duration to obtain average daily and yearly sediment yield (EM

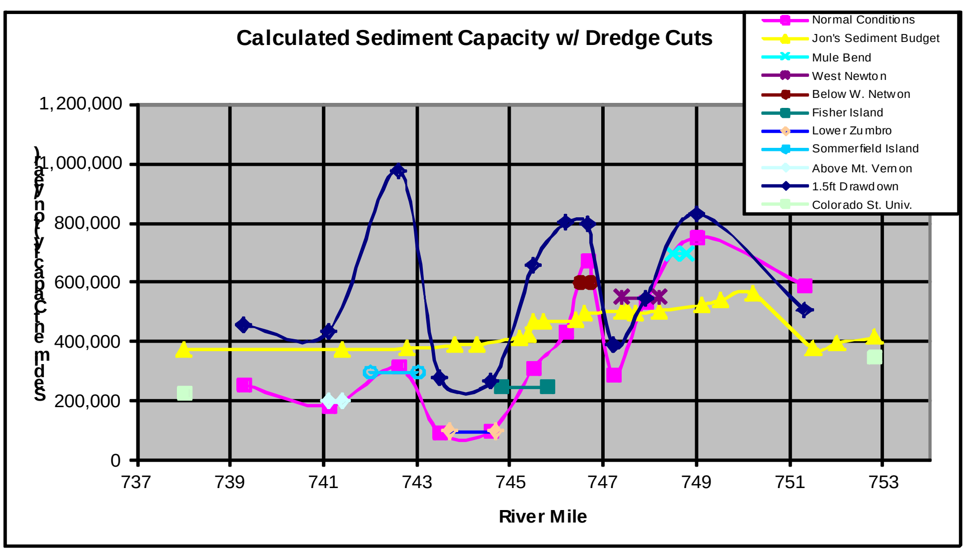


Figure . Calculated sediment capacity in Pool 5 using HEC-RAS.

BIOLOGICAL PARAMETERS

Vegetation Sampling, U.S.G.S.

Vegetation Monitoring

Pool 8 Drawdown

Seedbank Study

Kevin Kenow, *U.S. Geological Survey- Upper Midwest Environmental Sciences Center*

The drawdown was expected to dry and consolidate bottom sediments and, thereby, increase the area of emergent and submersed aquatic vegetation by natural seed germination. However, much of the river sediments that would be exposed during a drawdown had not been above water for over 60 years. The study was conducted to determine if a viable seedbank of desirable plants existed in the exposed area.

To quantify the availability of seed, we assessed the potential seed bank of selected areas of Pool 8 from substrate samples collected in spring, 2000. Fifty species of plants were identified in the seed bank samples. This included 29 wetland (10 submersed aquatic, 6 emergent, and 13 moist soil), 11 facultative wetland, and 10 upland species. Dominant taxa included arrowheads, false pimpernel *(Lindernia dubia)*, flatsedges, water star-grass *(Heteranthera dubia)*, love grasses, and rice cut-grass *(Leersia oryzoides)*. Submersed and emergent aquatic species were widely distributed, occurring in more than 90% of the samples. The plant response to the drawdown was very similar to the results of the seed bank study.

These results indicate experimental seed bank assessment is proving useful in determining, with some accuracy, the potential vegetation response to water level reductions.

Vegetation Response

Kevin Kenow, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

Researchers assessed vegetation response to the water level reduction during the drawdown through:

- Use of high-resolution aerial photography and land cover data generated from that photography;
- Field measures of the distribution and biomass of submersed aquatic vegetation;
- Field measures of the composition and productivity of moist soil and emergent perennial vegetation on exposed substrates.

Extent of Plant Coverage

On 21 July, 2001, during the period of maximum drawdown, a total of 1,954 acres (791 ha) were exposed (8.2 % of the area assessed)(Figure .) Maximum extent of the drawdown in 2002 was similar to that of 2001. However, because river discharge rates were generally higher in 2002, area exposed at any given time during 2002 was generally lower than that of 2001.

Aerial photographs were taken of Pool 8, from Root River south to Lock and Dam 8, during August of 2000-2003, to map the extent of aquatic plant coverage. Substantial expansion in the area of desirable aquatic plant communities were documented in the lower third of Pool 8, following the 2000 and 2001 drawdowns. In 2003, increases in deep marsh perennial (209 acres), rooted-floating aquatic (310 acres), and submersed aquatic vegetation (851 acres) communities were notable. Open water habitat was reduced by 1,362 acres (551 ha) during the same period (Figure .)

Vegetation Response on Exposed Substrates

Researchers monitored the development of vegetation on exposed substrates along transects at 13 sites throughout Pool 8 (south of Root River) (Figure).

The results were:

- More than 50 species of moist soil, perennial emergent and aquatic species were found. Rice cut-grass, broadleaf arrowhead *(Sagittaria latifolia)*, water stargrass, nodding smartweed (*Polygonum lapathifolium)*, chufa flatsedge, (*Cyperus esculetnus*), false pimpernel, and teal love grass *(Eragrostis hypnoides)* were the dominant species that developed on exposed substrates. Many of these species are a valuable source of food and cover for wildlife.
- Plant density was largely related to the duration of substrate exposure, with higher plant densities and more plant development occurring on substrates exposed for a good portion of the growing season (i.e., mid-pool sites that remained exposed through mid-September) and low plant density on those substrates that were re-inundated in mid-August 2001. For example, plant density ranged from less than 5 plants per m² on substrates exposed in the lower end of the pool to more than 100 plants per m² in the mid portion of the pool (e.g., north of Turtle Island and Shady Maple) (Figure .)
- Similarly, arrowhead tuber production ranged from none on substrates exposed in the lower end of the pool to 30 tubers per m² in other areas (e.g., Shady Maple, Stoddard Island Project Area.)
- We observed a shift from a plant community dominated by annuals to one dominated by perennials in 2002. (Figure .)

Substrates Exposed with the 2001 Drawdown of Pool 8

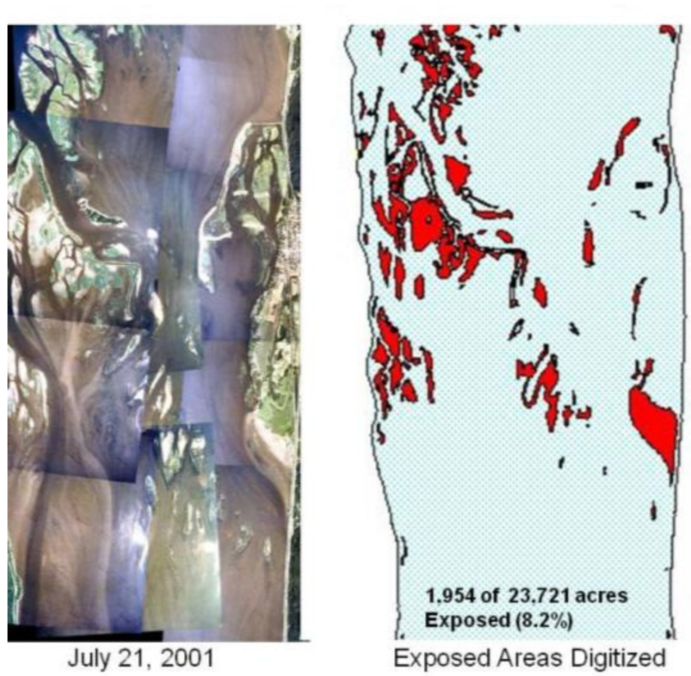


Figure 3. Delineation of substrates exposed with the 2001 drawdown of Pool 8. Photo 21 July 2001, USGS-UMESC

In some areas, effects persisted through summer, 2005. For example, vegetation change within a 500-acre (202 ha) area along the Raft Channel was monitored annually from 2000-2005. With drawdown, we observed the return of an important deep marsh perennial component to the Raft Channel area, and a return to the aquatic plant community diversity that had been present in 1975 (Figure .)

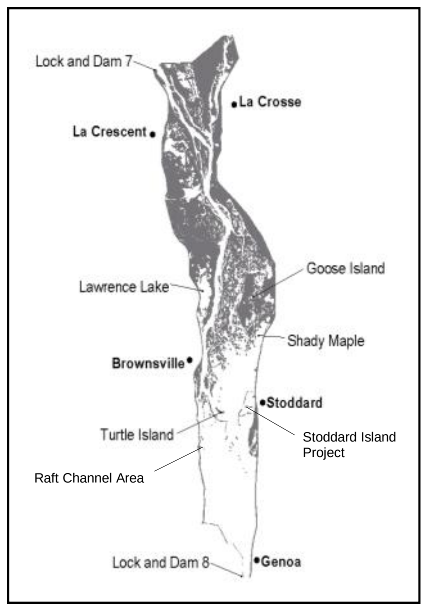


Figure . Map of Pool 8. Plant density in 2001 was highest in substrates exposed in the mid portion of the pool e.g. north of Turtle Island, Shady Maple, Stoddard Island Project.

Seed and Tuber Production

A variety of moist soil and emergent plant species, important food resources to wildlife, grew on substrates exposed during the drawdown.

- Seed production in 2001 was dominated by annual plants including:

rice cut-grass (51% of total production), chufa flatsedge (13%), barnyard grass (*Echinochloa crusgalli)* (13%), and nodding smartweed (11%).

- Tuber production in 2001 was dominated by arrowhead (52%) and sago pondweed (*Potamogeton pectinatus*) (44%). In 2002, arrowhead made up 94% of total tuber production. Arrowhead tuber production increased 16-fold (average = 3.4 g/m^2 in 2001 vs. 55.3 g/m^2 in 2002) across transects we examined during the two years.

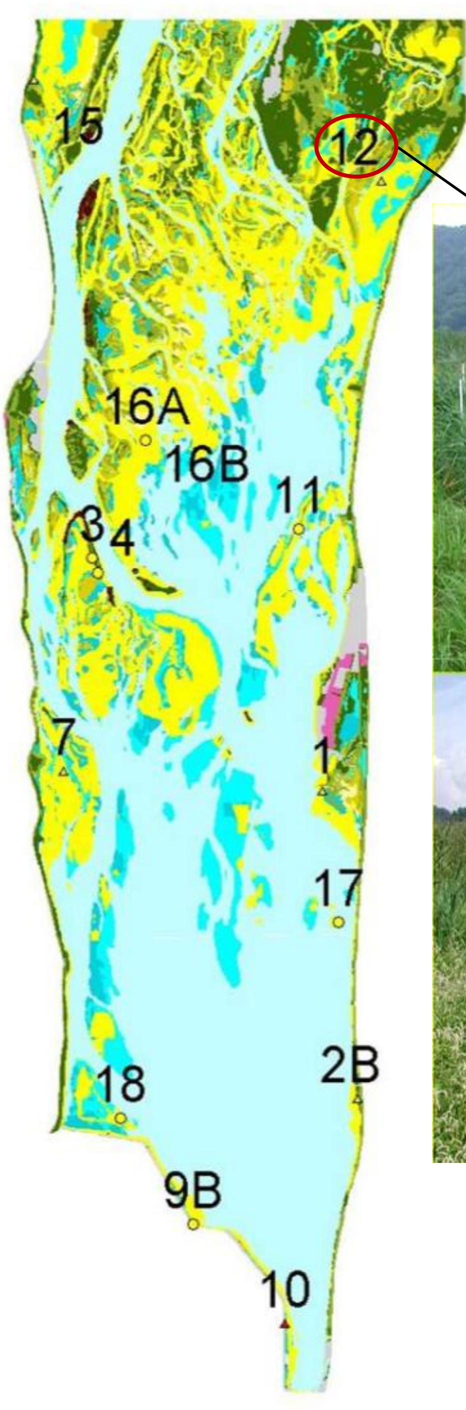


Figure . Pool 8 Vegetation Transect Locations. Plant response 2001 on Pool 8 Transect 12 was dominated by nodding smartweed, rice cut-grass, teal lovegrass and flatsedges. USGS-UMESC

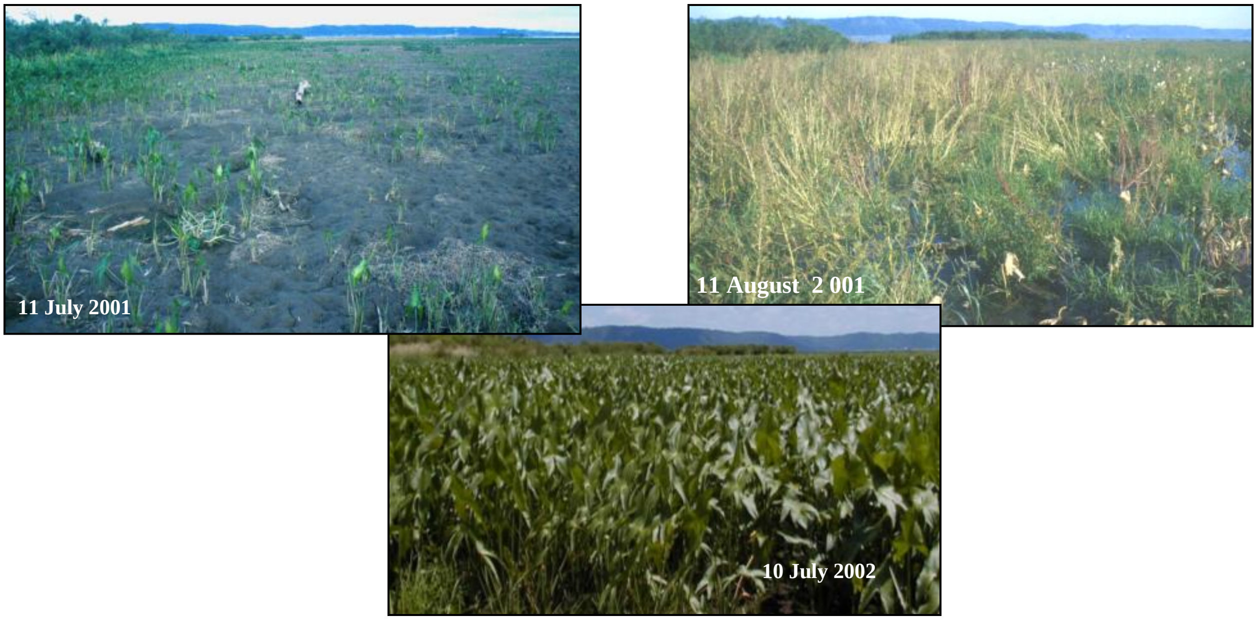


Figure 4. Vegetation response to 2001 and 2002 summer drawdowns of Pool 8. The plant community on the exposed sites shifted from one being dominated by annuals in 2001 to one dominated by perennials such as arrowhead, water stargrass, rice cutgrass and chufa flat sedge in 2002. Photo—Raft Channel West, USFWS.

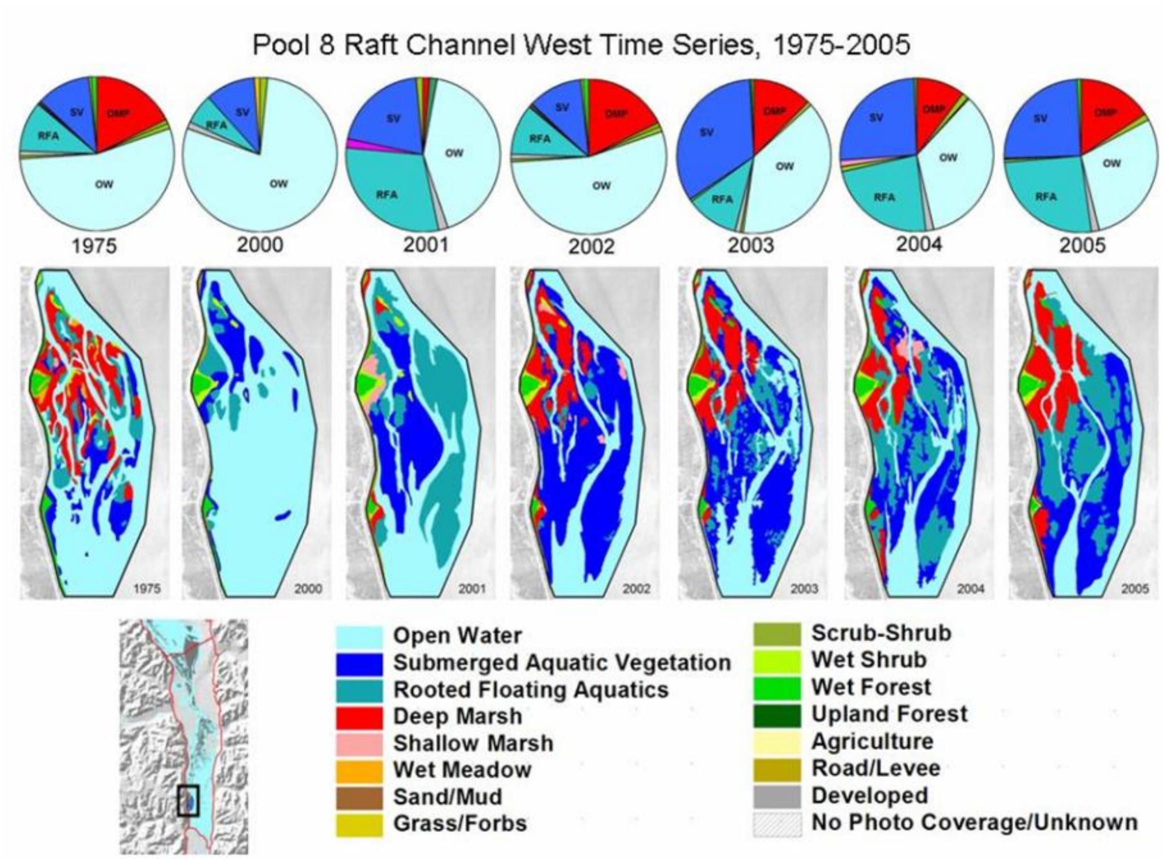


Figure 2. The deep marsh perennial plant community, essentially absent in 1999 and 2000, occupied 79 acres (16% of the area) in summer 2005. Rooted-floating aquatics occupied 97 acres and submersed aquatic vegetation 72 acres more in 2005 than prior to drawdown.

Pool 5 Drawdown- Vegetation Monitoring Response

Vegetation Response to a Water Level Drawdown in Navigation Pool 5 of the Upper Mississippi River, 2005

Kevin P. Kenow, James T. Rogala, and Larry R. Robinson, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

The primary objective of the drawdown, as established by the WLMTF was to improve conditions for the growth of aquatic vegetation with special emphasis on perennial emergent species. A combination of field sampling and interpretation of aerial photography was used for evaluating the vegetation response during the first year of the drawdown, including:

- Determine changes in distribution of emergent vegetation through the use of interpretation of high resolution aerial photography from pre- and post-drawdown years.
- Determine vegetation response/growth on exposed substrates during the drawdown at peak biomass through field measures of the composition and productivity of moist soil and emergent perennial vegetation on exposed substrates using a random sampling design. The extent of substrates exposed was determined using a GIS coverage generated from photography acquired during the time of peak drawdown (15 July 2005.)
- Determine changes in distribution and abundance of submersed aquatic vegetation through repeated annual surveys using a random sampling design. (See submersed aquatic vegetation summary.)

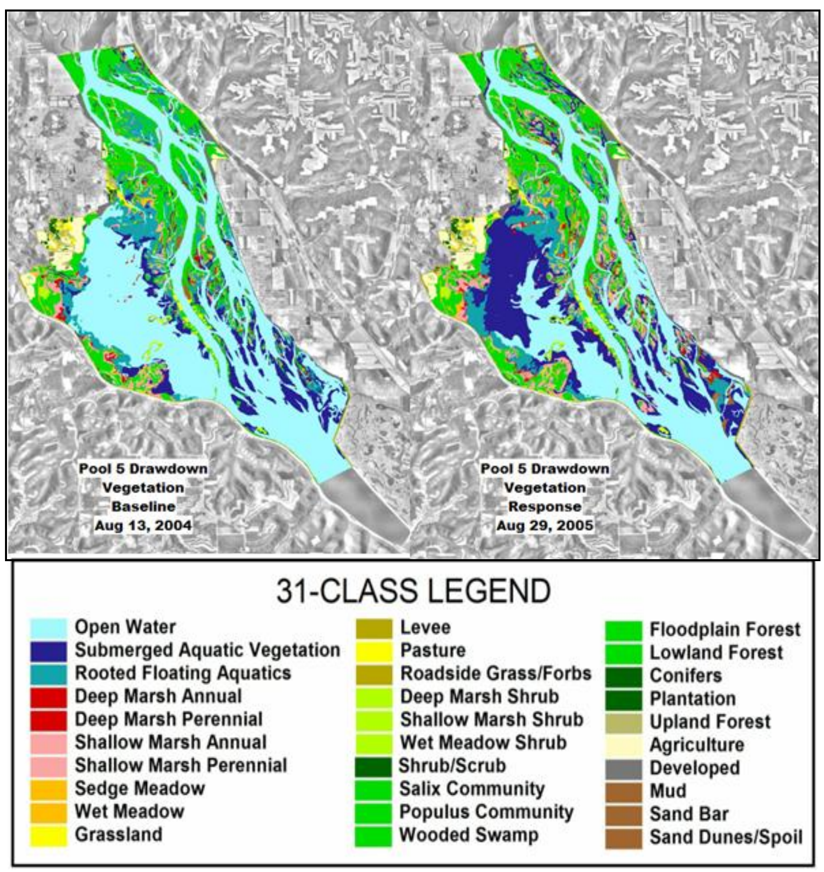
Extent of Plant Coverage

On 15 July 2005 during the time of peak drawdown approximately 405 ha (1000 acres) of substrate were delineated as newly exposed on aerial photography (Figure .) The drawdown of Pool 5 was not optimum over the target period in the summer of 2005. Low discharge restricted the drawdown during the period August to September.

The inability to maintain reduced water levels in the lower end of the pool under low discharge conditions is a function of regulations used to maintain depth suitable for commercial navigation.

In order to maintain required depths in the middle portion of the pool, the water level rose in the lower end due to the low slope of the water surface under low discharge conditions. Nonetheless, water levels in 2005 were lower than those levels found during the previous ten years.

Figure ?. Pool 5 study area land cover data for 2004 and 2005 overlying a mosaic of digital orthophoto quadrangles USGS-UMESC



Changes in the distribution of vegetation communities as interpreted from aerial photographs indicate an expansion of submersed aquatic vegetation and shallow marsh plant communities in 2005 (Figure). A large increase in submersed aquatic vegetation was documented in the Weaver Bottoms portion of Pool 5. Approximately 1,000 acres of the 1,435 acre pool-wide increase in submersed vegetation occurred here.

De-watered shallow areas occupied by rooted floating species in 2004, were supporting shallow marsh annuals and perennials in 2005. This change occurred primarily among the islands bordering the main channel. Overall, land cover classification changed on 2,314 of 13,626 acres (17%) from 2004 to 2005. Open water habitat was reduced by 2,054 acres (-30.4% within-class change) and the rooted-floating aquatic community decreased by 178 acres (-15.5%). Increases were observed in the shallow marsh annual (370 acres, 2077.1%), shallow marsh perennial (225 acres; 54.5%), and submersed aquatic vegetation (1,435 acres; 106.7%) (Figure .)

Vegetation Response on Exposed Substrates

Vegetation response on exposed substrates was determined at 166 randomly selected locations within the delineated exposed area. Sampling was conducted between 24 August and 15 September 2005. The 166 sites averaged 33 days exposed, with an average starting date of 19 July and average ending date of 29 August. Average maximum elevation above the water surface (i.e., drawdown) on these sites was 0.18 m (0.6 ft.), with a maximum of 0.40 m (1.3 ft.). Response was evaluated by measuring the above- ground biomass, and percent cover within a 1-m^2 quadrat.

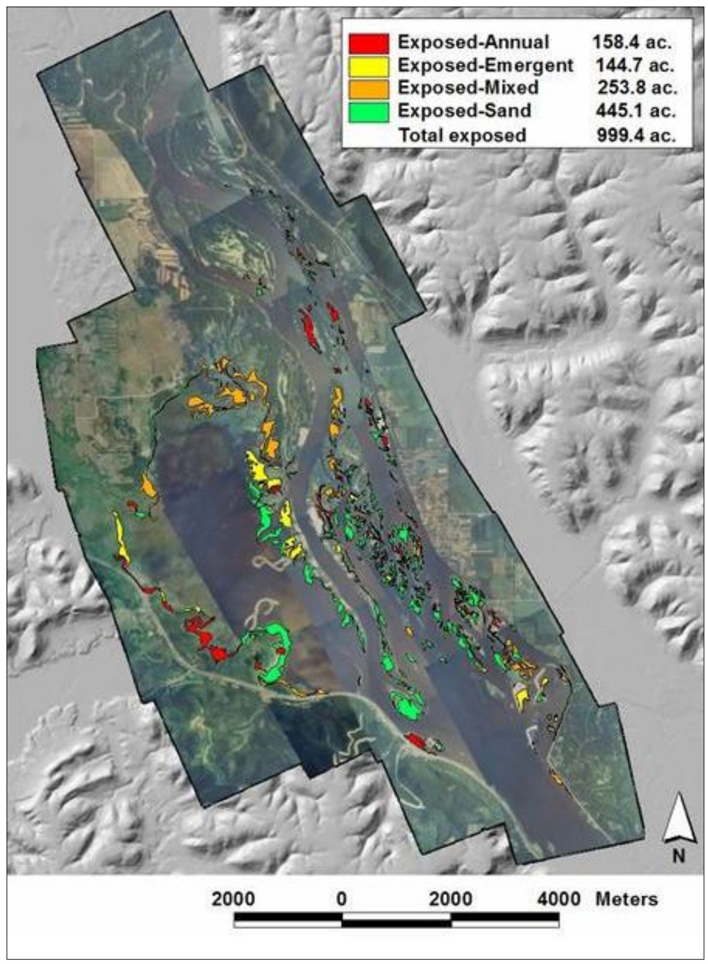


Figure . Delineation of substrates exposed with the 2005 drawdown of Pool 5, Upper Mississippi River. Photo 15 July 2005, L&D discharge 30,600, L&D Elevation 657.94 USGS

The results were:

- Seventy– two plant species were identified in sampling quadrats on exposed substrates of Pool 5. These areas were dominated by moist-soil and emergent species . The most frequently observed species were rice cutgrass (*Leersia oryzoides*), common arrowhead *(Sagittaria latifolia)*, sandbar willow (*Salix exigua*), grassleaf mudplantain *(Heteranthera dubia)*, and chufa flatsedge (*Cyperus esculetnus*). Growth progressed well despite the increase in water levels that occurred in late July in the lower end of the pool.
- Plant species diversity (number of species) of sample quadrats was related to amount of time the mudflats were exposed as well as the elevation above water surface and the reduction in soil moisture level.
- Submersed species (e.g., coon's tail [*Ceratophyllum demersum*] and Canada waterweed [*Elodea Canadensis*] were observed on sites dewatered for short periods (mean = 5 to 7 days exposed). Floating-rooted aquatic types (e.g., American lotus [*Nelumbo lutea*]) were more common on sites with an intermediate dewatering (i.e., mean = 22 to 32 days exposed).
- Common arrowhead tended to occur on sites with slightly longer periods of dewatering (mean = 37 days),

with soft-stem bulrushes (*Schoenoplectus tabernaemontani*) and rice cutgrass also more commonly found on sites exposed for a longer duration (mean = 45 days).

- Species considered more terrestrial (e.g., willows [*Salix spp*.] and flatsedges [*Cyperus spp])* were most prevalent among the list of most common species and were observed on sites dewatered longer than 50 days.

Above Ground Biomass

Above ground biomass averaged 108.4 ± 9.7 g dry wt/m^2 (median = 69.4; range = 0 to 586.1 g/m^2) among the 166 sites used in the analysis. American lotus (18.3 g/m^2), white waterlily (*Nymphaea odorata*) (12.4 g/m^2), teal lovegrass (*Eragrostis hypnoides*) (11.6 g/m^2), rice cutgrass (11.4 g/m^2), common arrowhead (9.8 g/m^2), sandbar willow (7.4 g/m^2), redroot flatsedge (6.6 g/m^2), and chufa flatsedge (6.3 g/m^2) dominated biomass production across all quadrats.

The mean number of days exposed and the magnitude of exposure (i.e., elevation above water surface and reduction in soil moisture level) were highly correlated (r^2 = 0.94) for plant species diversity and biomass production of sample quadrats, so the relations described above need to be interpreted with caution when weighing effects of magnitude verses duration of drawdown.

Conclusion:

Much of the plant response observed on exposed substrates was directly influenced by the drawdown. Many emergent, moist-soil, and terrestrial species that require exposed substrates or shallow water (i.e., < 5 cm) for germination and development would not have become established under the normal flooding regime in Pool 5 (Kenow, et al. 2009).

Evaluation of 2006 Vegetation Response on Areas Exposed during the 2005 Drawdown of Navigation Pool 5, Upper Mississippi River

Kevin P. Kenow, James T. Rogala, Pete J. Boma *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

The drawdown conducted in Navigation Pool 5 in 2005 exposed about 405 ha(1,000 acres), mostly in the lower and midpool areas. A second drawdown was prescribed for 2006 to enhance productivity of perennial emergent aquatic plants. The drawdown was initiated on 12 June 2006 and water levels were gradually reduced to about 1.5 feet below the normal secondary pool elevation of 659.5 feet above mean sea level (msl) at Lock and Dam 5 by 26 June. However, because of the low and declining river flows during summer 2006, river managers were only able to hold a full 1.5-foot drawdown at the dam (below the secondary control point of 659.5 feet msl to 658.0 feet msl) for a couple of days before having to shift to “primary control” and the pool water level was raised to the project pool elevation of 660.0 feet msl.

Despite the lack of a 2006 drawdown of Pool 5, UMR resource managers were interested in plant community change on those areas dewatered with the 2005 drawdown. The WLMTF partners were also interested in the long-term effects of drawdown on vegetation dynamics. The finding from the studies in Pool 5 across multiple years, along with vegetation monitoring in other drawdown pools, is expected to improve our understanding of vegetation response to periodic drawdowns on the UMR.

Vegetation above-ground biomass and per cent cover were measured at 217 randomly selected locations within areas of substrates exposed during the 2005 drawdown that are not exposed under normal pool operations. At each sample location, percent cover was determined by species, and stem counts obtained for most emergent, moist-soil, and terrestrial species occurring with a 1-m^2 quadrat. General substrate class, and evidence of herbivory (i.e., grazing by Canada geese [*Branta canadensis*] or muskrat [*Ondatra zibethicus*]) were recorded for each site. Vegetation sampling was conducted between 21 August and 14 September 2006.

Vegetation Response on Exposed Substrates

Fifty-one plant species were identified in sampling quadrats on exposed substrates of Pool 5, approximately 70 percent of the number of taxa that appeared within the same sampling frame during sampling in August-September 2005 (i.e., sampling during the 2005 drawdown).

In 2006 these areas were dominated by emergent perennial and submersed aquatic species. The most frequently observed species were coon's tail (*Ceratophyllum demersum*), common arrowhead (*Sagittaria latifolia*), Canada waterweed (*Elodea canadensis*), grassleaf mudplantain (*Heteranthera dubia*), rice cutgrass, white waterlily (*Nymphaea odorata*), and soft-stem bulrush (*Schoenoplectus tabernaemontani*). Growth progressed well in these species despite the lack of a drawdown in 2006.

Above Ground Biomass

Above-ground biomass of emergent perennial, floating-leaved aquatic, and moist-soil vegetation averaged 282.0 ± 22.9 g dry wt/m^2(median = 202.7; range = 0 to 1,819.4 g/m^2) among the 217 sites used in the analysis. Plant biomass was 260 percent higher than that measured on the same area in 2005 (108.4 ± 9.7 g dry wt/m^2.) Common arrowhead (64.5 g/m^2), ricecutgrass (53.8 g/m^2), white waterlily (29.0 g/m^2), sandbar willow (*Salix exigua*; 23.1 g/m^2), reed canary grass (*Phalaris arundinacea*; 19.3 g/m^2), and broadfruit bur-reed (*Sparganium eurycarpum*; 18.0 g/m^2) dominated plant biomass across all quadrats.

Plant biomass among sample quadrats in 2006 was positively associated (r^2= 0.14, P < 0.0001) with estimated number of days that the quadrat was dewatered in 2005 (determined from the water elevation model). Those quadrats that were exposed earliest in 2005 and were higher on the elevation gradient tended to have higher plant biomass in 2006.

Evidence of grazing was evident in 8 of the 217 sites (3.7 percent). However, plant biomass did not differ significantly between grazed (mean ± SE = 153.5 ± 43.5 g dry wt/m^2) and ungrazed (mean = 287.0 ± 23.9 g dry wt/m^2) plots ($\chi 2 = 0.06$, $P = 0.81$).

Plant biomass was also assessed only among those quadrats that contained a given species to better illustrate potential productivity of individual species (eliminated samples in which species did not occur). The rank order in biomass among sites where a species occurred was wild rice (*Zizania aquatica*; 526.4 g/m^2), sandbar willow (218.0 g/m^2), purple loosestrife (*Lythrum salicaria*; 204.1g/m^2), reed canary grass (199.1 g/m^2), rice cutgrass (149.8 g/m^2), and common arrowhead (142.9 g/m^2).

A general pattern of increase was observed in emergent and submersed aquatic plant species and decrease in moist-soil and terrestrial species in 2006 compared to the vegetation composition of the same area in 2005 (Kenow et al. 2007). Noteworthy were large reductions in the occurrence of sandbar (34 percent versus 12 percent frequency of occurrence in 2005 and 2006, respectively) and black willow (*Salix nigra*; 34 percent versus 7 percent), chufa flatsedge (*Cyperus esculentus*; 37 percent versus 1 percent) and redroot flatsedge (*C. erythrorhizos*; 29 percent versus 1 percent), false pimpernel (*Lindernia dubia*; 32 percent versus 1 percent), nodding smartweed (*Polygonum lapathifolium*; 27 percent versus 5 percent), and teal lovegrass (27 percent versus 0 percent). Rice cutgrass occurred at 45 percent of sites sampled in 2005 and 38 percent of sites sampled in 2006.

The occurrence of common arrowhead was about the same (45 percent versus 47 percent) in both years, while sessile fruit arrowhead (*Sagittaria rigida*; 6 percent versus 20 percent) and broadfruit bur-reed (*Sparganium eurycarpum*; 4 percent versus 15 percent) increased in 2006.

An increase in the occurrence of several submersed aquatic species (grassleaf mudplantain, Canada waterweed, coon's tail, Eurasian watermilfoil [*Myriophyllum spicatum*], wild celery [*Vallisneria americana*], and sago pondweed [*Potamogeton pectinatus*]) was also observed.

Compared to the biomass of emergent species in 2005, large increases were evident in the average above-ground biomass of common arrowhead, rice cutgrass, soft-stem bulrush, and broadfruit bur-reed.

Conclusion

Much of the emergent vegetation that occurred within the sampling area (substrates exposed in 2005) was likely established with the 2005 drawdown. Emergent species, such as arrowhead, that arose from seed where suitable conditions were created during the 2005 drawdown were small in stature but produced small tubers or rhizomes. Plants arising from these structures in the subsequent growing season tended to be much more robust, as observed on other UMR drawdowns at Peck Lake on Pool 9 and at Pool 8 (Kenow et al., 2001).

Evaluation of 2009 Vegetation Response on Areas Exposed during the 2005 Drawdown of Navigation Pool 5, Upper Mississippi River

Kevin P. Kenow *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

A long-term evaluation of vegetation response to the 2005 drawdown of Pool 5 is important because river managers are particularly interested in the persistence of vegetation established with periodic drawdowns of varying duration, timing, spatial extent, and magnitude. A long term evaluation is also important as the magnitude of response of some plant species may not be evident during the initial year. For example, arrowhead plants that arise from seed where suitable conditions are created during a drawdown, are typically small in stature but produce small tubers. Plants arising from tubers in the subsequent growing season tend to be much more robust.

Vegetation response on Pool 5 substrates exposed during the 2005 summertime water level reduction (drawdown) was evaluated by measuring the above- ground biomass, and percent cover within a 1-m^2 quadrat on 192 randomly selected sample sites located within areas of substrates exposed during the 2005 drawdown that were not exposed under normal pool operations. General substrate class and evidence of herbivory (i.e., grazing by Canada geese [*Branta canadensis*] or muskrat [*Ondatra zibethicus*]) were also recorded for each site. Vegetation sampling was conducted between 24 August and 09 September 2009.

Vegetation Response on Exposed Substrates

Thirty plant species were identified in sampling quadrats on inundated substrates of Pool 5, approximately 42% of the number of taxa that appeared within the same sampling frame during sampling in August-September 2005 (i.e., sampling during the 2005 drawdown).

In 2009, these areas were dominated by emergent perennial and submersed aquatic species. The most frequently observed species were Canada waterweed (*Elodea canadensis*), coon’s tail (*Ceratophyllum demersum*), common arrowhead (*Sagittaria latifolia*), grassleaf mudplantain (*Heteranthera dubia*), sessilefruit arrowhead (*Sagittaria rigida*), white waterlily (*Nymphaea odorata*), and broadfruit bur-reed (*Sparganium eurycarpum*).

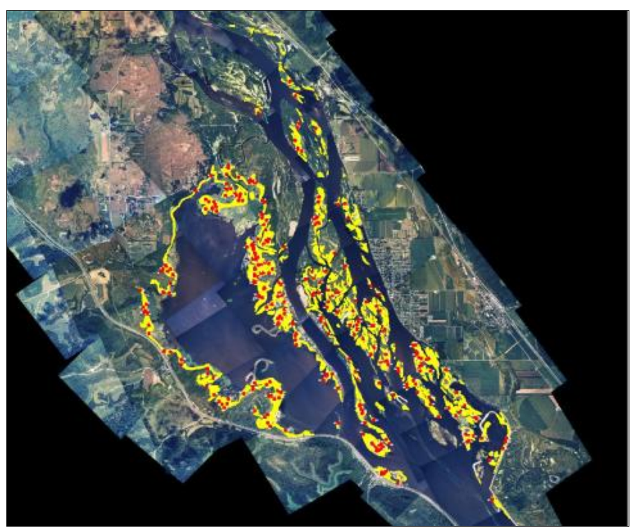


Figure 1. Location of sample sites (red dots) for evaluating 2009 vegetation response on substrates exposed (indicated in yellow) during the 2005 drawdown of Pool 5, Upper Mississippi River The extent of substrate exposed was determined to be approximately 1,000 acres (405 ha). USGS-UMESC

Above Ground Biomass

Above-ground biomass of emergent perennial, floating-leaved aquatic, and moist-soil vegetation averaged

183.6 ± 17.8 g dry wt/m^2 (median = 63.6; range = 0 to 1,482.7 g/m^2) among the 192 sites used in the analysis. Above-ground biomass of submersed aquatic plants averaged 72.0 ± 11.1 g dry wt/m^2 (median = 16.9; range = 0 to 643.5 g/m^2) in 2009. Broadfruit bur-reed (mean biomass = 71.8 g/m^2), common arrowhead (65.4 g/m^2), cattail (*Typha spp*.; 38.5 g/m^2), Canada waterweed (35.8 g/m^2), soft-stem bulrush (*Schoenoplactus tabernaemontani*; (29.6 g/m^2), and sessilefruit arrowhead (21.9 g/m^2) dominated plant biomass across all quadrats (Table 2).

Evidence of grazing was observed in 21 of the 192 sites (10.9%) included in the analysis. However, emergent, moist soil, and floating-leaved aquatic plant biomass did not differ significantly between grazed (mean ± SE = 192.5 ± 42.0 g dry wt/m^2) and ungrazed (195.2 ± 21.4 g dry wt/m^2) plots (χ^2 = 1.52, P = 0.22).

Plant biomass was also assessed only among those quadrats that contained a given species to better illustrate potential productivity of individual species (eliminated samples in which species did not occur). The rank order in mean biomass among sites where a species occurred was cattail (273.5 g/m^2), broadfruit bur-reed (255.3 g/m^2), wild rice (*Zizania aquatica*; 233.1 g/m^2), common arrowhead (193.2 g/m^2), softstem bulrush (160.0 g/m^2), and sessilefruit arrowhead (67.9 g/m^2) (Table 2).

Changes Observed from 2005 to 2009

A general pattern of increase was observed in submersed aquatic plant species and a decrease in moist soil and terrestrial species in 2009 compared to the vegetation composition of the same area in 2005-2007 including:

- The pattern in emergent aquatic vegetation varied by species. Figure illustrates the change in frequency of occurrence of terrestrial/moist-soil, emergent, floating-leaved, and submersed aquatic vegetation during 2005 through 2009.
- Large increases were noted in the occurrence of coon's tail (23% vs. 77% frequency of occurrence in 2005 and 2009 respectively), Canada waterweed (34% vs. 78%), sessilefruit arrowhead (6% vs. 32%) and broadfruit bur-reed (4% vs. 28%).
- Frequency of occurrence of common arrowhead (45% vs. 34%), soft-stem bulrush (27% vs. 17%), American lotus (*Nelumbo lutea*; 23% vs. 10%), rice cutgrass (45% vs. 2%), and reed canary grass (24% vs. 3%) generally declined over the same time period.
- Several terrestrial/moist soil species that were prevalent in 2005 (sandbar willow [*Salix exigua*], black willow [*Salix nigra*], chufa flatsedge [*Cyperus esculentus*], redroot flatsedge [*C. erythrorhizos*], false pimpernel [*Lindernia dubia*], nodding smartweed [*Polygonum lapathifolium*], and teal lovegrass [*Eragrotis hypnoides*]), were not detected among sample sites in 2009.
- Compared to the biomass of emergent species in 2005, large increases were evident in the average above-ground biomass of broadfruit bur-reed, sessilefruit arrowhead, cattail, and soft-stem bulrush in 2009. Much of the emergent vegetation that occurred within the sampling area (substrates exposed in 2005) was likely established with the 2005 drawdown. Emergent species, such as arrowhead, that arose from seed where suitable conditions were created during the 2005 drawdown were small in stature but produced small tubers or rhizomes. Plants arising from these structures in the subsequent growing season tended to be much more robust, as observed on other UMR drawdowns at Peck Lake on Pool 9 and at Pool 8 (Kenow et al., 2001.)
- Despite an increase in 2006, the average above ground biomass of common arrowhead remained relatively stable in 2009; rice cut grass and reed canary grass exhibited a pattern of declining biomass over the same time period.
- Compared to the biomass of submersed aquatic plant species collected at even-numbered sites in 2007 and 2009, an increase in average above-ground biomass was noted in coon's tail, Canada waterweed, and grassleaf mudplantain.

Conclusion:
A number of desirable plant species that were established on exposed substrates during the 2005 drawdown persisted, and in some cases flourished, through 2009. The dominant emergent species are recognized for their value as wildlife food and habitat structure for aquatic organisms.

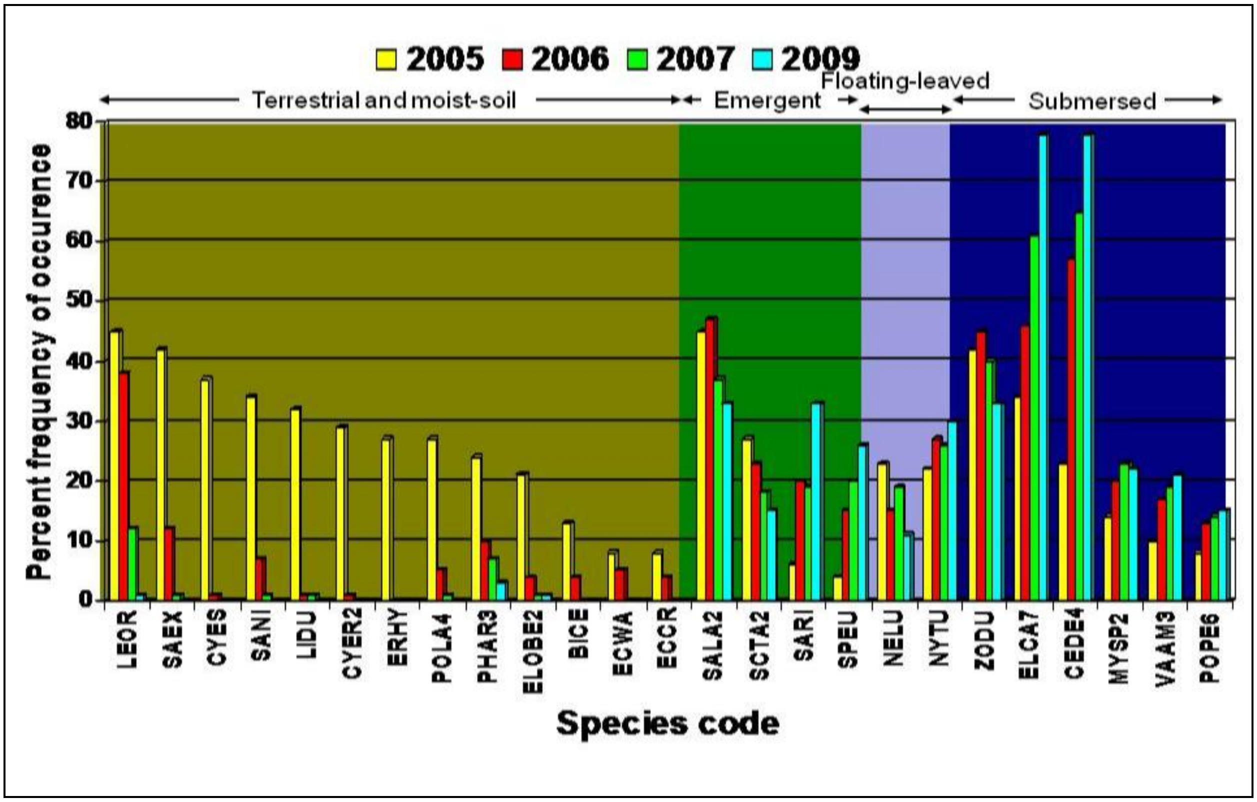


Figure 2. Frequency of occurrence of dominant terrestrial/moist-soil, emergent, floating-leaved, and submersed aquatic species in 2005 (yellow), 2006 (red), 2007 (green), and 2009 (cyan) found among Pool 5 sites that were exposed during the 2005 drawdown. Species codes are defined as follows :

LEOR	*Leersia oryzoides*	(rice cutgrass)
SAEX	*Salix exigua*	(sandbar willow)
CYES	*Cyperus esculentus*	(chufa flatsedge)
SANI	*Salix nigra*	(black willow)
LIDU	*Lindernia dubia*	(false pimpernel)
CYER2	*Cyperus erythrorhizos*	(redroot flatsedge)
ERHY	*Eragrostis hypnoides*	(teal lovegrass)
POLA4	*Polygonum lapathifolium*	(nodding smartweed)
PHAR3	*Phalaris arundinacea*	(reed canary grass)
ELOBE2	*Eleocharis obtusa*	(blunt spikerush)
BICE	*Bidens cernua*	(nodding beggartick)
ECWA	*Echinochloa Walteri*	(walter's millet)
ECCI	*Echinochloa crusgalli*	(barnyard grass)
SALA2	*Sagittaria latifola*	(common arrowhead)
SCTA2	*Schoenoplectus tabernaemontani*	(soft-stem bulrush
SARI	*Sagittaria rigida*	(sessilefruit arrowhead)
SPEU	*Sparganium eurycarpum*	(broad fruit bur-reed)
NELU	*Nelumbo lutea*	(American lotus)
NYTU	*Nymphaea odorata*	(white waterlily)
ZODU	*Heteranthera dubia*	(grassleaf mudplantain)
ELCA7	*Elodea Canadensis*	(Canada waterweed)
CEDE4	*Ceratophyllum demersum*	(coon's tail)
MYSP2	*Myriophyllum spicatum*	(Eurasian watermilfoil)
VAAM3	*Vallisneria Americana*	(wild celery)
POPE6	*Potamogeton pectinatus*	(sago pondweed)

Pool 6 Drawdown - Vegetation Response

Evaluation of Vegetation Response on Areas Exposed During the 2010 Drawdown of Navigation Pool 6, Upper Mississippi River

Kevin P. Kenow, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

During August and September 2010, scientists from the U.S. Geological Survey - Upper Midwest Environmental Sciences Center monitored the response of vegetation on substrates exposed during the 2010 summertime one-foot water level reduction (drawdown) of Pool 6 of the Upper Mississippi River.

A number of vegetation characteristics were monitored in the drawdown zone, including above ground biomass, species composition, frequency of occurrence, stem density, and cover class at randomly selected locations within areas delineated as exposed substrate during the drawdown that were not exposed under normal pool operations (Figure). General substrate class and evidence of herbivory (i.e., grazing by Canada geese [*Branta canadensis*] or muskrat [*Ondatra zibethicus*]) were also recorded for each site. Vegetation sampling was conducted between 18 August and 8 September 2010.

The extent of exposed substrates was based on a geographical information system (GIS) coverage generated from true color aerial photography acquired on 27 July 2010 (Lock and Dam 6 Discharge- 40,200 cubic feet per second (cfs), Lock and Dam 6. The drawdown was initiated on 18 June and a full 1-foot drawdown (at Lock and Dam 6) was achieved on about 01 July.

The drawdown initiated on 18 June was maintained through 26 August, when the Pool level was gradually raised to normal level by 3 September. An area of about 286 acres was identified as 'exposed' from the 27 July 2010 aerial photography, but extensive coverage of duckweed made interpretation difficult and some submersed aquatic beds were misclassified as exposed substrate. During sampling within the "exposed areas" only 46.5% of the sites fell on substrates exposed during the drawdown. Consequently, our best estimate of substrate exposed as a result

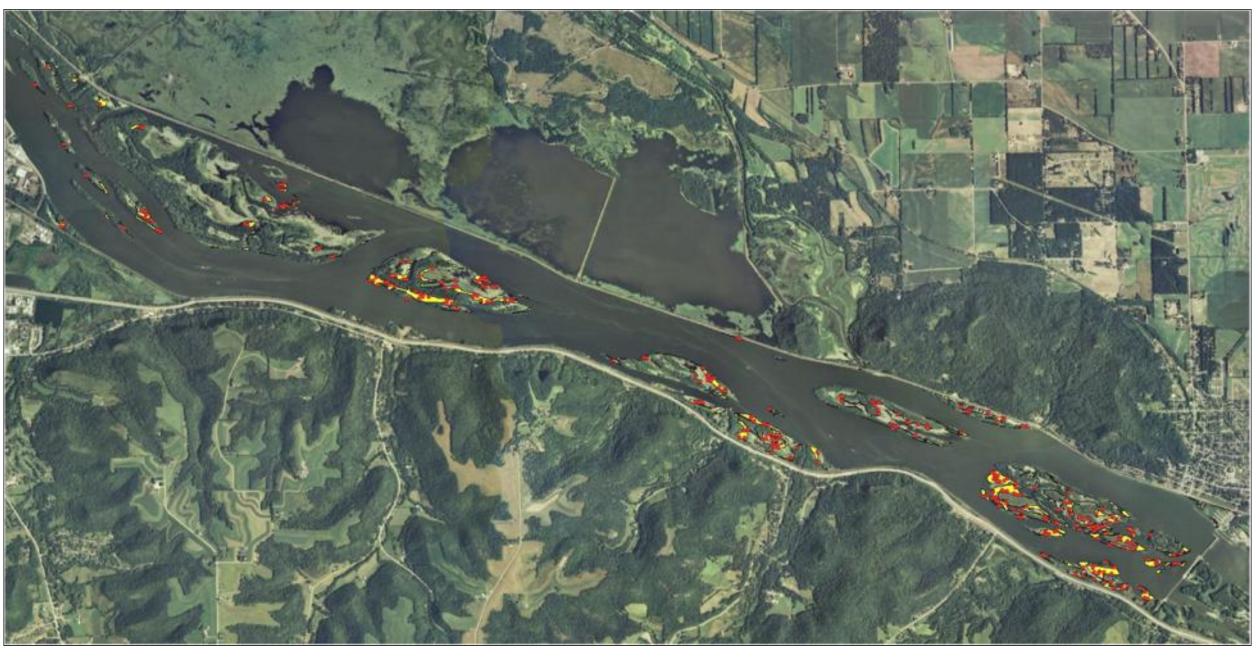


Figure . Location of sample sites (red dots) for evaluating vegetation response on substrates exposed (indicated in yellow) during the 2010 drawdown of Pool 6, Upper Mississippi River (random distribution based on exposed area depicted on 27 July 2010 photography).

of the drawdown is 133 acres (286 * 0.465=133) or 54 ha. Preferably, the photography would have been collected on about 01 July, but the U.S. Fish and Wildlife Service plane and pilot were not available for the photography mission until 27 July.

Data collected at 141 sample sites regarded to have been exposed during the drawdown was used in the subsequent analyses. The average length of exposure for the 141 sites was 22 days, and ranged from 1 to 66 days.

Vegetation Response on Exposed Substrates

Researchers identified about 66 plant species. The most frequently observed species were grassleaf mudplantain (*Heteranthera dubia*), Canada waterweed (*Elodea canadensis*), coon's tail (*Ceratophyllum demersum*), rice cutgrass *(Leersia oryzoides*), curly-leaved pondweed (*Potamogeton crispus*), reed canary grass (*Phalaris arundinaceae*), and white waterlily (*Nymphaea odorata*). Other common moist soil species included redroot flatsedge (*Cyperus erythrorhizos*), chufa flatsedge (*Cyperus esculentus*), and nodding smartweed (*Polygonum lapathifolium*). Emergent perennial species such as sessilefruit arrowhead (*Sagittaria rigida*), common arrowhead (*Sagittaria latifolia*), and broadfruit bur-reed (*Sparganium eurycarpum*) were less frequently observed.

Above Ground Biomass

Above-ground biomass of emergent perennial, floating-leaved aquatic, and moist-soil vegetation averaged 119.5 ± 13.4 g dry wt/m^2 (median = 47.4; range = 0 to 866.9 g/m^2) among the 141 sites used in the analysis.

- Above-ground biomass of submersed aquatic plants averaged 18.7 ± 5.1 g dry wt/m^2 (median = 0.4; range = 0 to 444.7 g/m^2).
- Broadfruit bur-reed (mean biomass = 23.4 g/m^2), rice cutgrass (16.0 g/m^2), chufa flatsedge (12.2 g/m^2), grassleaf mudplantain (9.6 g/m^2), and redroot flatsedge (9.6 g/m^2) dominated plant biomass across all quadrats.

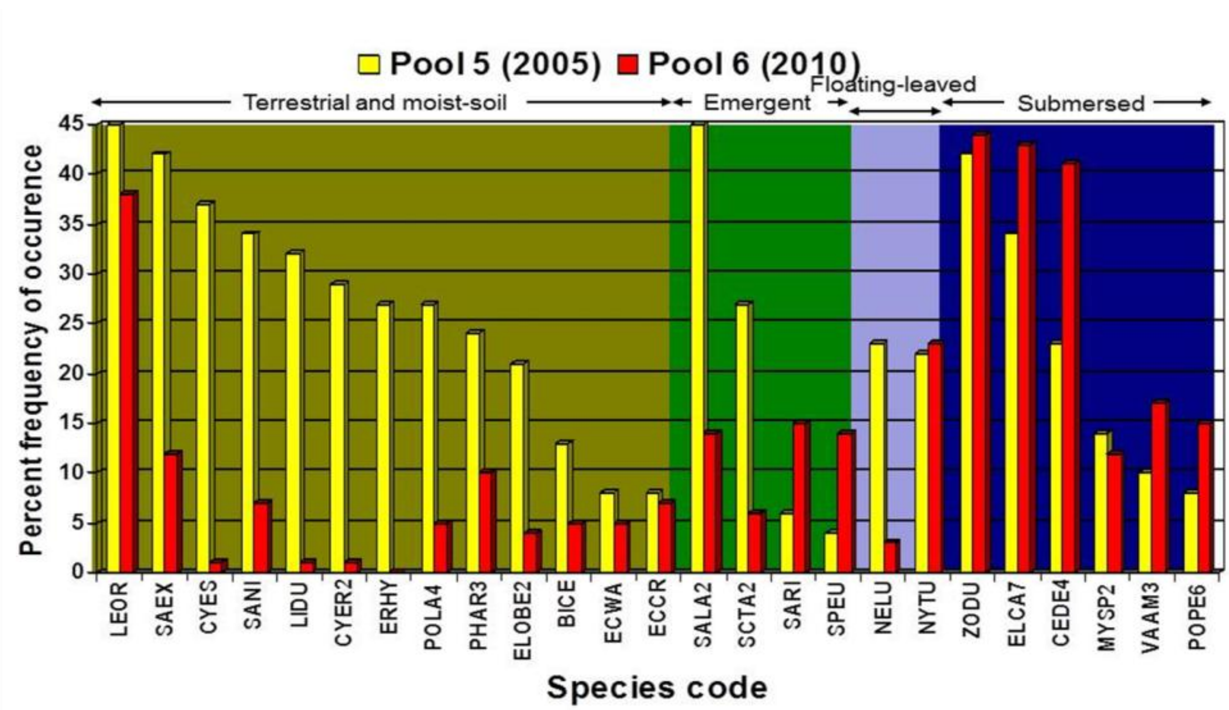


Figure 3. Frequency of occurrence of dominant terrestrial/moist-soil, emergent, floating-leaved, and submersed aquatic species in Pool 5 (2005; yellow) and Pool 6 (2010; red) found among sites that were exposed during the respective drawdowns. Species codes are defined in Figure) see pool 5 2009. USGS-UMESC

- Plant biomass was also assessed only among those quadrats that contained a given species to better illustrate potential productivity of individual species (eliminated samples in which species did not occur). The rank order in mean biomass among sites where a species occurred was broadfruit bur-reed (165.2 g/m^2), barnyard grass (*Echinochola crusgalli*; 92.4 g/m^2), pickerelweed (*Pontederia cordata*; 63.8 g/m^2), chufa flatsedge (57.3 g/m^2), redroot flatsedge (43.6 g/m^2), and rice cutgrass (42.7 g/m^2).
- Evidence of grazing was observed at 23 of the 141 sites (16%) included in the analysis. However, emergent and moist soil plant biomass did not differ significantly between grazed and ungrazed plots ($P > 0.12$).

Comparison with Pool 5

A comparison of frequency of occurrence of plant species observed during the Pool 6 drawdown to that occurring during the 2005 drawdown on Pool 5 indicate some notable differences. Moist soil species were not as prevalent, common arrowhead and soft-stem bulrush occurred less frequently, and submersed aquatic species were generally more widespread among Pool 6 sample sites compared to Pool 5 sites (Figure). We expect this pattern was related to the re-inundation of much of the exposed area of Pool 6 due to the bounce in the elevation (and river discharge) during mid-August. Several of the sites sampled were inundated at the time of inspection, and terrestrial/ moist soil plants that are intolerant to flooding (especially small plants) may not have persisted. Also, wave action and fish activity may have dislodged susceptible plants.

Conclusion

A number of desirable plant species were established on exposed substrates during the 2010 drawdown. Growth of broadfruit bur-reed, barnyard grass, chufa flatsedge, redroot flatsedge, and rice cutgrass was robust in some areas. These dominant moist soil and emergent species are recognized for their value as wildlife food and habitat structure for aquatic organisms.

Submersed Aquatic Vegetation Monitoring

Pool 8 Submersed Aquatic Vegetation Monitoring

Kevin Kenow, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

Baseline information was collected on more than 200 open water sites in 1999 and 2000 to determine where and how much submersed aquatic vegetation was present prior to the drawdown. This monitoring was continued through 2004. In general, submersed aquatic vegetation did not appear to be negatively effected by the drawdown. Submersed aquatic vegetation standing crop biomass was significantly lower in 2000 and 2001 (0 <20 g/m^2) from 1999 levels (35 g/m^2) and rebounded to 32 g/m^2 in 2002. By 2004, the average standing crop increased to 44 g/m^2.

Long Term Resource Monitoring Program- Submersed Aquatic Plant Trends 1998-2005

Heidi Langrehr,, *Wisconsin Department of Natural Resources*

Through the Long Term Resource Monitoring Program, personnel from the Wisconsin Department of Natural Resources and Iowa Department of Natural Resources have collected submersed macrophyte data from 1998 to 2005 in Navigation Pools 4, 8, and 13 (respectively), Upper Mississippi River.

In Pool 8, submersed macrophytes were recorded at 49% of the sites visited in 1998, 58% in 1999 and 48% in 2000. Since 2000, the percent of sites where submersed macrophytes were recorded has steadily increased to 71.4 % in 2006. The number of species recorded each year ranged from 14 to 16 species.

In comparison, submersed macrophytes were recorded at about 41% of the sites in Pool 13 from 1998 through 2003. The number of sites increased to 47% in 2004 and 61% in 2006. Twelve to 16 species were recorded each year. In Pool 4, submersed macrophytes were recorded at about 37.5% of the sites visited in 1998 through 2002.

(No data was available for 2003.) In 2004, the frequency was 31% and it steadily increased to 43.7% in 2006.

Islands built in 1998 and drawdowns conducted in 2001 and 2002 most likely contributed to increased water clarity and the increase in submersed macrophytes in Pool 8.

Additional macrophyte information and graphs can be viewed using the Upper Mississippi River Graphical Vegetation Database Browser located at: http://www.umesc.usgs.gov/data_library/vegetation/graphical/veg_front.html.

Modeling Submersed Aquatic Vegetation in the Upper Mississippi River

Yao Yin, Becky Kreiling -*U.S. Geological Survey -Upper Midwest Environmental Sciences Center*, and Heidi Langrehr, -W*isconsin Department of Natural Resources*, Megan Moore" *Minnesota Department of Natural Resources*

The Long Term Resource Monitoring Program (LTRMP) of the Upper Mississippi River System initiated a pool-scale, stratified random sampling protocol in 1998 to monitor aquatic plants. Since then the program has accumulated 12 annual increments of an unbroken string of data in Pools 4, 8 and 13. We are analyzing this data set to reveal and estimate the effects of recent adaptive management actions of island constructions (HREP) and water level reductions (Drawdown).

We developed a statistical model to predict probability of submersed aquatic vegetation (SAV) occurrence at individual sites based on a few site-specific and a few pool-wide variables. Vegetation data used for model development were LTRMP stratified random sampling data from lower Pool 4 (1998-2003), Pool 8 (1998-2000), and Pool 13 (1998-2003). We validated the model in several ways using the rest of the LTRMP dataset. The model met statistical criteria for goodness of model fit and withstood critical scrutiny based on our understanding of the river.

Our model revealed detectable effects of both HREP and Drawdown in Pool 8. After construction completion in 1998, the Stoddard HREP in Pool 8 demonstrated an immediate enhancement of 170 acres of SAV in 1999. Enhancement peaked in 2002 when approximately 370 acres of SAV were attributable to HREP. As SAV growth in Pool 8 trended up thereafter, the net effect decreased. By 2009, Stoddard HREP accounted for approximately 30 acres of SAV.

During the 2001 Drawdown (first year), Pool 8 had 240 acres loss of SAV due to dewatering. In 2002, the loss on dewatered sites was offset by gains in deep water regions and the pool as a whole had a net gain of approximately 1,300 acres. Approximately 1,200 acres of SAV in 2003 were attributable to the Drawdown. Our model revealed no significant drawdown enhancement in later years.

Pool 5 Submersed Aquatic Vegetation Monitoring

Kevin P. Kenow, James T. Rogala, and Larry R. Robinson, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

We anticipated that a drawdown would enhance conditions for submersed aquatic vegetation (SAV) growth on uncolonized substrates, due to an overall reduction in water depths that would allow sufficient light penetration to promote SAV germination and growth. However, short-term reduction of SAV was expected in areas that would be dewatered (i.e. SAV would not tolerate desiccation). Enhancing growth of SAV was not a primary goal of the drawdown, but we included SAV monitoring in this study for the purpose of obtaining a more comprehensive understanding of drawdown effects on vegetation.

Submersed aquatic vegetation response to the drawdown during the summer of 2005 was determined by comparing estimated frequency of occurrence through pool-wide random sampling during the period 1999 to 2005. Sampling surveys were conducted using the standard procedures (Yin et.al. 2000). The total number of sampling locations ranged from 145 to 400 sites per year during the period 1999 to 2005 . These data were stratified into four areas. However, not all areas were sampled all years. Data from 2002 were post-stratified into the selected strata.

Sampling surveys indicated an increase in SAV in Weaver Bottoms (a large backwater lake) during summer 2005 (Figure .) The increase observed in SAV was largely due to increases in coon's tail (*Ceratophyllum demersum*), Canada waterweed (*Elodea canadensis*), and grassleaf mudplantain (*Heteranthera dubia*). In contrast, the percent frequencies of SAV in 2005 in the other Pool 5 strata were not convincingly different than what was observed in previous years. However, the two other backwater strata (Lost Island Lake and Spring Lake) had higher occurrences of SAV prior to the drawdown, and the frequency of occurrence in 2005 was similar to that found in Weaver Bottoms. The remaining area that was monitored had comparable occurrence of SAV prior to and during the drawdown.

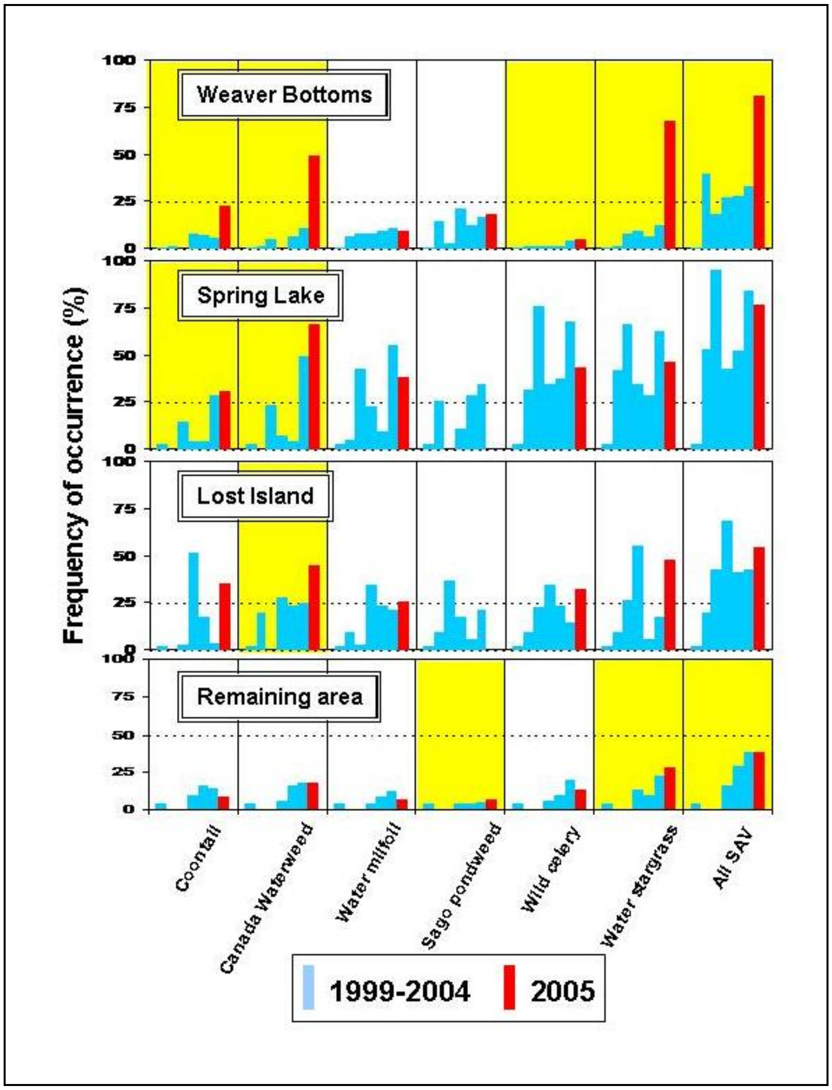


Figure . Frequency of occurrence for the six most common submersed aquatic species and all submersed aquatic species combined (SAV) found during the annual sampling between 1999 and 2004 (blue; 2003 not sampled) and during the 2005 drawdown (red) on Pool 5 of the Upper Mississippi River. Highlighted (in yellow) are species that had the greatest frequency of occurrence among years in the year 2005 for the respective strata. USGS-UMESC

It is difficult to attribute the observed change in the distribution and abundance of SAV directly to the drawdown. Reference information on the dynamics of SAV is available over the same period (1999-2005) for Pool 4 and Pool 8 as part of the standard monitoring under the Upper Mississippi River System Long Term Resource Monitoring Program.

While we observed increased distribution of SAV in Pool 5 (particularly in Weaver Bottoms) with drawdown, SAV was increasing on reference pools as well. (Figure .) Consequently, differences in observed SAV dynamics might be part of normal annual variability, or perhaps even a short term trend, as well as result of the drawdown. We can't attribute the increase in SAV completely to drawdown effects, although the drawdown probably contributed to some degree. Conservatively, we conclude at this point is that the drawdown did not negatively impact SAV.

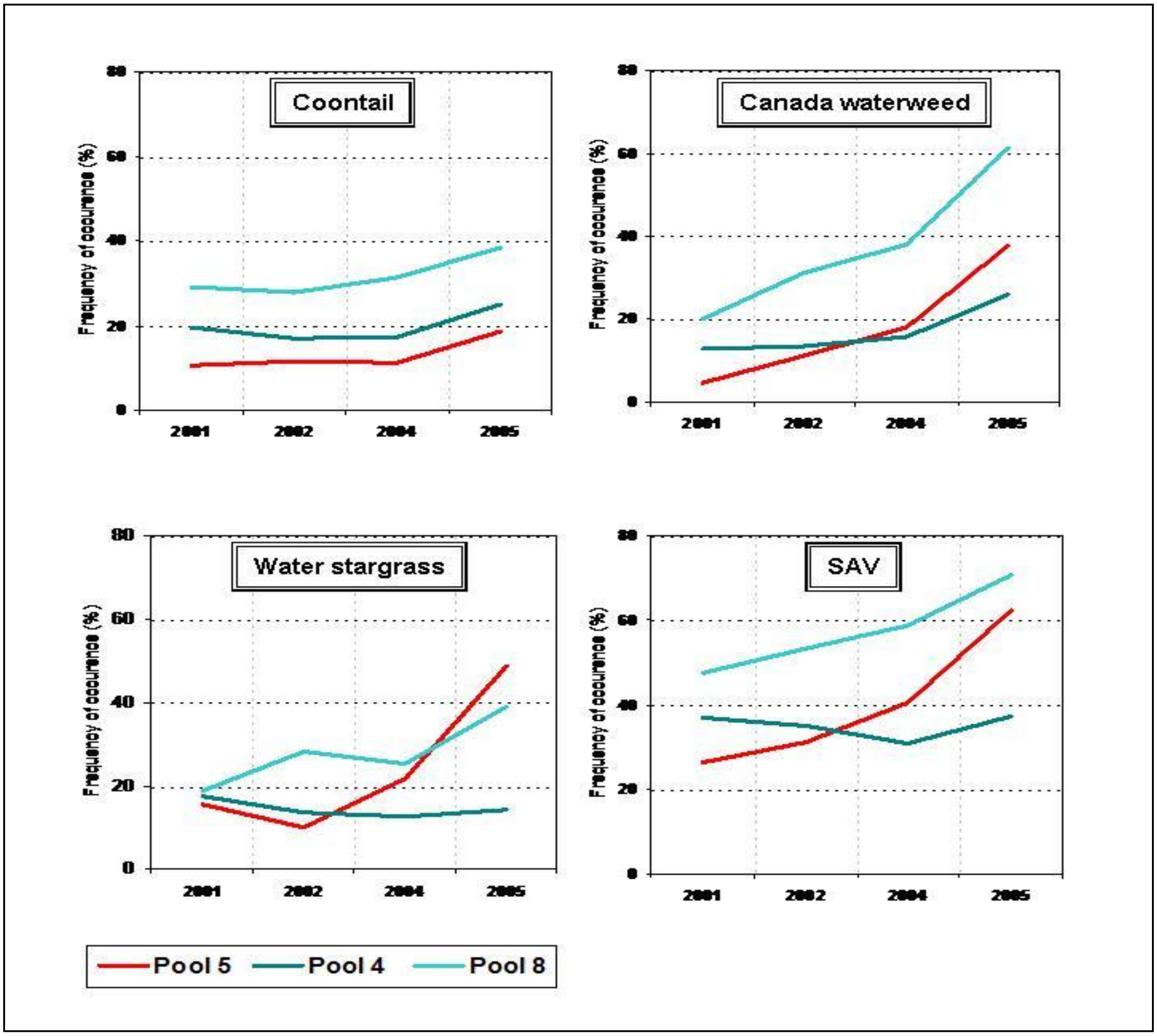


Figure 6. Comparison of percent frequency of occurrence by selected species and total submersed aquatic vegetation (SAV) in each year among Pools 4, 5 and 8. The drawdown occurred in Pool 5 in 2005.. USGS-UMESC

Fish

Prior to the drawdown it was anticipated that a drawdown could impact fisheries in a variety of ways. Possible negative impacts identified included:

- fish strandings,
- disruption of spawning by bluegills, largemouth bass, crappies, and other species that spawn during late spring and summer, recruitment of nest spawning species may be reduced during drawdown year,
- The drawdown could force many young of the year and smaller fish out of vegetated areas into open water making them more vulnerable to predation.
- Generally higher velocities during the drawdown would reduce the amount of suitable habitat for lenthic fishes, such as bluegills, largemouth bass, many minnow species, crappies, and yellow perch.

Positive impacts included:

- Backwater species such as bluegill and bass could benefit as improved vegetation and water clarity increase cover, food supply, and spawning habitat.
- Fish could rapidly recolonize the drawdown zone following reflooding. The standing vegetation should provide good cover for young of the year and small fish.
- Smaller macroinvertebrates and zooplankton thrive in the flooded vegetation, an effect that may last into the first part of the growing season in the year following the initial drawdown.
- Increased extent and density of emergent and submersed aquatic plants that may result from the drawdown could have a positive effect on fish in future years, by providing more cover, shelter from current, and a more abundant macroinvertebrate forage base.

To reduce the potential negative impacts to fish, the water level reduction in both pools 5 and 8 did not begin until mid June to protect spawning beds, and water levels were gradually lowered (.2 ft/day) to reduce the likelihood of fish strandings.

Fish Response Pool 8 Drawdown

Although fisheries impacts from a drawdown were expected to occur, monitoring was limited to surveillance for fish strandings and fish kills. Fish monitoring data from the Long Term Resource Monitoring Program (LTRMP) was assessed for the time period (1993-2004) for evidence of short term negative impacts. The LTRMP data for the time period 1997-2010 was utilized to evaluate any long-term effects in Pool 8. These results were compared to the long term results for the same time period for Pool 5 data.

Fish Strandings

The possibility existed that during a drawdown many small backwaters would become landlocked for a certain amount of time, some of which could dry up completely or become unsuitable for fish life. Backwater areas that could become isolated were incidentally monitored for dead and dying fish during the drawdown by the many field crews performing monitoring work in Pool 8.

No fish kills or strandings were reported in the backwaters, however one fish kill consisting of about 1000 bluegill in the 2-4 inch range, was reported in a pond connected to the Mississippi River by a ditch. The fish apparently were trapped in the pond as result of an artificial blockage to the culvert and died as the water levels receded during the drawdown. While the relatively quick lowering of water elevation from a near record spring flood to a full implemented drawdown may have contributed to this fish kill, the primary cause was the absence of an unobstructed escape route which left the fish vulnerable to entrapment and dewatering.

Long Term Resource Monitoring Program Fisheries Assessment

Andy Bartels-*Wisconsin Department of Natural Resources*

Because Pool 8 is a trend pool for the Long Term Resource Monitoring Program, data on fish abundance were available from 1993- 2004. The following evaluation of LTRMP data was conducted using the graphical fish browser available at: http://www.umesc.usgs.gov/data_library/fisheries/graphical/fish_front.html.

Fish species were selected to represent a variety of communities across different habitat types and were evaluated by comparing post drawdown catch rates in Pool 8 to pre- drawdown catch rates from 1993-2004 in order to detect evidence of short term negative impacts. Sampling methods selected included day electro-fishing, fyke netting, hoop netting and mini fyke netting, which were used for the periods of 01 August – 04 September and 15 September – 31 October for all years except 2003. (In 2003 sampling was conducted only by electro fishing during late September and October due to significant funding reductions.)

Species List by Community Group

Main Channel	Channel catfish *(Ictalurus punctatus),* Freshwater drum *(Aplodinotus grunniens),* Shorthead redhorse (*Moxostoma macrolepidotum),* Sauger *(Stizostedion canadense),* Walleye *Stizostedion vitreum)*
Backwater	Bluegill *(Lepomis macrochirus),* Yellow Perch *(Perca flavescens),* Black crappie (*Pomoxis nigromaculatus),* Largemouth Bass *(Micropterus salmoides)*
Forage Fish	Spotfin shiner (*Cyprinella spiloptera)* , Emerald shiner *(Notropis atherinoides)* , River shiner *(Notropis blennius)*
Exotic Species	Common Carp (*Cyprinus carpio)*

Community Response

The response to the drawdown by community group was as follows:

- Main Channel Group-no short term trends or differences in catch rates surrounding the drawdown were observed.
- Forage Fish Group- an increase in catch rates for day electro-fishing was observed in Pool 8 surrounding the drawdown.
- Backwater Group-some short term differences in catch rates for day electro-fishing existed, but they were in the observed variation or trend patterns outside the buffered drawdown period (e.g. bluegill, yellow perch, and black crappie.) There were increases in the catch rate for bluegill in mini fyke nets and largemouth bass in fyke nets.
- Exotic-an increase in catch rates for common carp in fyke nets was observed.

Overall, there were no negative short term trends or differences in catch rates that could be credited to the drawdown. An increase was observed in catch rates for the forage fish group surrounding the drawdown period which may warrant further investigation during a future drawdown.

Fish Response to the Pool 5 Drawdown

Dan Dieterman, Tim Schlagenhaft, *Minnesota Department of Natural Resources*

Similar to the Pool 8 Drawdown, monitoring for effects of the drawdown on fish was limited to surveillance for fish strandings and fish kills associated with the drawdown process. Fish monitoring data was available for Pool 5 because annual fish sampling has been conducted by the Minnesota Department of Natural Resources (MDNR) on Pools 3, 5, 5a, 6, 7, and 9 since 1993.

Fish Strandings

During the drawdown, backwater areas were periodically checked to document stranded fish or fish kills. No fish kills were documented during the 2005 drawdown, however dead fish were observed at a number of sites during the 2006 Pool 5 drawdown. The cause was most likely due to very low flows which occurred throughout the system combined with warm temperatures. Because of the low flows the drawdown in 2006 was ended prematurely and the pool was back to operation levels by 09 July 2006.

Fisheries Assessment

Shoreline seining (50 feet, ¼ inch mesh bag seine) for Young of Year (YOY) fish and forage species was conducted throughout Pool 5 in August and electrofishing (boat mounted electrofishing gear) for all sizes of sport-fish was conducted in late October and early November. The evaluation focused on bluegill and largemouth bass as these two species are backwater species that could benefit as improved vegetation and water clarity increase cover, food supply, and spawning habitat. These species could also be impacted negatively because of potential impacts from the drawdown on late spawning and reduced survival of young of the year during the drawdown.

Results:

Bluegill catch per hour from MDNR surveys showed increasing trends in most pools, including Pool 5, from 1997 to 2006, which indicates no short term negative effect from the drawdown. However in 2007 there was a large spike in bluegill abundance that was not reflected in the other pools sampled.

In Pool 5, seining results indicate a decreasing trend in bluegill YOY abundance from 2000- 2005 (Figure .) While the decrease in 2005 from 2004 numbers may imply there were potential impacts from the drawdown to that year class of bluegills (centrarchids), electrofishing sampling results from 2006 showed an increase in bluegill abundance similar to the other pools, indicating no detectable negative effect on the 2005 year class from the 2005 drawdown.

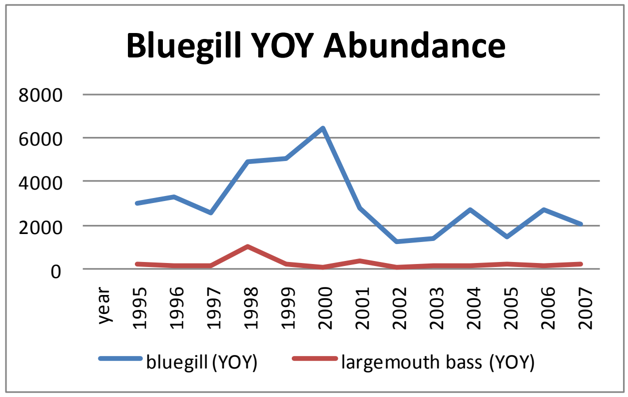


Figure . Pool 5 Seining summary for Young of Year (YOY) Bluegill and Large mouth bass. Unit of measurement = number / acre._ Bluegilll mean = 3066.4, Largemouth Bass mean = 276.7 MNDNR

Evaluation of Long Term Effects for Pools 5 and 8 Drawdowns

Electrofishing results indicate a very large increase in bluegill abundance two years post drawdown in Pool 5, a phenomena that also occurred two years after the drawdown in 2001 in LTRMP Pool 8 2003 electrofishing data in all strata (Figure .) While an increase in bluegill abundance was observed in upper Pool 9 during the 2003 peak in Pool 8, the increase was not of the same magnitude. This smaller increase most likely reflects the effect of natural environmental factors that can impact reproductive success such as timing of floods, aquatic vegetation and water quality. The large spike in bluegill abundance in 2007 that occurred in Pool 5 was not reflected in the other pools sampled. The large increase in abundance which occurred in both drawdown pools suggests the drawdown may have had a positive effect on habitat which was reflected by the bluegill abundance two years after the drawdown.

Conclusion

Impacts to fish can be difficult to assess because while there may be observable immediate impacts such as fish strandings, impacts to reproduction, whether negative or positive, may take several years of sampling before change can be documented and assessed. Even though there was a decrease in the bluegill YOY abundance in Pool 5 the year of the drawdown, there was no detectable effect from the drawdown on the 2005 year class by 2006. This data suggests that any negative impact on spawning success the year of the drawdown is outweighed by improved survival of the young of the year. The large increase in bluegill abundance which occurred in both pools two years post drawdown suggests the drawdown may have had a positive effect on habitat . This possibility warrants further investigation in future drawdowns.

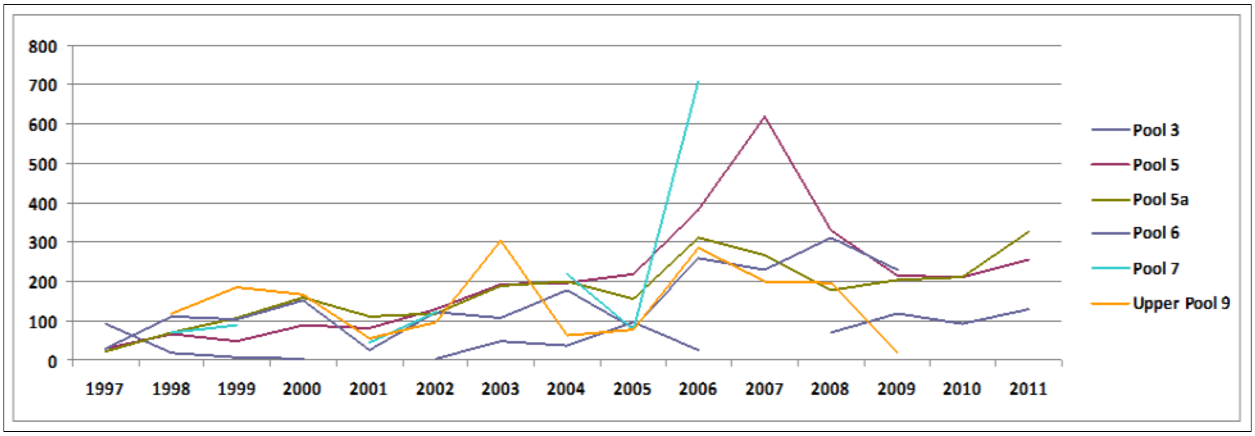


Figure A. Bluegill catch per hour sample from Minnesota DNR electrofishing surveys in Pools 3, 5, 5A, 6, 7 and upper Pool 9. In 2007 a spike occurred in bluegill abundance in Pool 5, two years post drawdown. (2005) This increase was not observed in the other pools sampled. Pools 4 and 8 were not included in the comparison because they are sampled slightly different as part of the LTRMP. See figure B for results from pools 4 and 8. Both figures show electrofishing catch per unit of effort over time. MNDNR

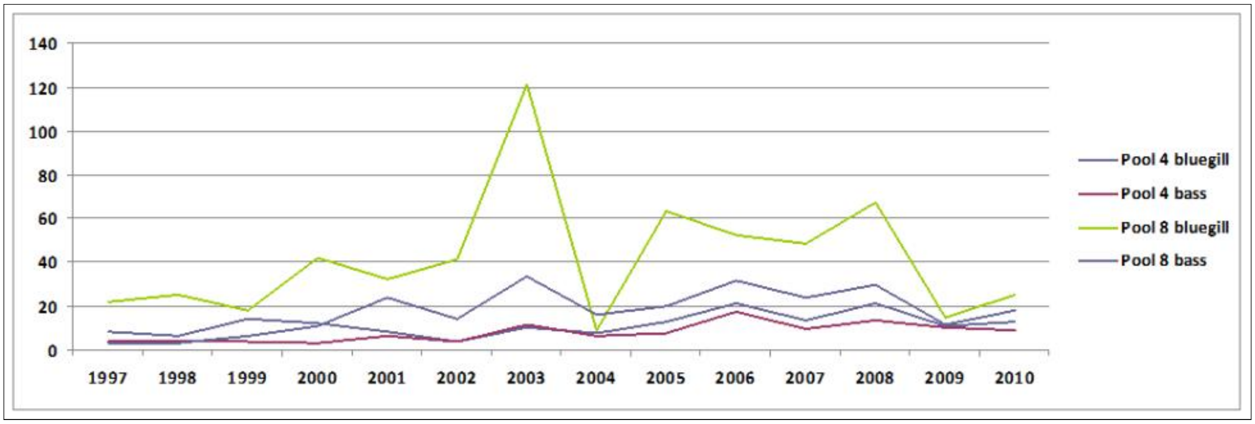


Figure B. Bluegill and largemouth bass catch per 15-minute sample from Long Term Resource Monitoring Program electrofishing surveys in Pool 4 and Pool 8 for all strata combined. In 2003 a spike occurred in bluegill abundance in Pool 8. A smaller increase also occurred in large mouth bass abundance in Pool 8 in 2003. This 2003 spike occurred two years after the first drawdown in Pool 8 in 2001. MNDNR

Freshwater Mussels

Pool 8 Drawdown

Gretchen Benjamin-*Wisconsin Department of Natural Resources*, Ken Lubinski-U.*S. Geological Survey-Upper Midwest Environmental Sciences Center*

No formal monitoring was planned to determine the effect of the drawdown on mussels because:

- The drawdown zone generally supports a limited number of mussels due to ice scouring of these shallow areas during the winter, a condition that makes it difficult for mussels to survive. This was also one of the reasons for the choice of the 1.5 –ft. drawdown level.

- A survey was conducted in 1999 of known mussel beds that might be impacted during a drawdown. The results of that survey also indicated limited numbers of mussels in the drawdown zone.

Volunteer Rescue Effort – July 2001

A volunteer rescue effort was organized by Mississippi River Revival to move stranded native mussels to deeper water as the water levels were down about 9-12 inches of the expected 18 inches. This timing was chosen to minimize excessive exposure of the mussels to the direct air, while also providing volunteers with the ability to move mussels in shallow water out to deeper water. The effort was concentrated in the lower portion of Pool 8 and along areas where mussel beds were thought to be present, similar to the pre monitoring effort described above. Volunteers, including U.S. Geological Survey biologists and Marian Havlik (Malacological Consultants), enumerated, sorted by species and moved over 5000 mussels to deeper water. During the survey more mussels were observed on the exposed sites than expected possibly due to the effects of the extended flood of 2001. The extended flood just before a drawdown may have put more mussels at risk because some mussels moved into shallow water during the flood. As a result of this monitoring questions arose for future drawdowns, including:

- How to minimize future mussel mortality during a drawdown?
- Can mussel risk to drawdown be anticipated?
- How fast do mussels colonize shallow water areas?

Pool 5 Drawdown

Based on observations from the Pool 8 drawdown, project planners concluded that a pool drawdown strands some mussels in the drawdown zone. Studies conducted in 2005 and 2006 were designed to evaluate the effects of the drawdown on native mussels in shallow water and to determine a pool wide population estimate.

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

Dave Heath, *Wisconsin Department of Natural Resources*, Mike Davis, *Minnesota Department of Natural Resources* and Dan Kelner, *U. S. Army Corps of Engineers, St. Paul District*

- Experimental plots were established in Pools 4 (control) and 5. Survival of marked mussels was compared for different water depths and bottom slopes. Unmarked mussels were also sampled along transects in dewatered areas of Pool 5. A pool-wide visual survey was also conducted to observe stranding and mortality. The study found that:
- Survival of marked mussels was 72% in Pool 5 compared to 100% in Pool 4 (control).
- Survival of marked mussels in Pool 5 was 98% for those placed in deep water (three feet) and 30% in shallow water (1-foot).
- Survival of marked mussels in Pool 5 was three times higher for those placed in sloping shoreline areas than on shallow flats.
- Survival varied by species and was 1.6 times higher for Ambleminae (three ridge) than Lampsilinae (plain pocketbook, fat mucket). Some mussels have the ability to close their valves tightly sealing in water whereas other species have a noticeable gape, which exposes tissues to water loss.
- Mortality of mussels in transects ranged from zero to three per square meter.
- Mussels exposed or partially exposed to the air were subject to lethal temperatures for an extended time period. This suggests that high temperatures contributed to observed mussel mortality.

Based on transect data, a large number of mussels may have been killed by the drawdown. However, the total number of mussels that died in Pool 5 as a result of the drawdown could not be estimated due to the limited scope of the study. The effect of mussel mortality from the 2005 drawdown on the Pool 5 mussel population could not be determined as a pool-wide population estimate of mussels was not available.

Recommendations for Future Work

Long-term monitoring of Pool 5 mussel populations would be beneficial to provide information on other effects of the drawdown on mussels. Very little is known about the effects of water elevation fluctuations in riverine systems on mussels. For example, a second year drawdown in 2006 was expected to cause less mortality to mussels than in 2005 because mussels were not likely to re-colonize the dewatered area in the short time frame between draw-downs. Potential positive and negative effects of water level drawdowns on mussels warrant further investigation.

Some possible positive effects identified include:

- improvement of water quality,
- improvement of filterable food quality and quantity,
- cleaning of substrates of fine material through scouring,
- gradation riverbed material to form and maintain gravel bar habitat,
- improvement of overall productivity,
- improvement of conditions for host fish species.,
- concentration of mussels into dense beds and fish into narrower channels where they are more likely to be infected with glochidia,
- increased recruitment into channel habitat due to fish host concentration,
- reducing mussel recruitment/colonization in areas that are vulnerable to winterkill and/or low water events.

Some potential negative effects could include:

- reduction of long-term recruitment via stranding and loss of reproductive age adults,
- elimination of shallow habitats, which are less affected by zebra mussels,
- destabilization of substrates, it is widely recognized that substrate instability is inimical to mussels.,
- increasing vulnerability to predators,
- other unknown changes to habitat.

Conclusions from this study were used to implement measures to minimize the effects of the planned second year drawdown on the mussel population. Some of the methods or techniques discussed to minimize the effects in-clude:

- A focused mussel rescue in locations containing rarer species, high population densities, or high species richness of stranded mussels. *On 21 June 2006, during the second planned drawdown, a mussel rescue fo-cused on areas of high quality mussel habitat was conducted. One particularly rich area for mussels was at RM 740, south of Minneiska, as over 4000 mussels were rescued at this location.*
- Reducing the rate and initiating the drawdown slightly earlier. An earlier starting date may help to reduce mussel colonization of the areas dewatered in 2005.
- Reducing the depth of the drawdown as there was a significant relationship between water depth and survival.

Population Estimates of Native Freshwater Mussels in Pool 5 of the Upper Mississippi River, 2006

Mike Davis - *Minnesota Department of Natural Resources, Lake City, Minnesota*

A post-drawdown study was conducted in 2006 to estimate the total number of mussels in Pool 5, and the 95% confidence interval for that estimate. Managers were hoping to obtain a relative error of less than 20%. A second objective was to estimate total live mussels within the area expected to be dewatered in 2006 in order to estimate the proportion of the total population that could be impacted by dewatering. The study was the first on the UMR to evaluate techniques for assessing mussel abundance on a pool scale.

A systematic grid with a random starting point was used to estimate the total number of mussels in the shallow water zone (area dewatered in 2005 plus all depths 0-0.5m) and the deeper zone (> 0.5m) deep under normal pool elevation.

Results:

- A total of 669 live mussels were collected from 716 samples representing 16 species. Five common species accounted for 90% of the mussels.
- The study estimated 189 million mussels in Pool 5 (95% CI range = 152 - 221million), with a relative error of less than 20%. Of this total, 2.3 million mussels were estimated in the shallow dewatered zone (95% CI range = 1.0 - 3.6 million).
- Recruitment of native mussels was evident; abundant species were represented by individuals of age one or less and every species collected in the sampling was represented by at least one individual less than 5 years of age.
- Zebra mussels were found on 66% of live mussels, but only 9% had more than 10 zebra mussels attached.

Conclusion:

It appears systematic sampling at the pool scale was an efficient way to obtain pool-wide mussel population data, as the sample size was more than adequate to determine population size within our objective of less than 20% error. These data are also useful for identifying high-density sites to focus additional research on in the future.

The estimate in the shallow zone had a relative error much greater than 20%. No mussels were collected in 2006 at depths less than 10 inches (0.25-meter) possibly due to a combination of increased aquatic vegetation in the shallow dewatered zone and mortality of mussels during the 2005 drawdown. Subsequent population estimates in Mississippi River pools similarly depth stratified would help to quantify this- if sampling is completed prior to any water-level drawdown effect on the shallow water strata.

High Density Sites Identified for Future Research

Mussel distribution in shallow water may be limited by winter ice cover and freezing, summer anoxia associated with still water, summer heat exhaustion, high BOD organic substrates, and species preferences and tolerances for these and other conditions. Areas that are shallow but do not freeze during winter due to constant flows across them often support mussels. Typically these areas are sandy or gravelly because currents carry the silt fraction away during most discharges. Some of these areas can support large populations of mussels.

- Most of Weaver Bottoms' shallow zone fails to support mussels, especially the area around the Whitewater River deltas (both the present one and older ones) and the former Zumbro River and East Indian Creek deltas in the NW and N of Weaver Bottoms where shallow water is pretty much devoid of mussels.
- There are large sand deposits on the East side of Weaver Bottoms that do support mussels where the main channel flow enters and deposits bed load. This is true also where side channels enter the impounded area and drop their bed load and flow continues over them year round reducing the amount of ice that forms most winters. Sand bars in the upper end of the pool, especially tailwaters area, fit this pattern too and support mussels in shallow water.

Pool 6 Drawdown

Population Estimates of Native Freshwater Mussels in Pool 6 of the Upper Mississippi River, 2007

Mike Davis, *Minnesota Department of Natural Resources*

The survey objective was to estimate total live mussels within Pool 6 of the Mississippi River in order to estimate the proportion of the total population that could be impacted by dewatering. As in the 2006 Pool 5 survey, a systematic grid with a random start was used to estimate the total number of mussels. Samples were collected between June 18 and June 29, 2007 from a total of 534 quadrats at 267 of the 304-targeted sites within the Pool 6 aquatic area.

Results

- In total, 380 live mussels representing 16 species were collected from 534 quadrats. Five common species accounted for 83% of the mussels. Three state listed mussel species were collected live; *Pleurobema sintoxia* – Threatened in MN, *Ligumia recta* – Special Concern in MN, and *Obovaria olivaria* – Special Concern in MN

- The study estimated 60,530,422 mussels in Pool 6 (95% CI range = 45,551,530 – 75,509,313).

- Zebra mussels, D*riesenia polymorpha*, were present in 20 of the 534 samples. Zebra mussels were not abundant or even common during the time this survey was conducted and so did not appear to be a present threat to the native mussel fauna. However, later in the season a large recruitment event was being reported by river observers for this species.

- Mussel presence by primary substrate type differed. While sand substrate was the most frequent primary type reported, quadrats with clay and silt primary substrate types had greater maximum mussel numbers in them than sand or gravel.

- Mussel recruitment in Pool 6 varied by species. While individuals ten or more years old accounted for 30% of all mussels, age one individuals (23%) represented the largest single year class in Pool 6.

Shallow Water Surveys of Native Freshwater Mussels in Pool 6 of the Upper Mississippi River: Population Estimates and Sampling Design Evaluation

James T. Rogala and Teresa J. Newton *U.S. Geological Survey, Upper Midwest Environmental Sciences Center*

Managers concerned with effects on mussels in the dewatered areas of Pool 6 planned for an assessment similar to that done in Pool 5 in 2006. Given that the systematic design did not produce acceptable estimates in the dewatered area during the 2006 Pool 5 survey, a different design was tested in Pool 6 in 2007. Due to the low density of mussels in the shallow water areas (i.e., areas less than 0.5 m at low river discharge), a complex sampling design was implemented that incorporates a rapid assessment of mussel density in the shallow water zone.

A one-stage cluster double sampling design was selected for surveying mussel populations in shallow areas. The clusters are transects extending out from the shoreline to a depth of 0.5 meters. The double sampling included semi-quantitative sampling at the surface for all sampling locations, and collecting a quantitative excavated sample at a subset of locations to determine detection probabilities (i.e., a ration estimator). There were a total of 128 quantitative quadrats and 517 semi-quantitative quadrats sampled along 96 transects. Total population size can be estimated several ways from these data:

- First, a simple inflation estimate can be obtained from the 128 quadrats that were excavated.

- A second method of estimating total population size uses a single ratio estimator for the semi-quantitative data from 517 quadrats.

- A third method of estimating total population size uses species-specific ratio estimators for each species, and then sums the totals across species for an overall population estimate.

Shallow Water Population Estimates

Shallow water estimates were attained using all the data from the transects that met the depth criteria of less than 0.5 m. (Table A.)

- Simple inflation estimate of 1,110, 617 mussels, with a 95% confidence interval of 412,003 to 1,809,230.
- A single ratio estimate of 1,414,968 mussels, with a 95% confidence interval of 351,244 to 3,193,474.
- A species-specific ratio estimate of 1,266,650 mussels, with a 95% confidence interval of 50,607 to 4,579,433.

Dewatered Zone Population Estimates

The shallow water area sampled in Pool 6 was much larger (about 121 ha) than the area expected to be drawdown (about 69 ha). Population size in the expected dewatered areas was calculated using similar methods, but only uses the subset of data attained in the predicted dewatered area. Using quantitative data, the total population size of the dewatered area was estimated to be 333,278 mussels. (Table B.)

- Simple inflation estimate of 333, 278 mussels, with a 95% confidence interval of 130,717 to 535,839 .
- A single ratio estimate of 204,351 mussels, with a 95% confidence interval of 46,095 to 474,103.
- A species-specific ratio estimate of 312,359 mussels, with a 95% confidence interval of 101 to 1,420,619.

Conclusion

Using species-specific ratio estimators would be the most appropriate method if the number of mussels collected was large enough to generate good ratio estimators, but we collected few individuals of most species. We therefore consider the estimates from the quantitative data (termed "simple inflation estimates') to be the best estimates from this survey. The density of mussels in the study area was 1.17 mussels/m², as compared to a density of 0.30 mussels/m² in the dewatered zone. This disparity probably reflects a simple depth relation, with more mussels in deeper areas. The other potential reason for the lower density in the dewatered area is the effect of location in the pool, but the mussel densities in the upper portion of Pool 6, which would not be dewatered as much, were not observed to be higher. The fraction of the total mussel population that might be affected during dewatering was one of the important estimates desired from this study.

A population estimate of 61 million (95% CI = 45 to 76 million) was obtained from the pool-wide survey of Pool 6 (Mike Davis, MN Department of Natural Resources, published data). Using the total population estimates in dewatered area from the quantitative sampling (total = 333,278; 95% upper confidence limit = 535,839), the percent of mussels that were in the predicted dewatered area was about 0.55% (95% upper confidence limit of 1.19%).

Mortality, Movement, and Behavior of Native Mussels during a Planned Water Level Drawdown in Pool 6 of the Upper Mississippi River

Teresa Newton, Steve Zigler, Robert Kennedy, Ashley Hunt, Patty Ries, U.*S.Geological Survey -Upper Midwest Environmental Sciences Center*

Systematic, pool-wide surveys of mussels in Pools 5, 6, and 18 have showed that there are considerable mussel populations in these pools including, a small, but significant fraction that resides in shallow water- the area poten-

Table A. Total population estimates within the 121-ha study area (and associated 95% confidence intervals) obtained for methods without ratio estimators (simple inflation) and with ratio estimators (double sampling).

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Segment of population	Simple inflation estimate			Estimated with ratio estimators*		
	Total population	Confidence interval lower	Confidence interval upper	Total population	Confidence interval lower	Confidence interval upper
all mussels	**1,110,617**	412,003	1,809,230	**1,414,968**	351,244	3,193,474
mussels ≥25mm	**617,911**	19,547	1,216,275	**671,101**	204,082	1,387,956
mussels ≥50mm	**442,223**	0	892,456	**266,457**	91,707	483,321
Toxolasma parvus	**258,195**	77,553	438,837	**527,384**	12	2,236,189
Pyganodon grandis	**296,780**	0	605,200	**150,892**	25,148	369,982
Leptodea fragilis	**64,493**	5,174	123,813	**29,545**	1	165,189
Amblema plicata	**164,346**	0	370,066	**310,141**	12,840	919,977
Fusconaia flava	**112,529**	0	236,722	**117,886**	12,596	324,314
Lampsilis cardium	**41,698**	0	86,129	**16,841**	3	57,047
Utterbackia imbecillis	**32,024**	0	83,707	**84,415**	4	304,449
Obliquaria reflexa	**92,848**	0	236,740	**16,883**	1	88,175
Potamilus ohiensis	**12,454**	0	37,489	**8,442**	1	63,607
Lampsilis siliquoidea	**35,249**	0	105,447	**4,221**	1	50,504

*For totals across species, an overall ratio estimator was used.

awdown. This research aims to estimate the fraction of mussels that are able to move, either vertically or horizon-

Table . Total population estimates within the 69-ha dewatered area (and associated 99% confidence intervals) obtained for methods without ratio estimators (simple inflation of quantitative data) and with ratio estimators (double sampling).

Segment of population	Simple inflation estimate			Estimated with ratio estimators*		
	Total population	Confidence interval lower	Confidence interval upper	Total population	Confidence interval lower	Confidence interval upper
all mussels	**333,278**	130,717	535,839	**204,351**	46,095	474,103
mussels ≥25mm	**109,781**	12,959	206,603	**91,348**	36,572	146,124
mussels ≥50mm	**60,069**	4	134,030	**28,107**	5,314	50,900
Toxolasma parvus	**128,837**	3,818	253,856	**257,692**	6	1,231,508
Pyganodon grandis	**16,260**	2	41,402	**25,279**	90	72,598
Leptodea fragilis	**42,670**	4	90,837	**0**	0	0
Amblema plicata	**41,012**	1	122,030	**0**	0	0
Fusconaia flava	**16,053**	2	40,815	**11,755**	2	44,186
Lampsilis cardium	**22,267**	3	56,534	**0**	0	0
Utterbackia imbecillis	**21,749**	2	65,841	**11,755**	2	44,694
Obliquaria reflexa	**11,599**	1	35,012	**0**	0	0
Potamilus ohiensis	**32,831**	1	98,081	**0**	0	0
Lampsilis siliquoidea	**0**	0	0	**5,878**	1	27,633

*For totals across species, an overall ratio estimator was used.

tally, to avoid short-term mortality during a water level drawdown.

Movement behavior of mussels is likely to be species-specific. A study of mortality of native mussels associated with water level drawdown in Pool 5 of the UMR indicated that Amblemini mussels had higher survival rates than Lampsilini mussels (WDNR et al. 2006). Thus, we hypothesized that Lampsilini mussels would be more likely to respond to water level drawdown by moving horizontally across the sediment surface to reach deep water, whereas Amblemini mussels would be more likely to burrow vertically into sediments.

Movement of mussels may also be influenced by physicochemical variables including discharge, water temperature, day length, water level, low dissolved oxygen concentrations in deeper sediment and perhaps by sediment temperatures. Slope of the sediment surface may also be important in predicting survival of mussels as water levels recede during a drawdown. Survival of mussels on sloped sites during a 2005 drawdown of a reach of the UMR appeared to be greater than on un-sloped sites (WDNR et al.2006). Highly sloped surfaces might cue directional movement and provide easier access to deeper water than un-sloped surfaces.

A mussel tagging and telemetry experiment using a Before-After-Control-Impact (BACI) design was selected to characterize the effects of water level drawdown on the mortality, movement, and behavior of a common Lampsilini species, *Lampsilis cardium*, and a common Amblemini species, *Amblema plicata*, in Pool 6 of the UMR during 2009 and 2010. Researchers attached PIT tags to the mussels' shells that allowed them to track individual mussels in 12 study plots, including control areas unaffected by the draw-down, and areas likely to be dewatered. The research plots were located in areas with high slope and low slope areas. The positions of the mussels were located weekly from June through November 2009 (non-drawdown year) and from June through September 2010 (drawdown year). The study was the first to use PIT tags on mussels in a large river.

PIT Tag Success

- We developed methods of rapidly applying PIT tags and buoyant line markers to mussels. Tag loss due to glue failure was negligible (<1%) over the 2 year study (Figure .)
- In preliminary experiments, unmarked, buried mussels in a sand substrate using the PIT tag reader and antenna indicated that mussels could typically be relocated within about 30 cm and to a depth of at least 20 cm. Most mussels detected with PIT tag equipment were subsequently observed with a viewing bucket, which allowed very precise location.
- We tagged and followed ~460 mussels, which were relocated about weekly during June to November 2009 and during June to September 2010. The total number of observations was >6,100.
- Recovery of tagged mussels was excellent and ranged from 88 to 100% in both years.

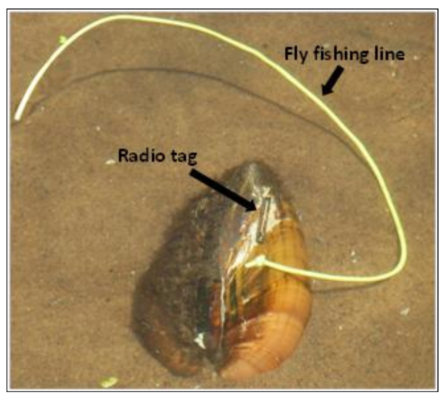

Figure . Mussel (*Lampsilis cardium*) showing the radio tag and buoyant line marker (fly fishing line) . The fly fishing line is used to measure how deep the mussel is burrowed into the substrate.. USGS-UMESC

Mussel Movement and Mortality

- Estimated mortality was 5% during the non-drawdown year (2009) and 11% during the drawdown year (2010) Mortality estimates in *L. cardium* were ~2 times higher than those in *A. plicata* (2% in *A.plicata* and 7% in *L. cardium* in 2009; 7% in *A. plicata* and 15% in *L. cardium* in 2010). In both years, about 18% of the mussels were completely buried in river sediments. However, during 2009 (non-drawdown year), most of the buried mussels were *L. cardium* and in 2010, most of the 11 buried mussels were *A. plicata* This is consistent with the hypothesis that *L. cardium* would move horizontally and follow the receding water, whereas *A. plicata* would burrow vertically.
- Background net movement of marked mussels, estimated from reference sites in 2009 and 2010, averaged

3.4 ± 0.2 m (1 SEM) and ranged from 2.1-3.7 m in *A. plicata* and from 3.2-5.1 m in *L. cardium.*

- Net movement of tagged mussels at treatment sites averaged 5.2 ± 0.4 m and was similar between species. Thus, overall mussel movement was ~1.5 times higher at the treatment sites than the reference sites in 2010.

- The mean weekly movement of mussels ranged from 0-15 m/wk and was similar between species, but varied between lower and higher slope sites. For example, movement ranged from 0-12 m at the lower slope sites and 0-5 m at the higher slope sites in 2009. In 2010, mussels moved more at the treatment sites (0-15 m/wk) than at the reference sites (0-4 m/wk) and the magnitude of this effect was generally greater for *L. cardium* .

- The timing of mussel movement was coincident with the initiation of the water level drawdown. Thus, the rate of mean weekly movement was significantly correlated with the change in water elevation in 2010 but not in 2009.

- All mussels generally moved about perpendicular to shore (mean angle of movement 100.9 ± 2.7°) into deeper water regardless of year, treatment, or slope.

Results from this study can be used by resource managers to better evaluate the effects of water level management on native mussel populations.

Mississippi River Pool 6 Drawdown – Survival Rates of Lampsiline and Amblemine Mussels Confined to Dewatered Areas – 2010

Dan Kelner, *St. Paul District-U.S. Army Corps of Engineers*, Mike Davis, *Minnesota Department of Natural Resources*

The study objective was to obtain periodic non-predatory mortality estimates of Lampsiline spp. (pocketbook, fat mucket) and *Amblemine pilicata* (three ridge) exposed in dewatered areas during the 2010 water level drawdown of Upper Mississippi River Navigation Pool 6.

Prior to the start of the drawdown five marked mussels of each species were placed in predator proof plastic corrals located on randomly selected sites located in < 1 ft. water depth under normal pool elevation in lower Pool 6. Twelve control corrals were placed in 3-5 ft water depth. Corral checks to assess the status and determine mortality were conducted on three different dates – July 12, 27, August 26.

Results

- Both species of mussels were found buried 37-39 % of the time during the final check on 26 August. Mortality of buried *Amblema plicata* was less than mussels located at or on the surface of the substrate. A similar number of Lampsiline mussels were burrowed in but none survived regardless of position.

- Although mortality increased with length of exposure, more Amblemine mussels survived in the shady sites than those exposed to more sunlight. Lampsiline mortality was relatively unaffected by sunny or shady locations.

As might be expected, burrowing into the substrate and being in the shade increased survival of *Amblema plicata*, but apparently afforded no apparent survival advantage to the Lampsiline species in this experiment despite similar burrowing behavior. Without the ability to move to deeper water these animals perished. Aestivation by sealing in moisture and avoiding temperature extremes brought on by exposure to direct sunlight is probably impossible for many Lampsilines due to shell morphology but was still only a marginally effective survival strategy for *Amblema plicata*. Without the ability to move to deeper water most mussels perished while those positioned in deeper water during the time of this study (reference groups) enjoyed 98% survival among those recovered.

Shorebird Response

While the Mississippi River is not a major migration corridor for shorebirds, drawdowns expose substrates and create shallow water areas that serve to attract hundreds of migrating shorebirds. Shorebirds using the interior migration corridor of North America tend to be opportunistic when it comes to stopover sites rather than showing a preference to a particular wetland. Therefore habitats created during a drawdown will still be used even if the habitat is not available on a regular basis. Fall shorebird migration typically occurs between mid July and late September in this area coinciding with the approximate times of the scheduled drawdown.(Upper Mississippi Valley/Great Lakes Regional Shorebird Conservation Plan.)

Mississippi River Pool 8 Drawdowns- 2001-2002, Shorebird Survey Results

Lara Hill, Amy Papenfuss *U.S. Fish and Wildlife Service,* Ruth Nissen, *Wisconsin Department of Natural Resources,* Ric Zarwell, Fred Lesher, Matthew Paulson

A weekly shorebird survey, was conducted in lower Pool 8 to determine the migratory shorebird use of new habitats created during the drawdown. Survey periods were 11 June to 26 September in 2001 and 23 May to 03 September 2002. A weekly shorebird survey was also conducted in Pool 7 in 2001 for comparative purposes. The results for Pool 8 monitoring were:

2001 Drawdown

- Twenty-three species of shorebirds and 1,255 shorebirds were observed during the surveys.
- Due to reduced flow in the river, the target level drawdown of 1.5-foot was achieved for only 6 weeks, from 10 July through 14 August. During the six surveys which occurred during the drawdown period, 921 (73%) of the 1,255 total individual shorebirds were observed and the average number of species observed was 8.3.
- The other nine surveys contributed only (27%) of the total shorebird observations, and the average number of species observed was 4.8.
- The primary peak of shorebird observations occurred on 24 and 31 July with a second smaller peak on 11 and 20 September even though no drawdown was in effect at that time.
- The most numerous shorebird observations were of spotted sandpipers (*Actitis macularia*), a local breeder, with a peak number of 246 observed on 24 July. Pectoral sandpipers (*Calidris melanotos*) were second with 233 observations. Pectoral sandpipers had a peak in late July followed by a second influx in September. Least sandpipers (*Calidris minutilla*) were third with 92 observations on 31 July.

2002 Drawdown

The target level drawdown of 1.5-foot was reached on 03 July and was maintained in the lower part of the pool until 16 September when refilling of the pool was begun as scheduled.

- The number of shorebirds observed during weekly monitoring surveys in Pool 8 nearly doubled from the 2001 season. Over 2,250 shorebirds of 22 different species were observed during 13 surveys compared to the 1,255 shorebirds recorded in 2001.
- The primary peak in shorebird observations occurred during the surveys of 19 and 27 August, with a smaller peak 17 July. No surveys were conducted after 03 September.

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- The most frequently observed shorebird was spotted sandpiper with 531 observations. The number of observations more than doubled from 2001, and were clustered around the surveys of 02 and 23 July. Least sandpipers were the second most frequent with 303 birds observed on the survey of 27 August. Third was lesser yellowlegs (*Tringa flavipes*) with 267 observations, 200 of which were during surveys on 19 and 27 August.

The majority of the increase over 2001 survey results was due to the number of shorebirds observed from 19 August to 03 September, a time frame when there was no drawdown in the lower part of the pool in 2001 (Figure.) . During these three surveys 1,402 shorebirds were observed which is more than the total number of shorebirds (1255) observed in 2001.

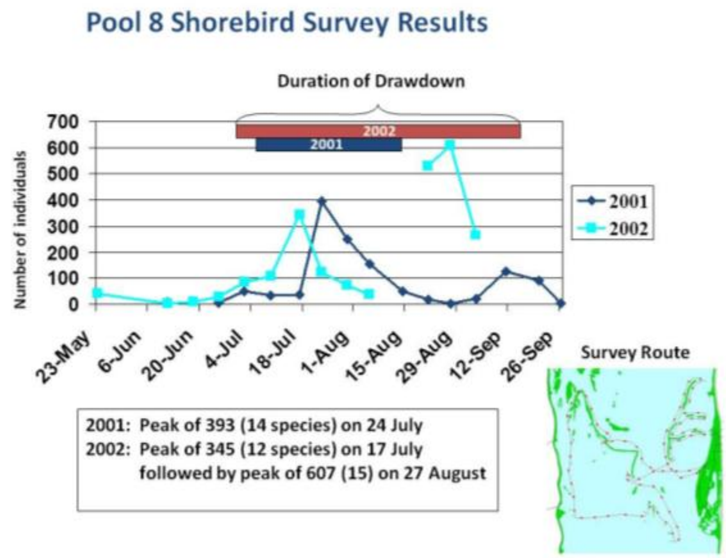


Figure . Pool 8 shorebird surveys results. The routes were adjusted to include areas used by shorebirds. In 2002 no survey was conducted 12 August, 2002. During the last three surveys in 2002 more shorebirds were tallied than were observed in all of 2001.USGS-UMESC.

This data indicates the importance of maintaining the drawdown through August if feasible. The peaks of shorebirds in mid September in 2001 also suggest a drawdown maintained the full scheduled time period will provide habitat for later migrating shorebirds

Historical Data

No data exists for shorebird use of Pool 8 under normal pool operation, but historical data was available for Pool 7. Shorebird surveys were conducted in Pool 7 from 1979-1983 Unpublished data, Fred Lesher.) The results of the Pool 7 surveys in 2001 were similar to the historical data. A much lower average number of shorebirds were observed in Pool 7 for both the historical data and 2001 when compared to Pool 8 results for 2001 and 2002 (Figure .)

Even though there are no other surveys in Pool 8 for comparison, the data suggests that the water level reduction in Pool 8 created important feeding habitat for migrating shorebirds as indicated by the number of shorebirds and the number of different species observed.

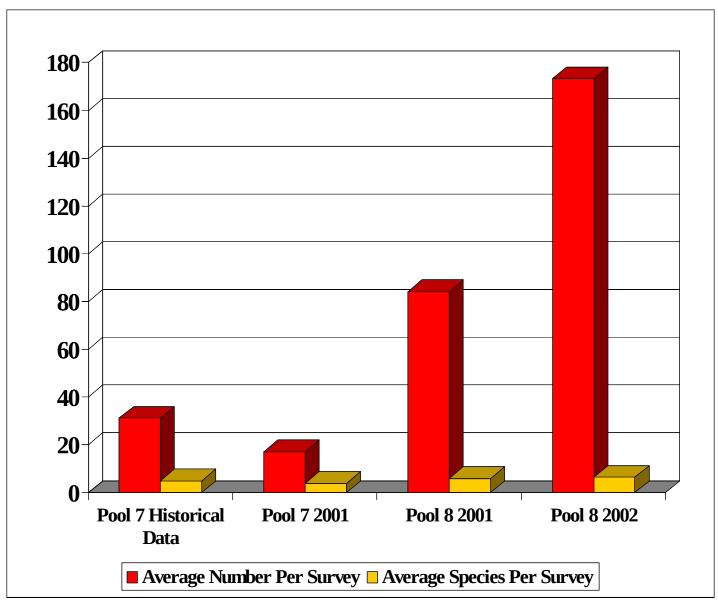


Figure . Comparison of average shorebird numbers and average species observed between Pools 7 and 8.

Conclusion

Monitoring in Pool 8 in 2001 and 2002 suggests that the temporary feeding areas created by the drawdown were utilized by migrating shorebirds. The difference in numbers between 2001 and 2002 (80% more) indicates the importance of maintaining a drawdown into late August and September if feasible to provide habitat for the late surge of migrating shorebirds which occurs from mid August to mid September.

Pool 5 Drawdown Shorebird Monitoring Results

Lisa Reid, *U.S. Fish and Wildlife Service-Upper Mississippi River National Wildlife and Fish Refuge*

Surveys were conducted by the U.S. Fish and Wildlife Service during the Pool 5 drawdowns in 2005 and 2006 to determine shorebird use of the exposed flats and shallow water areas. In 2005, five surveys were conducted (approximately every three weeks) from 23 June to 29 September. Similarly, five surveys were conducted from 28 June to 26 September in 2006. The survey route was adjusted slightly as the drawdown progressed to focus on accessible areas with exposed mud or sand flats. (Figure .) Spring Lake was initially included, but the habitat restoration work which included island building and dredging, made it difficult to access that area.

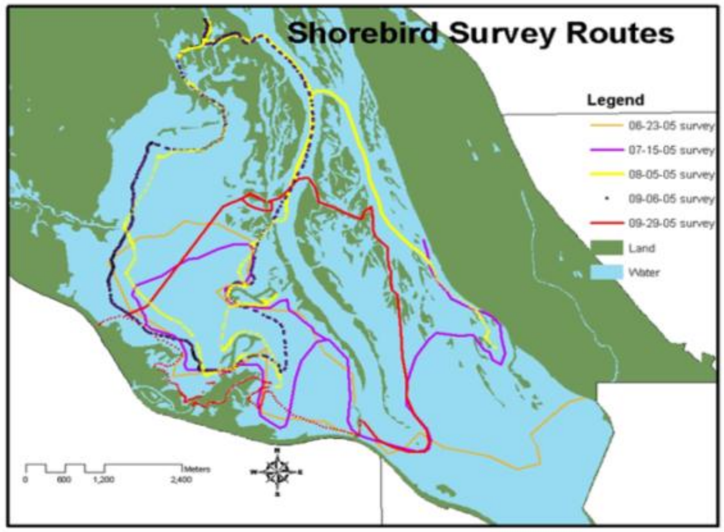


Figure . The Pool 5 shorebird survey routes were adjusted as the drawdown progressed to focus on accessible areas with exposed substrate. USFWS

The procedure used to survey shorebirds during the Pool 8 drawdown was followed with two exceptions:

- The survey was not conducted weekly due to limited staff time.
- Different boats were used than those used for the Pool 8 surveys. Two different boats were used in Pool 8- a 16-foot flat bottom boat and later a Go- Devil when water levels dropped. Pool 5 surveys were conducted with a Go-Devil except , an airboat was used for two surveys (15 July and 29 September) on an experimental basis due to an inability to get close enough to the exposed flats using the Go- Devil. The airboat provided a better estimate of the number of shorebirds present even if the species could not be identified. Consequently, an airboat was used for all surveys in 2006 to get a more accurate total of shorebird numbers and survey more of the area in a shorter time.

Results

2005

- A total of 83 shorebirds were observed during five surveys consisting of four identified species and 14 birds of an unknown species. The peak occurred during the 05 August survey but was comprised mainly of killdeer and spotted sandpipers, known local breeders. Six semipalmated sandpipers were observed on 05 August and 13 yellowlegs (lesser and greater) were observed on 29 September.
- From late July and through September low river flows caused a shift in pool operation which exposed an additional 1,000 acres in the middle and upper end of Pool 5 for the remainder of the drawdown period but reflooded areas that had been exposed in the lower portion of the pool. This change was beneficial for shorebirds as the vegetation growth on many of the mudflats in the lower portion of the pool prevented use by shorebirds. The newly exposed areas maintained feeding areas for shorebirds in the middle portion of the pool.

While the number of shorebirds observed during the surveys was limited, anecdotal observations obtained during aquatic vegetation and invertebrate sampling in Pool 5 in 2005 using the airboat indicated shorebird use was more extensive than detected through the shorebird surveys. Flocks of 50-100 unidentified shorebirds were observed in the distance as were small flocks of 10-20 yellowlegs after mid July. In addition, approximately 200 shorebirds were observed feeding in some of the last remaining flats in the Whitewater River Delta on 26 September. Observations indicate that in the Weaver Bottoms area and near Buffalo City total numbers of shorebirds may have peaked at between 300 and 1000 birds at any one time during peak migration.

2006

The drawdown scheduled for 2006 was begun on 12 June, and the target drawdown depth was reached on 26 June. Due to low discharge on the Mississippi River and the inability to maintain adequate depth for commercial navigation the drawdown was discontinued and the pool was back to operation levels by 09 July. The duration of the drawdown was only 27 days from initiation to the return to normal operation level on 9 July.

- A total of 227 shorebirds were observed consisting of seven species, including two American avocets and 55 birds of an unknown species.
- The peak (83 birds) occurred during the 28 July survey and was comprised mainly of spotted sandpipers, similarly to the 2005 survey. The peak count in 2006 was equal to the total count in 2005.

Historical Data

Shorebird surveys were conducted two to three times over the course of the summers in 1986 -1990, both killdeer (*Charadrius vociferous*) and spotted sandpipers were noted. The surveys that did not occur during migration saw 1-6 shorebirds and those taking place during migration noted 3-66 birds. The greatest number, 62 semipalmated sandpipers *(Calidris pusilla*), was recorded on 02 June during the spring migration.

Conclusion

Monitoring suggests that temporary feeding areas created by the drawdown were quickly found by locally breeding shorebirds. Although the surveys did not detect a significant increase in migrating shorebirds this is probably due to both the lack of a weekly survey and an inability to get close enough to the exposed flats using the Go- Devil in 2005 and the premature end of the drawdown in 2006 in late July. Fall shorebird migration typically occurs between mid July and late September in this area.

Waterfowl Response

Drawdowns have been an important tool of wildlife managers for many years to restore marsh vegetation, particularly emergent aquatic plants, and to manage annual moist soil plants to improve food resources for waterfowl. The drawdowns of Pool 8 and Pool 5 were therefore expected to have a beneficial effect for waterfowl and other wetland wildlife.

Waterfowl Response to Pool 8 Drawdowns on the Upper Mississippi River

Ruth Nissen, *Wisconsin Department of Natural Resources,* Lisa Reid, *U.S Fish and Wildlife Service-Upper Mississippi River National Wildlife and Fish Refuge,*

The presence of dabbling ducks, Canada geese (*Branta Canadensis*) and tundra swans (*Cynus columbianus columbianus)* was used as an indicator to evaluate the effects of the drawdown on aquatic emergent plants, as they utilize this vegetation type for both food and cover during migration. Swan use especially can be an indicator of the effect of the drawdowns as they feed primarily on the tubers of arrowhead during their migration stopover on the Upper Mississippi River. Research suggests 52% of cygnets and about 25% of the Eastern Population of tundra swans used the Upper Mississippi River during autumn migration. (Thorson et al. 2002). Research results of 39 satellite- tracked tundra swans banded on the wintering area indicated 43% of the marked birds used the Upper

Mississippi during fall migration for 33.6 days (Wilkins et al. 2010,) Increased Eastern Population (EP) tundra swan use of the Upper Mississippi River (Thorson et al. 2002) and the Great Lakes (Petrie et al. 2002) make protection of these important migration areas critical to the continued health of the Eastern Population.

Diving ducks or divers generally use the deeper and more open portion of the pools for both feeding and loafing during fall migration; hence they would be less affected by the drawdown.

Aerial Surveys

Monitoring the effects of the drawdowns on waterfowl relied primarily on the results of the weekly aerial waterfowl survey conducted in Pools 4 through 13 by the U.S. Fish and Wildlife Service and the Wisconsin Department of Natural Resources. Waterfowl surveyed include tundra swans, Canada geese, and 18 species of ducks. Birds are counted out from the aircraft to a distance of about 1/8 mile on established flight lines; hence, these counts do not provide a total count of birds using a pool but instead provide an index to the number of birds using the area. Weekly flights generally begin during the last week of September and end the week after waterfowl hunting season closes in Minnesota and Wisconsin, usually in late November or early December unless the river freezes first. Not all pools may be counted each week due to weather or other flight delays.

Waterfowl Use Days

The extent of waterfowl occurrence is described in terms of waterfowl use days, a number calculated from aerial survey counts. Use days account for variability issues inherent to these surveys (see above). In general, a use day(s) is defined as: One bird on the river for one day equals one use day. Use days are calculated by averaging the number of birds counted on two consecutive flights and multiplying by the days between flights. (If 5000 birds were counted on one flight and 15,000 birds were counted on the next flight ten days later; use days would equal 100,000.)

Evaluation of Waterfowl Response

Because drawdowns are frequently used to manage annual moist soil plants to improve food resources for waterfowl, particularly dabblers, aerial waterfowl survey data as well as ground level surveys and observations were used to evaluate waterfowl response to this aspect of the drawdowns.

Moist Soil Response

The initial plant community which developed during the first year of the drawdown contained a mix of annual (moist soil plants) and perennial emergent and aquatic species. Seed production in 2001 was dominated by annual plants including: rice cut-grass (51% of total production), chufa flatsedge (13%), barnyard grass (13%), and nodding smartweed (11%) (Kenow et al.). These moist soil plants, are well known as a food resource for waterfowl (Cottam 1939, Martin and Uhler 1939, Bellrose and Anderson 1943, Weller 1978, Fredrickson and Reid 1988).

Waterfowl aerial surveys do not begin on

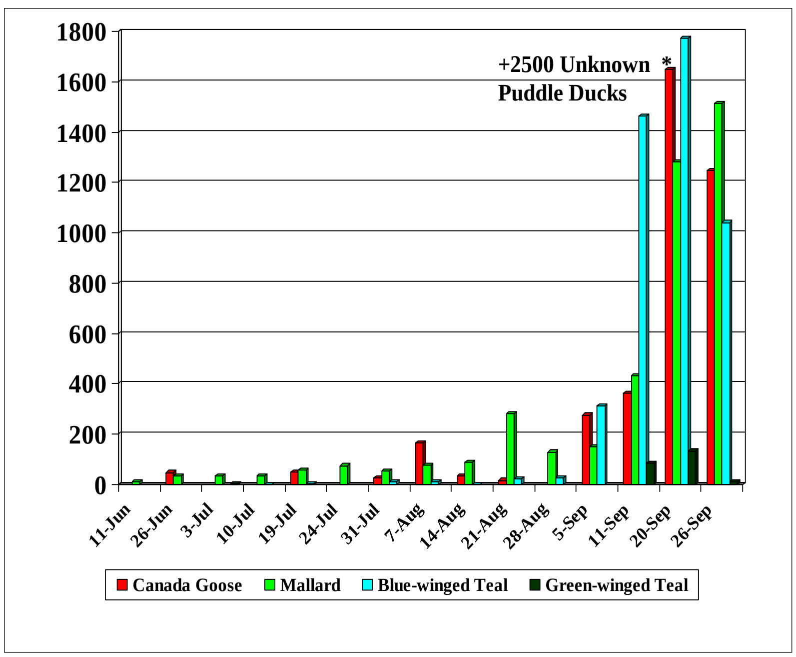


Figure . The number of waterfowl counted during the shorebird surveys in lower Pool 8 increased in late August and through September 2001. Note: the count on 20 September does not include 2500 unidentified dabbling ducks. USFWS the Upper Mississippi River until late September. No formal ground surveys were conducted during August and early September but waterfowl use was recorded during the weekly shorebird surveys of lower Pool 8 in 2001. Shorebird use decreased and waterfowl use increased as the habitat changed from open mudflats in July to flooded annual moist soil plants by mid September (Hill et al.) (Figure).

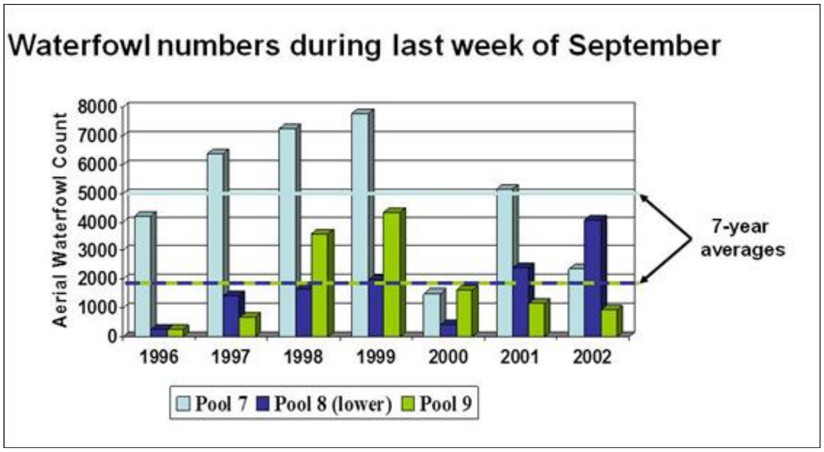


Figure . The numbers of birds counted in Pool 8 during the late September survey in 2001 and 2002 showed a distinctly different pattern in comparison to Pool 7 and Pool 9 data. Pool 8 numbers in 2001 and 2002 exceeded the 7 year average for Pools 8 and 9. USGS-UMESC

Waterfowl observations were also recorded by river managers monitoring the effects and progress of the drawdown in 2001. Large flocks consisting of 1000-2000 blue wing teal, in addition to Canada geese and coots were documented using the flooded vegetated flats below Boomerang Island, and in the Wisconsin Islands Closed Area. (Nissen unpublished data.)

The results of the late September waterfowl aerial survey for Pools 7, 8 and 9 suggest waterfowl were responding to the availability of food resources in Pool 8 in 2001 and 2002. (Figure)

Dabbling Ducks, Tundra Swans and Diving Ducks

Waterfowl use days for dabbling ducks, tundra swans and diving ducks were compared between Pool 8, and Pools 7 and 9. In recent years, these three pools and Pool 13 have provided the main waterfowl use areas on the Upper Mississippi River National Wildlife and Fish Refuge. The use days for Pool 8 were also analyzed for potential changes by dabbling ducks and tundra swans within the pool.

Dabbling ducks

Changes Between Pools

With two exceptions, year-to-year increases and declines in use days have followed similar trends in Pools 7, 8, and 9 between 1997and 2006 (Figure 7.) The change in dabbling duck use days in 2002 suggests dabbling duck feeding patterns appear to have shifted from other pools that year, primarily Pool 7, to Pool 8 most likely due to improving habitat conditions. However, the data also suggests that habitat conditions improved in Pool 9 as well.

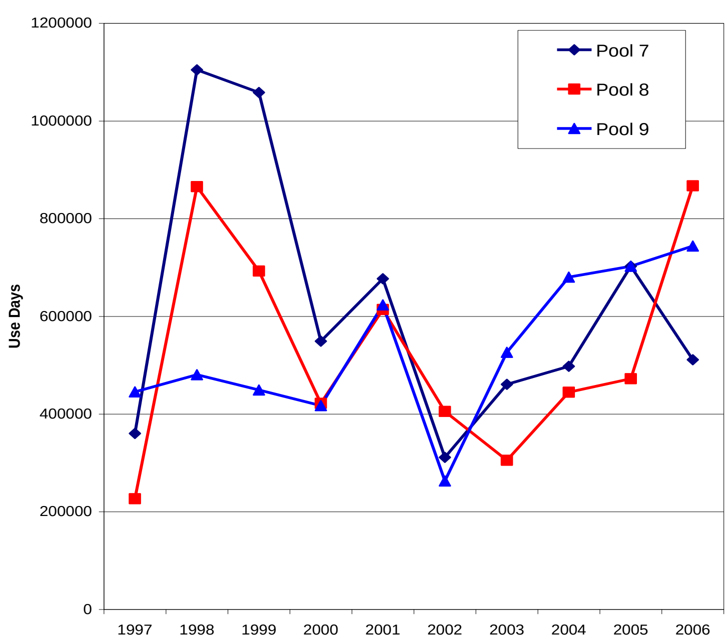


Figure 7. Dabbling duck use days followed similar trends in Pools 7, 8 and 9 between 1997 and 2006. WIDNR

Changes Within Pool 8

The response of dabbling ducks to the change in vegetation which resulted from the draw-down is best observed on a localized level.

The Goose Island No Hunting Zone, which covers 876 acres in the mid pool area of Pool 8, has historically provided the majority of dabbling duck use days in Pool 8. In contrast, the Wisconsin Islands Closed Area (6,461 acres), also closed to waterfowl hunting and located in the lower portion of the pool, has not supported large numbers of dabbling ducks.

The exposed substrates in the Wisconsin Islands Closed Area which includes the Raft Channel area supported extensive flats of moist soil plants in 2001. By 2002 the vegetation had changed to predominately perennial emergents, After 2001, there was a shift of dabbling duck use within Pool 8 to the Wisconsin Islands Closed Area, as reflected by the steady increase in the percentage of use days in the Wisconsin Islands Closed Area and corresponding decrease in the Goose Island No Hunting Zone compared with the total pool.

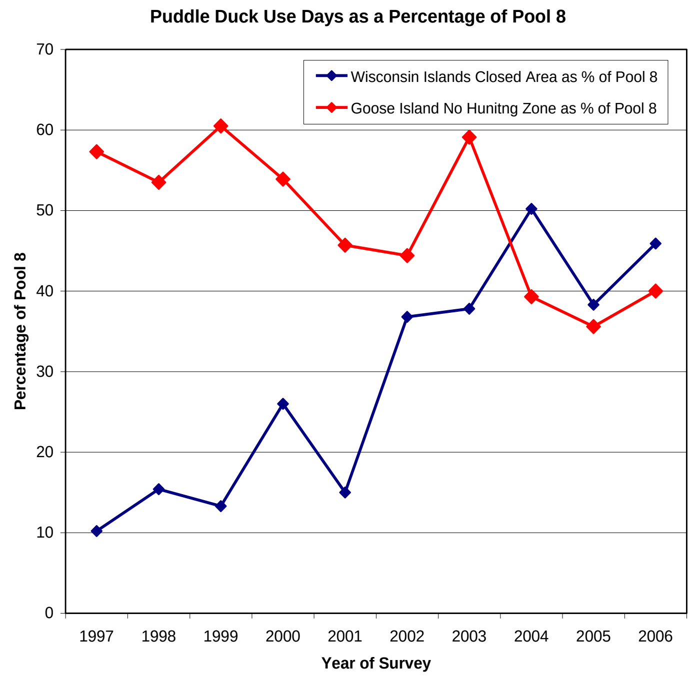


Figure 8. Dabbling duck use days as a percentage of Pool 8 for Wisconsin Islands Closed Area compared to Goose Island No Hunting Zone. By 2004 the number of puddle duck use days recorded in the Wisconsin Islands Closed Area exceeded those in the Goose Island No Hunting Zone. WIDNR

By 2004, the number of dabbling duck use days recorded in the Wisconsin Islands Closed Area exceeded those in the Goose Island No Hunting Zone (Figure 8.)

Tundra Swans

Between Pools

Because Pool 8 has provided the most tundra swan use days on the Refuge each year from 1997-2009 with the exception of 2005, it is difficult to detect changes due to the effects of the drawdown. (Figure 9.)

Changes Within Pool 8

Prior to the drawdowns of 2001 and 2002 swans congregated in several places in Pool 8 including Wisconsin Islands Closed Area, Goose Island No Hunting Zone, and the lower Pool 8 area open to hunting.

Tundra swans quickly responded to the development of arrowhead beds in the

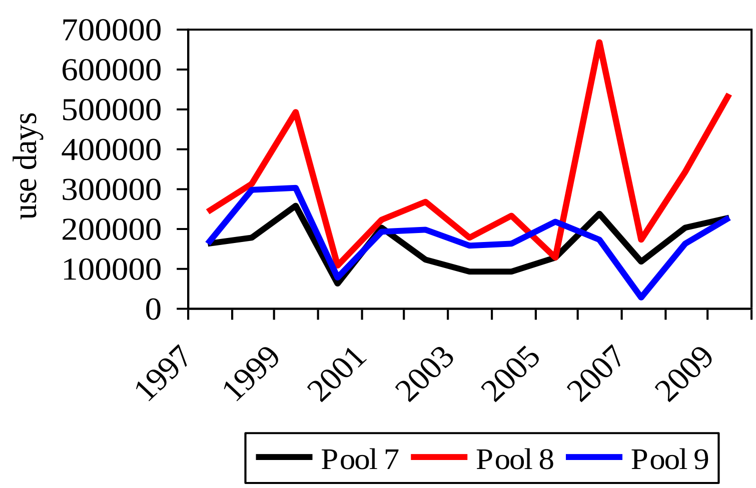


Figure 9. Tundra swan use days for Pools 7, 8 and 9. Pool 8 provided the most use days from 1997-2006 with the exception of 2005. WIDNR

Wisconsin Islands Closed Area which resulted from the drawdowns as exhibited by the shift in swan use within Pool 8 after 2001 to the Wisconsin Islands Closed Area (Figure 10.)

This 6,461 acre closed area provided the most swan use days on the entire refuge from 2002 through 2006 with the exception of 2005 when Pool 9 had the most. This trend culminated in 2006 when the Wisconsin Islands Closed Area had 50% of the total swan use days on the entire Refuge. In 2006 the peak count in the Wisconsin Island Closed Area was 31,560 swans, Pool 8 Open was 175 and Goose Island No Hunting Zone was 645. This data suggests the drawdown effect on the expansion and development of arrowhead beds in the WICA has been sustainable for at least 7 years post drawdown.

Diving Ducks

Diving duck use days on Pool 8 decreased in 2000, and continued the downward trend during the years of the drawdowns in 2001 and 2002. Use days increased in 2003 and every year thereafter. In contrast the submersed aquatic vegetation (SAV) standing crop biomass in Pool 8 dropped in 2000 from 1999 levels and then tended to increase through 2004. Wild celery biomass also increased in a rather consistent pattern during 2000 to 2004. These positive changes in SAV biomass during the drawdown years while canvasback use days decreased indicate that other variables affect the number of diving duck use days besides the abundance of SAV. Likewise the increase in diving duck use days on Pool 8 since 2002 is probably the result of several variables including the increase in the abundance of submersed aquatic vegetation, especially wild celery.

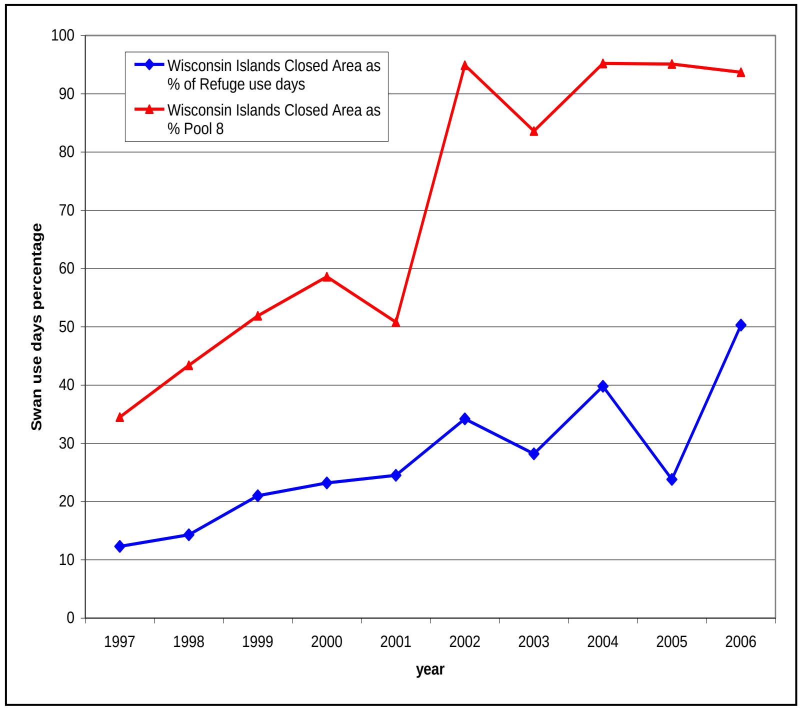


Figure 10. Tundra swan use days in the Wisconsin Islands Closed Area as a percentage of Pool 8 use days and as a percentage of the Upper Mississippi River National Wildlife and Fish Refuge which is comprised of Pools 4-13. Swan use within Pool 8 shifted after 2001 to the Wisconsin Islands Closed Area. WDNR

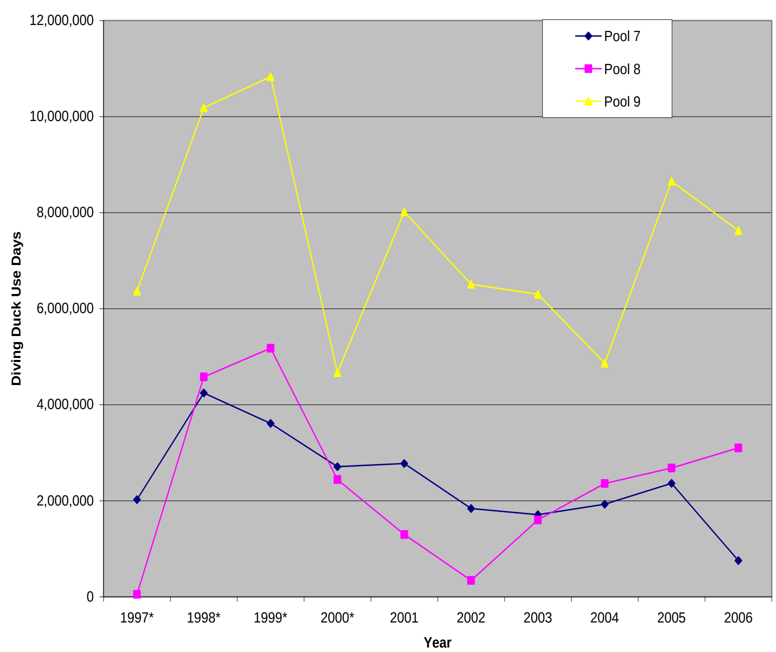


Figure 11. Diving duck use days on Pools 7, 8 and 9 of the Upper Mississippi River. The breeding population estimate for canvasback ducks hit a 10-year low in 2002, the same year as the second year drawdown in Pool 8. (Waterfowl Population Status 2003) WDNR

Conclusion

It is difficult to assign changes in waterfowl distribution on an individual pool or a refuge basis to one event or variable such as a drawdown because distribution is influenced by many factors, including: the effects of hunting and other forms of human disturbance on waterfowl, the amount of available food, the longitudinal distribution of food resources on the river and the distances ducks are known to fly from roosting to feeding sites, and other biological needs (UMRNWFR Comprehensive Conservation Plan 2006).

Waterfowl use days are also affected by flyway waterfowl populations and the timing of freeze-up in the fall. For example, swan use days in 2005 were low because tundra swans spent far less time than normal on the river due to an early freeze-up, and the midwinter abundance index (in thousands) for the Eastern population of tundra swans was 70.5 – the second lowest since 1996. Similarly, the breeding population estimate for canvasback ducks hit a 10-year low in 2002, the same year as the second drawdown in Pool 8 (USFWS Waterfowl Population Status 2005) . Hence, any trends in waterfowl use on a single pool or refuge-wide basis need to be evaluated with caution. With these caveats in mind the results of the surveys suggest:

Pool 8

- Survey results and observations from late August to late September indicate waterfowl were responding to the availability of food resources offered by flooded moist soil plants during the first year of the drawdown in 2001.
- Use days for dabbling ducks in Pool 8 fluctuated similarly to Pools 7 and 9; however, the change in dabbling duck use days in 2002 suggests dabbling duck feeding patterns appear to have shifted from other pools that year, primarily Pool 7, to Pool 8 most likely due to improving habitat conditions. The dabbling duck response to the effects of the drawdowns was more evident on a localized basis. There was a consistent shift of dabbling duck use within Pool 8 to the Wisconsin Islands Closed Area, which had a demonstrated vegetation change starting the first year of the drawdown in 2001.
- The decline in diving duck use days during the drawdowns in 2001 and 2002 on Pool 8 were more than likely due to other variables as the frequency of submersed aquatic plants, including wild celery, actually increased during those years.
- The drawdowns in Pool 8 had a dramatic effect on tundra swan use in Pool 8. Swans quickly shifted to the Wisconsin Islands Closed Area (WICA) in response to the development of arrowhead beds. Swan use of WICA has been maintained since the drawdowns as this area produced 50% of all Refuge-wide (Pools 4-13) tundra swan use days in 2006. This data suggests the drawdown effect on the expansion and development of arrowhead beds in the WICA has been sustainable for at least 7 years post drawdown.

Waterfowl Response to the 2005 Drawdown in Pool 5

Lisa Reid, *U.S Fish and Wildlife Service-Upper Mississippi River National Wildlife and Fish Refuge,*

Monitoring the effects of the drawdown on waterfowl relied primarily on the results of the weekly aerial waterfowl survey conducted in Pools 4 through 13 by the U.S. Fish and Wildlife Service and the Wisconsin Department of Natural Resources. Waterfowl surveyed include tundra swans, Canada geese, and 18 species of ducks. Waterfowl use days for tundra swans, dabbling and diving ducks were compared between Pool 5, the drawdown pool, and Pool 5A and lower Pool 4, non-

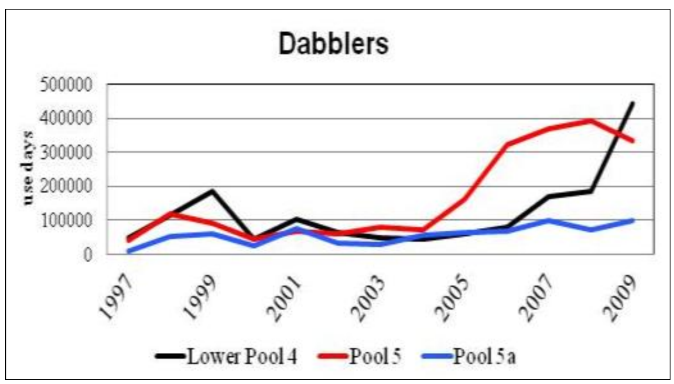


Figure . Dabbling duck use days doubled from 2004 to 2005 and doubled again by 2006. Dabbling duck use days have been maintained in the range of a 321,000 to 390,000 from 2006-2009. USFWS drawdown pools.

Dabbling Ducks

Dabbling duck use days doubled from 2004 to 2005 and doubled again by 2006. Dabbling duck use days have been maintained in the range of a 321,000 to 390,000 from 2006 -2009, suggesting that habitat conditions improved after the drawdown. (Figure .)

Diving ducks

Diving duck use days increased from 58,145 in 2005 to 240,800 in 2006. Use days from 2006-2009 remained between 223,500 to 320,000 in 2009. The increase in diving duck use days on Pool 5 since 2005 is probably the result of several variables including the increase in the abundance of submersed aquatic vegetation, especially wild celery. (Figure .)

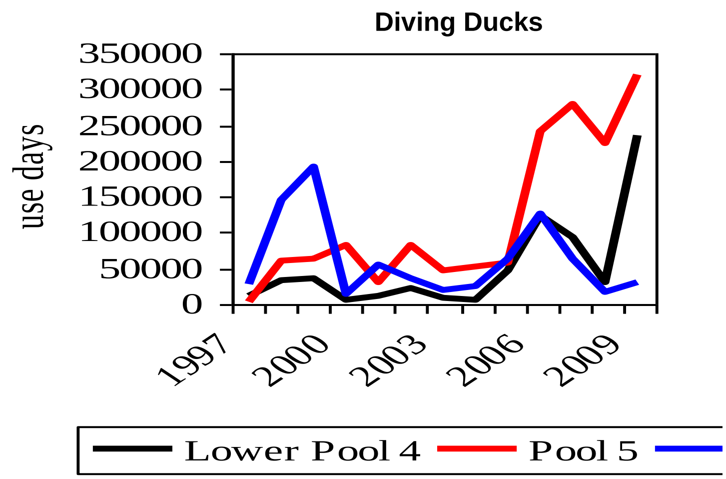


Figure . Diving Duck Use Days 1997– 2009 for Pools 5, 5a and lower 4. There were four times as many use days in 2006 as in 2005. USFWS

Tundra Swans

Tundra swan use days in Pool 5 increased after the drawdowns. In 2006 and 2008 use days were comparable with that of lower Pool 4 and use days in 2009 were similar to 2006. No dramatic change in use patterns occurred primarily because one area that benefited from the drawdown- Weaver Bottoms- has always been the primary tundra swan use area on Pool 5.

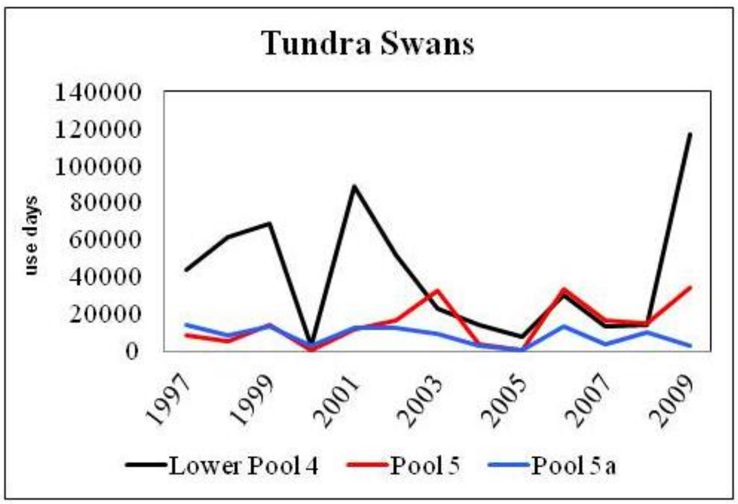


Figure . Tundra swan use of Pool 5 increased the year after the drawdown, but no dramatic changes in use patterns occurred after 2006. Swan use days in 2005 were low because tundra swans spent far less time than normal on the river due to an early freeze-up, and the midwinter abundance index (in thousands) for the Eastern population of tundra swans was 70.5 – the second lowest since 1996. USFWS

Conclusion Pool 5

Waterfowl use days are also affected by flyway waterfowl populations and the timing of freeze-up in the fall. For example, swan use days in 2005 were low because tundra swans spent far less time than normal on the river due to an early freeze-up, but also the midwinter abundance index (in thousands) for the Eastern population of tundra swans was 70.5 – the second lowest since 1996. Similarly, the breeding population estimate for canvasback ducks hit a 10-year low in 2002, the same year as the second drawdown in Pool 8. Hence, any trends in waterfowl use on a single pool or refuge-wide basis need to be evaluated with caution. With these caveats in mind the results of the surveys suggest:

The response by waterfowl including dabbling ducks, diving ducks and tundra swans to the Pool 5 drawdown was evident. Use days for puddle ducks, divers, and swans were the highest recorded in 10 years. And although adjacent pools also saw an increase, the increases in Pool 5 were much more dramatic particularly for dabblers and diving ducks.

Waterfowl Hunter Surveys

Lara Hill-*U.S. Fish and Wildlife Service-Upper Mississippi River National Wildlife and Fish Refuge*

In 2001, personnel from the U.S. Fish and Wildlife Service and U.S. Geological Survey conducted interviews with 924 waterfowl hunting parties at access sites around Pool 8. These interviews or "bag checks" occurred on 25 randomly selected days throughout the 60-day duck hunting season, 29 September through 27 November. Hunting parties may have been interviewed on multiple occasions during the season. During each bag check, hunters were asked a number of questions related to their day's hunting experience in addition to two questions specific to the Pool 8 drawdown:

- Were you aware of the water level reduction in Pool 8?
- If yes, do you feel the water level reduction had a positive or negative effect on river habitat?

Results indicated 94% of the parties) were aware of the drawdown, and 62% of those felt it produced positive results, while 14% thought the results were negative. (Table .)

In 2002, interviews were conducted with 344 waterfowl hunting parties at access sites around Pools 7 and 8. These interviews occurred on 12 randomly selected days (five surveys days on Pool 7 and seven days on Pool 8) throughout the 60-day duck hunting season. Hunters on both pools were contacted because many hunters hunt waterfowl in both pools and a comparison between survey results for the two pools would offer some perspective. The results were:

- A total of 175 parties from Pool 8 answered the first question. Of those 139 (79.4 %) said they were aware of the drawdown, 36 (20.5%) were not. This was a slight increase from 6% of parties not aware of the drawdown in 2001.
- The percent of hunters who thought the drawdown had obtained a positive result was 66.9%, a slight increase from 2001. The percent of hunters who thought the drawdown had a negative effect dropped from 14% in 2002 to 6.4% in 2002, while the number of hunters undecided about the results rose from 20% to almost 22.3%.

Table 2. A summary of the drawdown survey results from waterfowl hunter bag checks in 2001 and 2002..

Year	# of parties	Aware-Yes	Not aware	Positive results	Negative results	undecided	No change
2001	921	94% (865)	6% (54)	62% (535)	14% (124)	20% (172)	4% (34)
2002	216	78.7% (170)	21.2% (46)	64.1% (109)	7.6 % (13)	22.9% (39)	Not asked
Pool 8 total	175	79.4 % (139)	20.5 % 36)	66.9% (93)	6.4% (9)	22.3% (31)	
Pool 7 total	41	75.6% (31)	24.3% (10)	51.6% (16)	12.9% (4)	25.8% (8)	

Survey results indicated Pool 7 hunters were only slightly less aware of the drawdown in Pool 8 but were inclined to be less positive about the results of the drawdown.

Avian Botulism

William Thrune-*U.S. Fish and Wildlife Service-Upper Mississippi River National Wildlife and Fish Refuge*

Avian botulism is an often fatal disease of birds resulting from ingestion of toxin produced by the bacterium Clostridium botulinum. This bacterium persists in wetlands. Important environmental factors that contribute to initiation of avian botulism outbreaks include water depth, water level fluctuations, and water quality; the presence of carcasses; rotting vegetation; and high temperatures. Because many of these factors may be present during a drawdown, extra monitoring was planned for lower Pool 8 during the drawdown.

Crews from the Wisconsin DNR, U.S. Geological Survey, and U.S. Fish and Wildlife Service engaged in drawdown monitoring activities were also on the lookout for the presence of sick/dead waterbirds. They observed minimal waterbird mortality on lower Pool 8 during 2001 or 2002. The only occurrence of avian botulism was on a stretch of the Black River in upper Pool 8. (Botulism has occurred on this stretch in the past.) During the summer of 2001 nearly 50 sick/dead mallards and one herring gull were removed from the area. Additional mortality may have occurred but was not reported or observed. Many local residents, marina owners and boaters aided local resources managers in locating these birds. Avian botulism was confirmed by the National Wildlife Health Center in a mallard carcass collected 8 August.

EFFECTS ON PHYSICAL AND CHEMICAL PARAMETERS

Water Quality Sampling, Wisconsin DNR

Water Quality

Pool 8 Drawdown

Water Quality and Meteorological Monitoring Used in the Assessment of Water Level Drawdown of Navigation Pool 8 of Upper Mississippi River in 2001

John Sullivan - *Wisconsin Department of Natural Resources*

Continuous monitoring of dissolved oxygen, water temperature, light penetration and wind speed and direction were made in lower Crosby Slough off Stoddard, Wisconsin during June to September 1999 (pre-drawdown) and 2001 (during drawdown). In addition, daily composite samples of turbidity and total suspended solids were collected with a automatic water sampler and measurements of gross sedimentation were estimated using sediment traps. The purpose of this monitoring was to assess potential changes in water quality associated with the drawdown.

River flows were greater during the drawdown in 2001 than pre-drawdown measurements made in 1999 which presented difficulty in evaluating drawdown-induced water quality changes. It was suspected that drawdown would promote increased sediment resuspension due to wind stress over shallower water. However, wind-induced effects on sediment resuspension (increased total suspended solids or turbidity) were generally low at the monitoring site and were easily over shadowed by changes in river flow. Other results were:

- Mid-day light penetration was less in 2001 yielding a confounding response compared to measurements of total suspended solids.
- Diurnal dissolved oxygen fluctuation (maximum-minimum) increased noticeably in 2001 as compared to 1999 and was likely a drawdown-related. These changes in dissolved oxygen were attributed to increased submersed aquatic plant growth and attached algae in the vicinity of the monitoring platform in 2001 rather than increases in phytoplankton concentrations. Although dissolved concentrations showed large daily fluctuations in 2001, levels rarely fell below the 5 mg/L water quality standard.

In general total suspended solids and turbididty were not significantly greater during the summer of 2001 when the pool was drawn down 1.5 feet as compared to 1999 when accounting for changes in river flow between the monitoring periods. Wind induced effects on sediment resuspension explained less of the variation in total suspended solids, turbididty or light penetration than river flow. As a result, it can not be concluded that wind-induced effects on sediment resuspension were greater during the drawdown based on these data.

Long Term Resource Monitoring Water Quality Trends 1988-2005

Jim Fischer- *Wisconsin Department of Natural Resources*

A number of factors affecting water quality have been monitored in Pool 8 since 1988 through the Long Term Resources Monitoring program and these same factors were monitored during the 2001 drawdown. Notable trends include:

- Suspended solids concentrations during summer stratified random sampling (SRS) events continued on a decreasing trend. Median concentrations in the backwater and impounded strata (7.4 and 6.8 mg/L, respectively) of Pool 8 during 2005 were the lowest recorded since SRS began in 1993.

- A record-low dissolved oxygen concentration (DO) was observed at a lower pool fixed-site in July 2001, but it followed a trend that had started before the drawdown. The median DO concentration (8.9 mg/L) during summer SRS was similar to other years in the impounded stratum, suggesting that the drawdown had no detectable effect on DO concentrations in that stratum.

- Nutrient and chlorophyll a concentrations and patterns were generally similar to those observed in Pools 4 and 13 during the summer SRS period. For example, median nitrate-nitrite concentrations in the backwater stratum of the three pools ranged from 1.1 to 1.6 mg/L during 2001 and from 1.5 to 1.7 mg/L in 2002.

- The highest median nitrate-nitrite nitrogen concentration during 12 years of summer SRS was recorded for Pool 8 backwaters in 2004, however backwater concentrations were similarly high in Pool 4. Higher concentrations were also recorded in the main channel and were likely a result of increased watershed inputs.

In general, there were no obvious changes in water quality parameters that could be directly attributed to the drawdowns; most parameters were within the normal range of variability and followed the same patterns or trends as previous years.

Pool 5 Drawdown

Analysis of Water Quality Following a Drawdown in Navigation Pool 5, Upper Mississippi River System.

Rob Burdis- *Minnesota Department of Natural Resources*
Upper Mississippi River Restoration - Environmental Management Program, Long Term Resource Monitoring

Water quality monitoring was conducted at fixed sites in Pools 4 and 5 as part of the Upper Mississippi River Restoration - Environmental Management Program's Long Term Resource Monitoring component. Sampling in Pool 5 was discontinued in 2004 due to program cuts; however, special funds were obtained to continue monitoring historical fixed sites to evaluate the effects of the Pool 5 drawdown on water quality.

A BACI (before-after-control-impact) design was used to detect any effects of the drawdown on water quality. Utilizing fixed sites in Pool 4 as controls, the mean differences in water quality parameters between paired sites in Pool 4 and 5 pre-drawdown were compared statistically to the mean differences post-drawdown to determine if the drawdown had any effect on water quality.

River discharge in the UMR was very low in the two years following the drawdown, particularly in July and August due to minimal rainfall. Discharge can have a major influence on water quality and should be taken into consideration when examining the data over this period. In addition, submersed aquatic vegetation (SAV) in lower Pool 4 was at the highest percent frequency measured there since the current method of sampling SAV was initiated in 1998.

Results of the analysis were as follow:

- Turbidity and total suspended solids were not statistically different pre- and post-drawdown at either backwater or main channel sites when analyzed using the BACI design. However, turbidity was noticeably lower at the control backwater site in Pool 4 and the Pool 5 backwater site in the two years following the drawdown, indicating a reach wide reduction in turbidity unrelated to the drawdown.

- Total phosphorus and chlorophyll-a concentrations pre- and post-drawdown were significantly different between the backwater sites but not the main channel sites. Prior to the drawdown, concentrations of both of these water quality parameters were consistently higher at the Pool 5 backwater site than the Pool 4 site, but were more similar post- drawdown resulting in a statistical difference.

- The difference pre- and post-drawdown for dissolved silica and conductivity were significant at the main channel sites. Concentrations of dissolved silica at Lock and Dam 5 were lower at times compared to Lock and Dam 4 in the two years following the drawdown. Similarly conductivity was lower at Lock and Dam 5 on several dates resulting in a statistical difference.
- No statistical differences were found at the backwater or main channel sites for water temperature, dissolved oxygen, pH, volatile suspended sediments, soluble reactive phosphorus, total nitrogen, nitrate-nitrite nitrogen, and ammonia.

There was no response in Pool 5 water quality that could be directly attributed to the drawdown in the two years following at either backwater or main channel sites. There were statistically significant differences pre- and post-drawdown in total phosphorous and chlorophyll-a between the backwater sites and in silica and conductivity between the main channel sites. However, the differences are most likely not drawdown related. Although summer turbidity levels at the Pool 5 backwater site were at record lows following the drawdown, similar results were observed in lower pool 4 over the same time period. The low turbidity in 2006 and 2007 is likely the result of increased aquatic vegetation in these backwaters and the low discharge that occurred during this period.

Continuous WQ Monitoring of Weaver Bottoms

John Sullivan, *Wisconsin DNR- Mississippi River Team*

Continuous monitoring data of dissolved oxygen, water temperature, light penetration, surface photosynthetically active radiation (PAR), wind speed and wind direction were collected in upper Weaver Bottoms during May to September, 2005. An automated water sampler was used to collect daily composites samples for total and volatile suspended solids. Monitoring equipment was installed on a small platform located in open water in the northern portion of Weaver Bottoms. Gross sedimentation was measured with cylindrical sediment traps deployed near the monitoring platform.

Results:

- Very high dissolved oxygen concentrations (> 20 mg/L) and large diurnal fluctuations in dissolved oxygen were noted during early July during the period of maximum drawdown. This response occurred during the period of maximum water temperatures (greater than 86F) which likely contributed to increased photosynthetic activity. Wind speeds were also lower during this period which may have contributed to reduced mixing and increased algal concentrations.
- Highest total suspended solid (TSS) concentrations generally occurred during periods of highest wind speed although the actual correlation between TSS and wind speed was low. Daily average wind speeds were usually less than 10 mph with only one day exceeding 15 mph. Correlation between average daily wind speed and total suspended solid concentrations were hampered by inconsistent and variable sampling intervals.

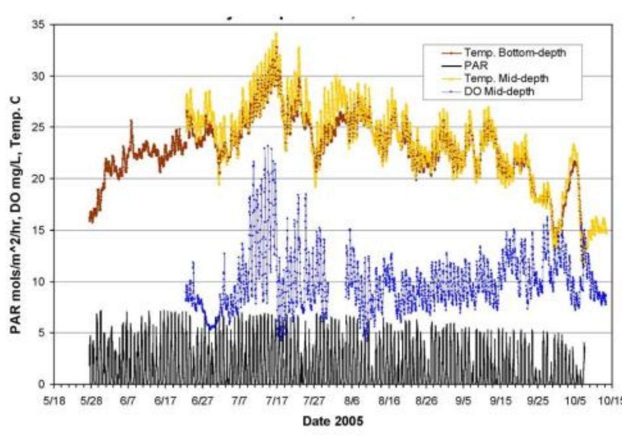


Figure . Very high dissolved oxygen concentrations and large diurnal fluctuations in dissolved oxygen were noted during the period of maximum drawdown. WDNR

- A marked increased in light penetration was noted in September and occurred during a period of very low TSS concentrations, some less than the report limit (<3 mg/L). Gross sedimentation rates declined during August and very low rates were measured during September, consistent with the low TSS levels. Sedimentation rates in September were 50-90% lower than similar measurements made in upper Weaver Bottoms in September 1993 and 1994. The mechanism for this response was not specifically determined but was likely influenced by increased aquatic plant growth (reduced sediment resuspension) in the vicinity of the monitoring site and low phytoplankton concentrations.

Weaver Bottoms 2005 Sediment Data Collection, Summary & Analysis

Corby Lewis, *US Army Corps of Engineers-St Paul District*

Automated surface water samplers were used to collect daily composite samples for total suspended solids and total volatile solids at major inlets and outlets to Weaver Bottoms from June 1 to September 30, 2005. The intent of this effort was to develop a total suspended solids "budget" for the Weaver Bottoms area.

A similar study was done in 1993 &1994 as part of the Resource Analysis Program for The Weaver Bottoms Rehabilitation Project (Nelson, et al. 1998). Although the scope of the previous study was larger than in this 2005 study, the same sampling locations were used and comparisons can be made. The comparison will therefore address the long term trends as well as effects of the 2005 pool-wide drawdown.

The sampling units were set up on accessible shorelines. Intake tubes set were fixed to temporary posts placed in areas where water depths were generally about 4-5 feet. The intakes themselves were set about 2-3 feet above the river bottom. Flow rates for all inlets and outlets to Weaver Bottoms were determined based on measured flow data.

The data were used to develop a sediment budget for Weaver Bottoms.

Figure . Location of sampling stations in Weaver Bottoms .USACE

Wind, Weaver bottoms TSS, and SAV growth

Wind and wave action within Weaver Bottoms are considered the most important factors in the re-suspension of fine sediments. The wind data collected by the WDNR, combined with the TSS data is shown in figure. The data shows high TSS concentrations coincided with windy periods from June through mid-August, but that the TSS concentration fell to lower levels and were not affected by windy periods in September. This non-responsiveness to wind also coincides with the growth of submerged aquatic vegetation (SAV), which has the affect of protecting bottom sediment from re -suspension.

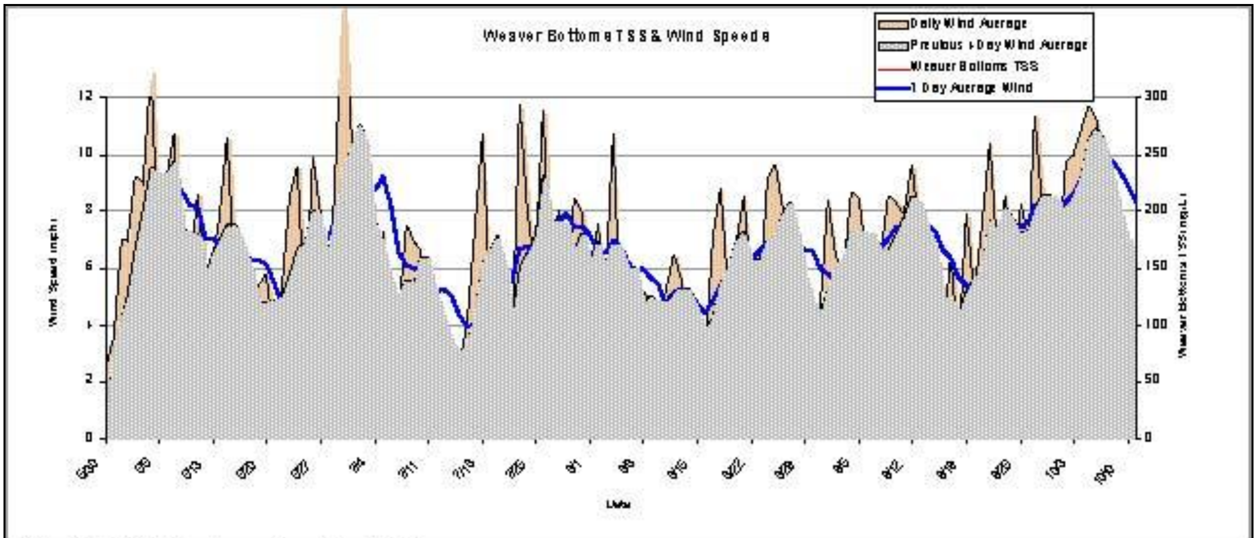
Sediment Budget:

A daily inventory of sediment inputs and outputs to Weaver Bottoms from 01 June to 30 September was developed based on flow rates and TSS concentrations. This "sediment budget" showed a net outflow of TSS from Weaver Bottoms of just over 5,000 tons. Much more sediment was being moved in the area during the early part of the season before mid-July due to higher Mississippi River Flow and the effects of the drawdown.

Drawdown Effects:

The 2005 drawdown clearly had the effect of reducing the percentage of river flow being carried through the back-waters. This resulted in less sediment being carried into Weaver Bottoms. The influence on the net sediment accu-mulation in the backwaters is not so clear, as reduced inputs are offset by reduced outputs. Factors that are not di-rectly affected by the drawdown such as wind & SAV growth play a significant role in net sediment accumulation in Weaver Bottoms.

A distinction must be made between fine and coarse sediments. This TSS budget does not attempt to estimate the movement of coarse material (sand), most of which travels very near to the riverbed. An iso-kenetic sampler must be used to measure the suspended sediment flux in the water column. Nearly all coarse material (sand) that is trans-ported into the backwaters is deposited in deltas at the mouth of the inputs. An example of this is the large sand



Wind & TSS data throughout the 2005 season

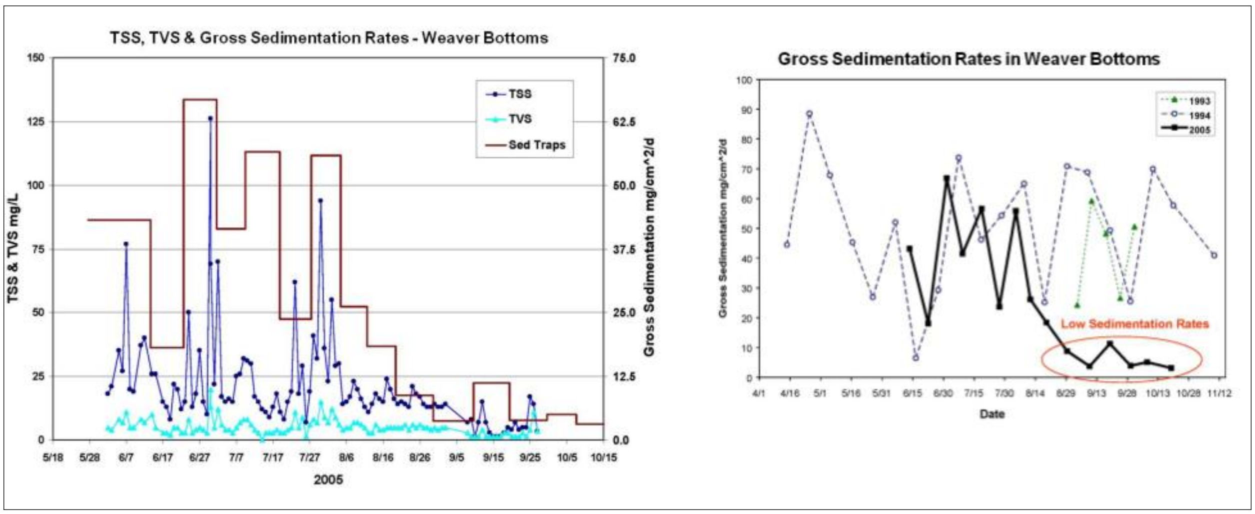


Figure . Low TSS concentrations were observed during September. Gross sedimentation rates declined during August and very low rates were measured during September, consistent with the low TSS levels.

delta formation at the MN-7 inlet to Weaver Bottoms (Figure .)

It stands to reason that the drawdown may reduce coarse sediment deposition in the backwater deltas near the inlets as overall flow into the backwaters is reduced. However, sand transport is weighted heavily during high flows and a significant percentage of the deposition normally occurs during high flow/flood conditions when the Lock and Dams are operated in an "open river" condition (i.e. when the drawdown operation has no effect).

Comparison to 1993/94 Data:

Several major changes have taken place in Weaver Bottoms since the 1993-4 TSS work was done. The three major alterations are:

- Major erosion at MN-7 resulting in higher flows, making it the largest source of TSS into Weaver Bottoms.
- Modification of site MN 14-1 (WBOE)—this site now accepts a larger percentage of the total outflow from

Weaver bottoms (94%). This project was aimed at improving main channel navigation conditions and has some local effect on sediment transport, but very little influence on the overall sediment movement through Weaver Bottoms.

- Recovery of SAV in Late 1990's (after crash in late 1980's).

The recovery of SAV in Weaver Bottoms reduces sediment re-suspension by wind and wave action. This effectively improves that trap efficiency of the backwater area, so that a larger percentage of the sediment entering Weaver Bottoms is deposited. SAV reduces TSS concentrations and improves water clarity.

Contaminant Monitoring

Numerous investigations have documented environmental contaminants and their effects in the Upper Mississippi River ecosystem. These investigations indicated that while environmental contaminants occur within the Pool 8 ecosystem with the possible exception of localized "hotspots", significant threats to fish and wildlife resources were not expected under normal circumstances. However the degree to which these contaminants could become available to the food chain and result in adverse effects due to water level management practices in Pool 8 was unknown.

Contaminants in Tree Swallows in Relation to Water Level Management

Dr. Thomas Custer and Dr. Christine Custer, *U.S.Geological Survey-Upper Midwest Environmental Sciences Center*

The purpose of this study was to determine the degree to which the bioavailability of environmental contaminants in Pool 8 was affected by the drawdown. Contaminants were a concern as sediments would be exposed in the lower part of Pool 8 for the first time in 60 years during the drawdown. Also flooding of previously dried out wetlands, such as a year following a drawdown, could have increased the rate of mercury methylation and in turn made mercury more available to terrestrial vertebrates that feed in aquatic environments. Tree swallows were a useful species for contaminant assessment of sediments. They feed on emergent aquatic insects and therefore their eggs and tissues reflect sediment contamination. Tree swallows were also used to identify contaminant pathways and to determine if these contaminants may affect reproductive success. Samples of swallow eggs and nestlings were collected and analyzed for mercury and other contaminants in 2000, 2001 and 2002. The findings were:

- Mercury concentrations in tree swallow eggs and nestlings did not significantly increase after the Pool 8 drawdown. Mercury concentrations in eggs were intermediate to levels reported in tree swallows from other North American locations.
- Metals and other elements, PCB's, and organochlorine insecticides did not increase following the 2001 drawdown and were not elevated compared to other samples collected from other North American locations.
- Hatching success of eggs did not differ among years or locations and was comparable to a nation wide average.

In conclusion, the bioavailability of contaminants did not appear to increase as a result of the drawdown.

Sediment Consolidation

Sediment characteristics identified as being potentially affected by the drawdown included chemistry of pore water, organic matter content, and concentration of nitrogen compounds.

Prior to the drawdown it was known that sediment organic content in the drawdown zone would decrease depending on the sediment type, initial water content of the sediment, position in the drawdown zone, length of the drawdown period, rainfall during the drawdown, air temperature, wind, humidity, groundwater seepage, and reflooding.

Limited consolidation of sediments was expected because most of the drawdown zone was silty sand with low organic content. (Figure .) (Definite Project Report)
However more information was needed regarding impacts of changes in sediment characteristics as a result of the desiccation and rewetting process.

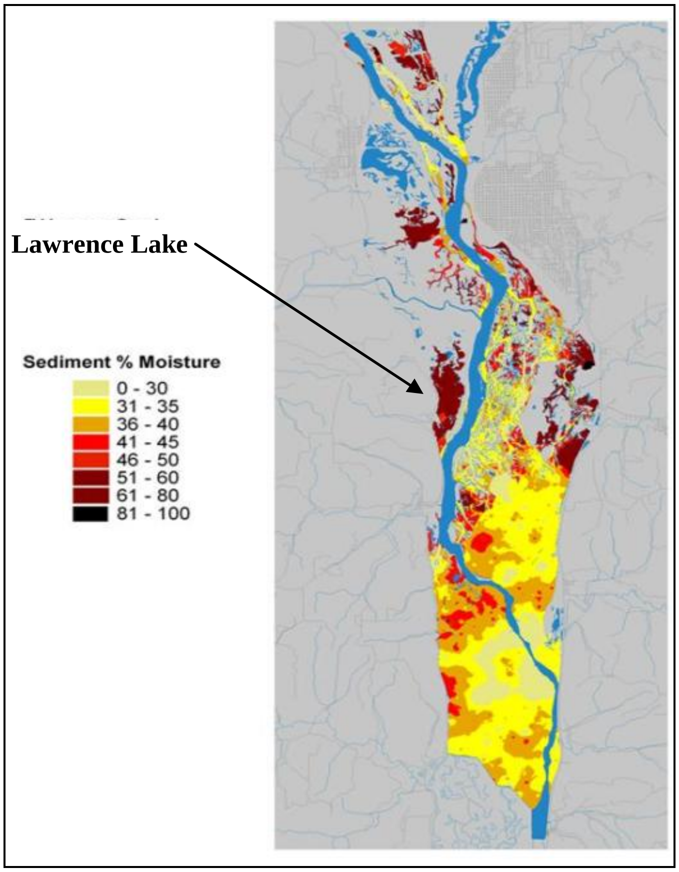


Figure . Sediment moisture content in Pool 8. Areas with low moisture content (yellows) have corresponding low sediment carbon content, and high moisture sediments (black areas) have high organic carbon content. USGS-UMESC

Experimental Determination of the Impacts of Sediment Desiccation and Rewetting on Sediment Physical and Chemical Characteristics in Lawrence Lake, Pool 8

William F. James, John W. Barko and Harry L. Eakin- *U. S. Army Corps of Engineers*

In June, 2000 over fifty intact sediment cores were collected at a station (depth = 0.7m) located near the entrance to Lawrence Lake (Figure .) The surface sediments at this site exhibited high moisture content and low sediment density.

The sediments were dried under laboratory conditions and subjected to treatments to determine loss of moisture from sediment cores over time, chemistry of pore water, organic matter content, and concentrations of nitrogen and phosphorus compounds.

The results were :

- The desiccation process resulted in substantial sediment consolidation as the percent moisture and organic matter content declined while sediment density increased after the rewetting process.
- Sediment desiccation and rewetting resulted in marked changes in sediment P (phosphorus) characteristics including, pore water P mass, and mean mass of aluminum bound P and calcium bound P. However the mean mass of sediment organic P appeared to remain approximately constant.
- There was an overall net loss of organic N as a result of the desiccation and rewetting process that could not be accounted for by increases in other N fractions. This pattern suggested that N was being lost to the atmosphere via denitrification.

Increases in available nitrogen, coupled with consolidation of loose organic sediments suggested that desiccation of sediment in Lawrence Lake would likely result in improved conditions for submersed aquatic plant growth including: reduction in sediment resuspension potential, improvement of rooting medium (i.e. nutrients and sediment texture) for submersed aquatic plant growth, conversion of soluble nutrients to particulate forms and reductions in organic matter concentrations.

Nitrogen Cycling

Nitrogen Cycling in Backwater Sediment

Dr. William Richardson, *U.S. Geological Survey-Upper Midwest Environmental Sciences Center*

Nitrogen enrichment of the Mississippi River may be the cause of two important environmental issues in the Midwest—high levels of toxic ammonia in river sediments and wide spread hypoxia (low oxygen concentrations) in the Gulf of Mexico at the mouth of the Mississippi River. Little is known about how nitrogen in the Mississippi River is processed, stored or biologically removed by the River ecosystem.

Water level management has the potential to affect significant changes in nitrogen cycling and reduce the accumulation of potential harmful ammonia in highly organic backwater sediments. Ideally, a drawdown will dry and oxygenate organic sediments, increasing the oxidation of accumulated ammonia to nitrate. Upon rewetting, sediments again become anaerobic, and nitrate is removed through the natural process of bacterial denitrification (converted to inert nitrogen gas and released to the atmosphere). This process requires anaerobic conditions, highly organic sediments, and nitrate - all conditions provided by drying and rewetting of backwater areas (Figure 12.)

Sediment Nitrogen Cycling-Pool 8

As part of a larger research program on nitrogen cycling in the Upper Mississippi River Basin, Dr William Richardson and team of scientists from the U.S.G.S.- Upper Midwest Environmental Sciences Center in La Crosse measured a suite of sediment characteristics and bacterial processes before, during and after the summer drawdowns of Pool 8 in 2001 and 2002.

In 2002 they determined the effects of sediment drying and rewetting resulting from the water level drawdown on patterns of sediment nitrification and denitrification and concentrations of sediment and surface water total nitrogen, nitrate and ammonium. In 2001 they only examined sediment ammonium and total nitrogen. The results were:

- Sediment ammonium (NH4) decreased significantly during periods of drying although there were no consistent trends in nitrification and denitrification or a reduction in total sediment nitrogen.
- The reduction of sediment ammonium (NH4) was likely a result of increased plant growth and nitrogen assimilation, which was then redeposited back to the sediment surface upon plant senescence.
- Water level drawdowns likely reduce denitrification due to reduced delivery of nitrate-rich river water, water retention time, and river floodplain connectivity, while promoting significant accumulation of organic nitrogen.

These results indicate that water level drawdowns are probably not an effective means of removing nitrogen from the Upper Mississippi River.

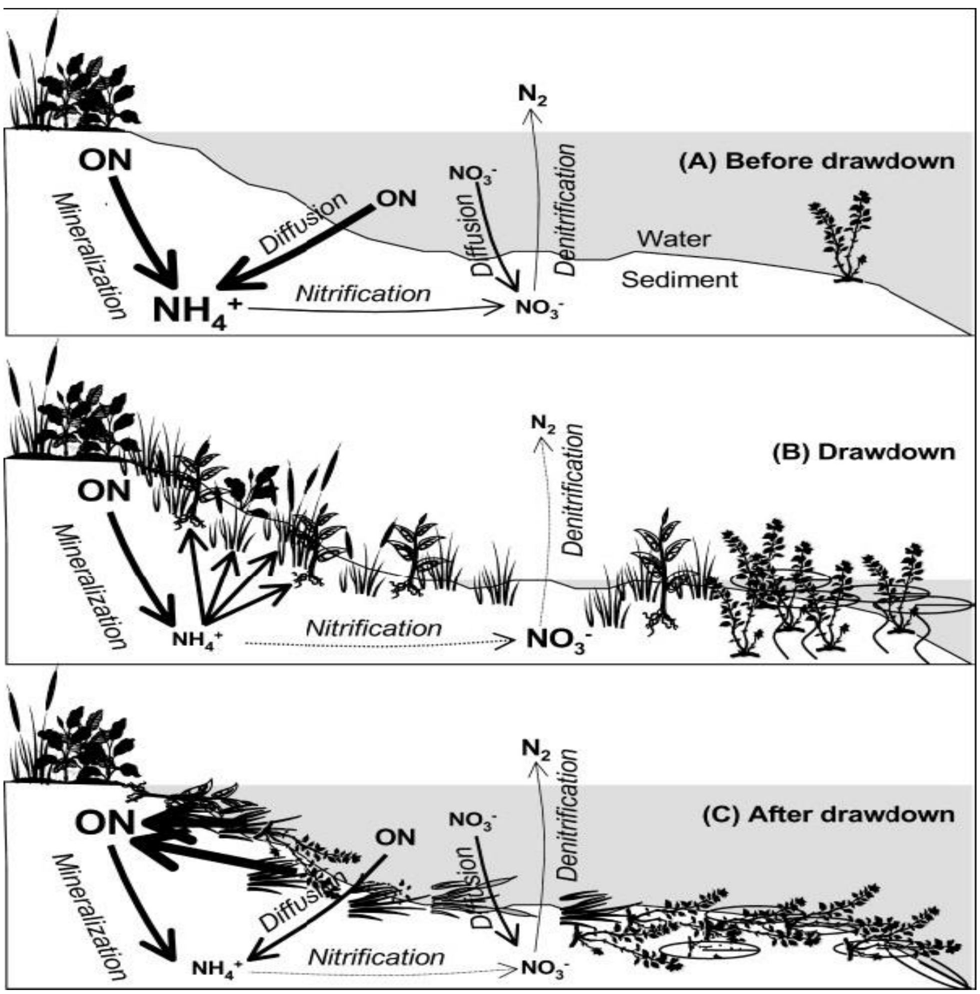
Sediment Nitrogen Cycling (for Pool 5- 2005 drawdown)

Our previous work in the drawdown of Pool 8 suggested rooted emergent and submerged aquatic plants may be important in removing large amounts of N from river sediments.

During the 2005 Pool 5 drawdown we manipulated plant densities in areas impacted (dry sediments) and unaffected (wet) by the drawdown in attempt to clarify the effect of plants on N removal processes. We measured sediment nitrogen in areas with or without plants and plant tissue nitrogen before, during, and after the drawdown. We found that sites affected by the drawdown exhibited greater plant growth and removal of ammonium from sediments than unaffected sites. Surprisingly, total sediment nitrogen levels did not change during the drawdown (wet versus dry areas), nor did we detect a reductions in sediment N related to plant densities. Areas with significant plant growth actually contained higher levels of sediment nitrogen near the sediment surface in the fall compared to areas without plants. In addition, exposing sediments to the atmosphere during a drawdown inhibited the natural process of bacterial denitrification (natural nitrogen removal process). The nitrogen content of rooted submersed aquatic plants throughout the Pool was also measured, and this information will be used to quantify the amount of N stored in sediments relative to the amount removed either by bacterial denitrification or plants during growth.

This study, and that of the Pool 8 drawdown, suggests that rooted aquatic plants move large amounts of nitrogen into their tissues from deeper sediments during summer growth, but the amount of N in the sediments is so large that it is difficult to detect a plant effect on total sediment N. During the fall, these N-rich plants decompose and deposit organic N on the sediment surfaces – essential acting a N-pumps bringing N from N-rich deeper sediment up to the sediment surface. Once on the sediment surface, the N-rich plant tissues will either be flushed down-stream during floods or recycled back into sediments through uptake by algae and bacteria.

Figure 12. Conceptual model of nitrogen (N) cycling in Upper Mississippi River Pool 8 in 2002:



Under normal pool management (A), there is a significant pool of sediment ammonium (NH4+), primarily generated from mineralization of organic nitrogen (ON); nitrification and denitrification are coupled resulting in very low levels of sediment nitrate (NO3-).

During drawdown conditions (B), plant assimilation, initial increases in nitrification, and potentially a slowing of mineralization significantly reduces the sediment NH4+ pool, whereas nitrification and denitrification are uncoupled resulting in a build up of sediment NO3-.

Upon rewetting (C), plant senescence and decomposition increase the organic N pool, but the anaerobic conditions and low NH4+ in the sediment continues to inhibit nitrification. Anaerobic conditions also stimulate denitrification and subsequent reduction in sediment NO3-.USGS-

RIVER USE MONITORING

Lower Pool 8, Wisconsin DNR

Commercial Navigation

Commercial Tow Operator Survey

Paul Machajewski, *U.S. Army Corps of Engineers St. Paul District*

The potential navigation impacts of the drawdown were coordinated extensively with the navigation industry through the River Resources Forum, the Water Level Management Task Force, the River Industry Action Committee, and the U.S. Coast Guard. Pilot surveys were conducted to get user input on the condition of the main channel. Similar survey methods were used for the drawdowns in Pool 8, 5.and 6. The questions asked were the same for each pool.

Pool 8

Towboat operators were provided survey forms at L/D 8 (upbound) and L/D 7 (downbound) and asked to turn the forms in at the next lock and dam after they traversed Pool 8. Between 4 July and 15 August (dates of the earliest and latest returned forms) roughly 100 towboats passed through Pool 8. Of the 100 towboats, 10% turned in survey forms.

Pool 5

Between 17 June and 8 September, 2005 (first and last completed survey received) roughly 100 towboats passed through Pool 5. Of the 100 towboats, roughly 10% completed an informal survey asking the pilots their opinion on the drawdown impacts to navigating Pool 5.

Pool 6

Between 1 June & 1 September, 2010, roughly 325 towboats passed through Pool 6. Of the 325 towboats, approximately 10% completed an informal survey asking the pilots their opinion on the drawdown.

Results

Below are the questions asked and a summary of how they were answered:

1. Compared to previous years was navigating the pool ….

	Pool 8 N~10	Pool 5 N~10	Pool 6 N~ 32
About the same	6 60%	20% 2	40%
More difficult	4 40%	50% 5	60%
Less difficult	0	10% 1	Not asked

2. How have the main channel current velocities affected you during the drawdown?

	Pool 8	Pool 5	Pool 6
Same	70%	30%	30%
Less	0	10%	Not asked
More	30%	20%	70%

3. How has the outdraft at the L/D affected you during the drawdown?

	Pool 8	Pool 5	Pool6
Same	20%	10%	60%
Less	20%	0	Not asked
More	40%	10%	40%
No effect	20%	30%	Not asked

4. How has the drawdown affected your flanking ability/ maneuverability throughout the pool during the drawdown?

	Pool 8	Pool 5	Pool 6
Same	40%	0	30%
Less	0	10%	Not asked
More	40%	30%	70%
No effect	2 20%	10%	Not asked

5. List any general or specific comments you have below regarding the Pool 8 drawdown.

Pool 8
Sub par channel conditions; too shallow and narrow (6)
Great idea for habitat improvement (2)
Barges pulled towards shallow water (1)

Pool 5
Sub-par channel conditions: too shallow and narrow; more dredging needed (12)
Navigation safety has been compromised (1)

Pool 6
Very swift current in Pool 6 this year.
Shallow conditions throughout Pool 6; more dredging needed.
Drawdowns have a negative effect on commercial navigation.

In summary,

Pool 8 is generally described as a pool that is already tough to navigate. During the drawdown, navigating the pool was a bit tougher, however it was still navigable.

Pool 5 is generally described as a pool that is already tough to navigate. During the drawdown, navigating the pool was tougher especially in certain reaches of the pool (i.e. Lower Zumro and Mt. Vernon.) The ability to navigate safely during the Pool 5 drawdown was questioned. However, it is important to note: during the drawdown, there were six groundings reported. None of the groundings were directly correlated as being caused by the drawdown, and the grounding reasons were similar to reasons for groundings during normal operations. The majority of the groundings were caused by tows out of the main channel. None of the groundings caused significant delays.

Tow pilots describe Pool 6 as a shallow pool especially immediately downstream of Winona (below Winona Railroad Bridge, Homer, & Blacksmith Slough). The drawdown makes the conditions more pronounced and tougher to navigate. During the drawdown navigating the pool was more difficult, as compared to a non-drawdown year, and had a more swift current. The pilots reported the drawdown having an effect on their flanking ability and the outdraft condition at Lock & Dam 6.

Recreation and Commercial Uses

Although the long term environmental and ecological improvements expected from a summer drawdown would benefit boating and fishing enthusiasts, the potential short term negative effects on these activities were recognized by the Water Level Management Task Force. These effects were primarily associated with reduced access to launch ramps, docks, harbors, marinas, boat houses, and some reduced backwater access and potential safety concerns due to submerged hazards such as wing dams. As a result an effort was made to minimize those effects prior to the drawdowns in Pool 5, 6 and 8. Impacts on recreation during the drawdown were monitored in several ways. Pool 8 impacts were evaluated using the Recreational Boating Study. Pool 5 impacts were evaluated using this same study but also used recreational lockages data, public access use surveys, and a windshield interview survey.

Pool 8 Recreation Summary

Extensive information was gathered about boating access sites, beaches, popular backwater areas, wing dams, and commercial recreational facilities on Pool 8. On this basis, as well as public input received at public meetings and results from questionnaire surveys provided to commercial and recreational interests, a minimum elevation at the La Crosse gage of 4.2 was selected, to minimize adverse effects in the La Crosse area on commercial and recreational interests. (Please note that the official La Crosse gage at Isle la Plume hit a low of approximately 3.8 -4.0 during the weekend of August 11-12. Sand from the high floodwaters during spring filled the gage causing inaccurate readings. The gage was repaired and the water level was remedied as quickly as possible.)

The effect on commercial and public recreational facilities in lower Pool 8 also entered into the selection of a target drawdown level at Lock and Dam 8.

Recreational Access Dredging

Provisions were also made for dredging to provide adequate access at some recreational boat landings and access channels through the federal Continuing Authority Program – Section 1135 which provided a 75 percent cost share to local governments or residents. The Minnesota-Wisconsin Boundary Area Commission served as the non-Federal sponsor for the project. They did not provide funds, but collected funds from local entities. Nine sites were dredged as part of this project. Dredging in four sites was financially supported by local government units. In two locations local property owners banded together. The remaining three sites were dredged to mitigate the effects on commercial enterprises. The two commercial enterprises affected provided the non-federal financial support.

Dredging was conducted under two contracts. Eight sites were dredged under one contract by L&S Industrial and Marine. Inc. at a coast of $199,860, which was completed in June. The ninth site required use of land based excavation equipment, completed by Strupp Trucking, Inc. in July at a cost of $14,585.

The estimated cost of the 1135 dredging from planning to implementation was $245,000. The non=federal share was approximately $61,200. However, federal contract regulations increased the cost of dredging substantially for the 25 percent local cost share.

Recreational Use Assessment

The impacts on recreational use during the drawdown were evaluated using the biennial Recreational Boating Study of the Upper Mississippi River which began in 1989 and is repeated in odd numbered years. This aerial survey includes a study area from lower Pool 4 to the U.S. Army Corps of Engineers -St. Paul District line in Pool 11, near Guttenburg, Iowa.

Aerial surveys confined to the main channel capture about 60% of total boating use based on the results of a mail in survey conducted in 2003. The other 40% is off the main channel in side channels and backwater areas. However the results of the aerial survey provide perspectives of trends in boating use over the 1989-2003 period and enable comparisons between Pools 7, 8, and 9 to determine effects from the drawdown.

While the techniques have remained consistent, the number of survey flights was reduced to five in 2003 due to a reduction in funding. The years 1999 and 2001 were more comparable with 11 flights in 1999 and 12 in 2001.

In general, recreational boating activity within the study area (Pools 4-11) during 2001 appeared to be slightly lower than the levels documented between 1989 and 1999. In contrast the average peak day watercraft counts for 2003 greatly exceeded all of the other years in the study period. This may be due to the fact that the 2003 survey consisted of only five flights, four of which were on peak days and one of which took place on Saturday, 05 July, a day when an exceptional amount of recreational boating activity occurred.

Geographic Distributions

The data suggest that watercraft were distributed widely within the study area from 1989 to 2003. Some geographic trends related to the drawdown in Pool 8 as well as Pools 7 and 9 include:

- Pools 4, 8 and 10 had the most boating activity during the study period.
- The total numbers of boats observed during the 2001 surveys decreased for all pools in 2001 from 1999 levels. However the proportion of boating activity actually increased in Pool 8 during 2001 and was slightly higher (+/- 2%) than the 1989-2003 average (not including the Black River zone, which was discontinued after 1997.)
- In terms of boat distribution on Pools 7, 8 and 9, the 2001 drawdown of Pool 8 does not appear to have had a significant positive or negative impact on recreational boating activity.

In summary, there does not appear to have been any major fluctuation in recreational boat activity in Pools 7, 8 or 9 other than the general decrease in boating activity during 2001 which occurred in all pools in the study area.

Recreation Use in Pool 5

The Pool 5 Recreational Boat Access Survey was conducted by the Minnesota Department of Natural Resources and included in the Pool 5 Drawdown Initial Report. This survey , which included an assessment of public boat access sites, private docks, and other access areas, provided baseline information for planning for the drawdown.

Recreational Access Dredging

The public generally supported a Pool 5 drawdown as long as some "reasonable" level of public access could be provided. A Citizens Advisory Committee provided a map to the Water Level Management Task Force highlighting priority access sites. Three sites were identified as needing dredging, and alternative solutions to dredging (moving temporary docks or developing a new access) were identified for two additional sites. All areas identified were channels typically used to access the main river channel from a public boat ramp. Sites needing to be dredged were near Murphy's Cut by Half-moon Landing on the Minnesota side, and at two locations in Belvidere Slough on the Wisconsin side. Dredging was completed to mitigate for impacts as a result of the drawdown not to improve recreational access. After the dredging was completed the access routes were buoyed to help identify the channel.

Funding Sources for Recreational Access Dredging

Reducing or negating the effects of a drawdown on recreational boat access generally means dredging. Funding this aspect of a drawdown is a challenge and relies on a variety of sources. Possible sources identified prior to the drawdown included Section 1135. Projects under Section 1135 must be cost shared on a 75 percent federal and 25 percent non-federal basis. The drawdown project would also have to be approved as a Section 1135 project. The Wisconsin Department of Natural Resources has a state funded program (Recreational Boating Fund) that could cost share 50% of the recreational boat access dredging if it is in association with a public access site such as a boat landing.

For the Pool 5 drawdown the USFWS provided $50,000 (sufficient funds to accommodate a 2.0 foot drawdown estimated at $49,000) to cover the upfront costs of the recreational access dredging. Table .The necessary funds were transferred to the U.S. Army Corps of Engineers (COE). The states reimbursed the USFWS for their agreed share. (WI – ½ total cost for all sites in WI waters, MN - $15,000). There was also a 6% transfer fee for the USFWS to provide funds to the COE. Izaak Walton League provided $2500 to purchase channel marker buoys.

Table . **Pool 5 Drawdown - Recreational Access Dredging for 1.5- foot Drawdown**
All sites dredged were channels typically used to access the main river channel from a public boat ramp. Dredging was completed to mitigate for impacts as a result of the drawdown not to improve long term recreational access.

Dredge cuts	Planning Estimate	Pre dredge Est.	Total Removed
Halfmoon Landing (Murphy's Cut)	8	183	395
Belvidere Slough	197	374	1,396
Buffalo City	556	951	1,908
Total	761	1508	3,699

Recreation Boating Study

Kevin Berg, *U.S. Army Corps of Engineers –St. Paul District*

A recreational boating survey, including aerial photography from a series of 10 flights, was conducted for Pools 4, 5, and 5A during the summer of 2005. Data from 2005 was compared to recreational usage data collected during the period of 1989-2003. This survey involves aerial counts of boats throughout the summer season and is repeated in odd numbered years. Results from the recreational boating study indicate no major fluctuation in boating activity in the immediate or adjacent pools as a result of the drawdown.

Recreational Boat Lockages

Scot Johnson, Minnesota Department of Natural Resources
Recreational boat lockages through lock and dams 3, 4, 5, and 5A were examined for trends for the years 1989-2005. No significant trends were detected for the 15 year time period. Approximately 13% of recreational boats use the locks according to surveys conducted in 2003 and 2006.

Results from 2005 and 2006 Mississippi River Pool 5 Drawdown Study of Public Access Use

Minnesota Department of Natural Resources
To monitor the effects of the drawdown on public access use, public access locations in pools 5,5A, and 4 were monitored in 2005 and 2006 from mid- June to early October. Because of low flows the drawdown was cancelled in mid- summer but the monitoring of public access continued. The results were compared to a similar study completed in 2003. In 2006 a windshield survey was distributed at public access in pools 5, 5a and 4.

Results - Public Use Access Levels for Pools 4, 5 and 5A in 2003, 2005, and 2006

Both 2005 and 2006 had more boating use than 2003 during the summer period. Although 2006 had less boating use than 2005, most of the boating use differences between 2006 and 2003 are statistically significant.

The boating use differences between 2003 and 2005 were mostly due to the much larger contribution of three accesses in 2005 (Ike's Park- lower Pool 4, Alma landing (Pool 5), and West Newton- Pool 5, which was new in 2005) while the remaining 24 accesses generated about the same amount of boating use in both 2003 and 2005.

Windshield Survey Results

During the 2006 boating season, 998 surveys were randomly distributed on windshields at designated public boat landings in Pool 5, with 431 returned. The survey showed:

- 94% of boaters in Pool 5 were satisfied or very satisfied with their boating experience.
- 91% of boaters in Pool 5 had some knowledge of the drawdown.
- 76% of the boaters in Pool 5 observed an increase in aquatic vegetation.
- 51% of the boaters in Pool 5 rated the drawdown as very effective or mildly effective for improving fish and wildlife habitat.

In summary, the drawdown had little effect on public use of Pool 5.

Pool 6 Recreational Access

The Pool 6 drawdown was a minor drawdown with a target water level reduction of 1-foot at the lock and dam. Concerns regarding the effects of the drawdown were expressed by several marina owners, one near Winona and two marinas located in the lower end of the pool. The Water Level Management Task Force agreed to provide as much assistance as possible to marina owners such as educate boaters, provide signs, dredging permit assistance, etc. The goal was to communicate frequently with the owners to work on solving problems as they occurred.

Problems addressed included:

- Recreational access dredging- 500 cubic yards of material from behind the lock wall was dredged by Sunflower Enterprises/Newt in 2010. USFWS paid for dredging the channel for access to the Sunset Marina, with the understanding the marina would be open to the public with no charge. The channel was marked by buoys.

- Sunset Marina had problems with a hump off from the ramp about 55 feet, most likely caused by power loading. COE marked the hump for boaters.
- Maps showing the drawdowns depths were provided to every marina and every boat landing in Pool 6. Winona Marina received a staff gauge to help boaters navigate past the last dock slips.
- Buoys were placed at Straight Slough.
- A hump at the end of the boat ramp was leveled off and later concrete blocks and a log were removed from the ramp area for Pla-moor Campground. In addition the channel from the marina was marked to keep boats out of the shallow water.

The issues appeared to have been alleviated with no alteration to the planned water level reduction until mid August when the submersed plants in Pools 4-10 were uprooted due to a substantial rise in water levels due to heavy rains. The plants moved downstream in the current and accumulated in the lower end of the pools. The effect was system wide and unrelated to the drawdown.

The problems due to this event were resolved at one marina by moving the boats out of the slips and helping the vegetation mass to move downstream, the other marina located in the SE corner of the pool had continuing difficulties with the mass of uprooted plants and debris. As the marina was located in a bay and had no current moving through it, there was no way for the plants to wash out of the marina. Due to this situation ,combined with the onset of decreased flow on 25 August, the drawdown was ended and the pool was at normal levels by 03 September.

Dredging along the lock wall. 500 cubic yards were removed. USFWS


Marina located in SE corner of Pool 6 with large quantities of uprooted aquatic vegetation combined with filamentous algae and duckweed trapped in the marina. A weed harvester removed over 200 tons (wet weight.) WDNR

CULTURAL RESOURCES MONITORING

Burial mounds in Iowa– Photo by R Clark Mallum

Cultural Resources Investigation - Associated with the Drawdown of Pool 8 and Pool 5

Bradley Perkl, *U.S. Army Corps of Engineers- St. Paul District*

There are approximately 240 known cultural resource sites recorded within the floodplain and along the terraces and uplands in Wisconsin and Minnesota in Pool 8, and 63 sites in Pool 5.

Many pre-contact sites in floodplains are important because they have never been plowed, and in fact were covered by flood sediments soon after they were used. In some places, this sedimentation has created "stratified" sites which can be studied by excavating one layer after another, going back further in time with each successive layer. Up to 30 m of bankline retreat is documented for sites in Pool 8, destroying significant portions of these sites.

Shoreline erosion can be caused by flood events, fluctuating water levels of the pool, and wave action from wind and commercial and recreational boat traffic. The susceptibility of each archeological site to erosion has many factors. In addition to site destruction, indirect impacts from erosion potentially include site vandalism and artifact looting. Thus, the effects of a pool drawdown to individual cultural resources are difficult to predict and the Pool 5 and 8 drawdowns had the potential to impact numerous cultural resources.

Figure . Archeological site erosion USACE

In an effort to understand the impacts that a drawdown would have on cultural resources, a cultural resources monitoring study was conducted which focused on known archeological sites located on the shoreline portion of Pool 8. and later Pool 5. In addition to examining the known sites, previously unrecorded sites exposed during the drawdown were identified.

The results were:

- Thirty -three archeological sites were monitored during the 2001 Pool 8 drawdown. Fifteen of these sites had a high probability of impact from shoreline erosion or looting.
- Five archaeological sites were monitored during the 2005 Pool 5 drawdown . Two of these sites had a high probability of impact from erosion and looting.

The differences in known sites between the pools appears to be factor of geomorphic masking of sites in Pool 5. Locations susceptible to damage by vandals are being monitored by law enforcement personnel.

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