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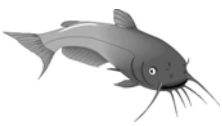

Evaluation of 2006 Vegetation Response on Areas Exposed During the 2005 Drawdown of Navigation Pool 5, Upper Mississippi River

US Army Corps of Engineers®
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Upper Mississippi River System
Navigation and Ecosystem Sustainability Program

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

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1 Introduction

A key component of the character of many large rivers is an annual cycle of fluctuation in water levels with high water during spring floods and low water during low flow periods in summer and winter. On the Upper Mississippi River (UMR) this annual hydrologic cycle has been modified, primarily by the system of dams installed by the U.S. Army Corps of Engineers (Corps) in the 1930s to enhance commercial navigation (Wlosinski 1999). The navigation pools that resulted from the artificially-maintained high water levels were initially diverse in structure and supported a rich variety of fish and wildlife (Wiener et al. 1998). Over time, alteration of the hydrologic regime, island loss due to erosion, and increased sedimentation of the UMR is believed to have affected the distribution and abundance of aquatic vegetation (U.S. Geological Survey 1999, U.S. Army Corps of Engineers 2005). Consequently, habitat quality of these pools has degraded and large expanses of open water with little aquatic vegetation have developed that are of less benefit to fish and wildlife resources. The existing system of locks and dams provides an opportunity to manage water levels on a pool-wide basis for purposes other than navigation. A temporary reduction in water levels (drawdowns) during the growing season has the potential to yield substantial ecological benefits in the lower portion of navigation pools, with minimum societal costs.

The Corps has implemented water level reductions on the UMR during the summer growing season under deviations from approved reservoir regulation plans. These drawdowns were recommended by the Water Level Management Task Force (WLMTF) of the River Resources Forum, a coordination group to the Corps, St. Paul District, for the primary purpose of enhancing aquatic plant production and habitat diversity. A drawdown was conducted in Navigation Pool 5 near Fountain City, Wisconsin, in 2005. 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 (U.S. Army Corps of Engineers 2005). An increased abundance and distribution of emergent aquatic vegetation is expected to be a primary biological response to the drawdown. In turn, increased emergent aquatic vegetation offers considerable ecological benefits for fish and wildlife.

The drawdown exposed about 405 hectares (ha) (1,000 acres), mostly in the lower and mid-pool areas. In 2005, UMESC and state partners monitored vegetation response to the drawdown (Kenow et al. 2007). A number of vegetation community characteristics were documented on substrates exposed during the drawdown, including species composition, frequency of occurrence, cover, and above ground biomass.

A second drawdown was prescribed for 2006 to enhance productivity of perennial emergent aquatic plants. The drawdown was initiated on June 12, 2006 and water levels were gradually reduced to about 1.5 feet below the normal secondary pool elevation of 559.5 feet above mean sea level (msl) at Lock and Dam 5 by June 26. 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 559.5 feet msl to 558.0 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.

2 Methods

Vegetation above-ground biomass was measured at 311 randomly selected locations within areas of substrates exposed during the 2005 drawdown that are not exposed under normal pool operations (figure 1). The extent of exposed substrates was based on a geographical information system (GIS) coverage generated from 1:10,000-scale true color aerial photography acquired on July 15, 2005 (approximate time of peak drawdown in 2005; Lock and Dam 5 discharge- 30,600 cubic feet per second (cfs), Lock and Dam 5 elevation- 657.9 feet msl, Alma elevation- 659.8 feet msl; see Kenow et al. 2007). Sample sites were marked with a post during 5 to June 8, 2006 and water depth was measured at that time. Vegetation sampling was conducted between August 21 and September 14, 2006. Clusters of sites to be sampled each day were randomly selected to avoid any spatial bias, because plants potentially were still germinating, growing, and senescing during the 3-week sample period. Field crews relocated the post at sampling sites using a Garmin GPS receiver. In the event that the post at a site was missing, a new site was established in the same general location with the GPS receiver. 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 (it was not always feasible to count stems for species with rank, spreading growth forms; e.g., rice cutgrass [*Leersia oryzoides*], teal love grass [*Eragrostis hypnoides*], blunt spikerush [*Eleocharis obtusa*]). Date, field-derived coordinates, general substrate class, and evidence of herbivory (i.e., grazing by Canada geese [*Branta canadensis*] or muskrat [*Ondatra zibethicus*]) were recorded for each site. The above-ground portion of all emergent, moist-soil, and terrestrial vegetation was removed from the quadrat, sorted by species, and returned to the laboratory for biomass determination. Vegetation was oven-dried at 105° C to constant mass (about 24 hours) and then weighed. All biomass data are expressed as dry weight.

Water surface elevation relative to bed elevation was calculated for each day during the 2005 drawdown period for each 2006 sample site, using estimates of bed elevation at each site and a GIS model of water surface profile during the 2005 drawdown. This information was used to determine the likelihood that a given sample site was dewatered with the 2005 drawdown. Water levels were determined within the Pool 5 study area by linear interpolation between data from U.S. Army Corps of Engineers gages at Lock and Dam 5 and Alma, Wisconsin (U.S. Army Corps of Engineers, 2005). Water elevation was calculated for each river mile for each day based on the 8:00 a.m. gage data. Using a GIS, vegetation sampling sites were assigned a river mile within the study area. Water surface slope laterally across the floodplain was assumed to be zero. Bed elevations for the exposed substrate sample sites were estimated by measuring the depth or elevation relative to the water surface on the day of survey and using the estimated water surface profile on the day of survey to calculate bed elevation. The maximum bed elevation above the water surface during the drawdown (i.e., magnitude of exposure), first and last date of exposure, and number of days exposed were calculated for each site using the estimated daily water surface described above.

Descriptive statistics concerning frequency of occurrence, average above-ground biomass, and substrate exposure characteristics were generated using SAS® software. The relation between total plant biomass and number of days exposed was evaluated using a simple regression model. Wilcoxon scores of plant biomass and the Kruskal-Wallis statistic (SAS® NPAR1WAY procedure) were used to test for biomass differences between grazed and ungrazed plots.

3 Results and Discussion

Based on GIS water elevation model estimates, 94 sampling sites (30 percent of the 311 sites visited) were probably not dewatered during the drawdown. This discrepancy was probably the result of one or more of the following: (1) inaccuracies in mapping areas exposed during the 2005 drawdown, (2) error in locating the sample sites in the field using GPS receivers (error typically ± 5 m), and/or (3) inaccuracies in the water elevation model. The remaining 217 sample sites are expected to have been influenced directly by the 2005 drawdown, and information from these sites was used in the analyses. A database of species composition, plant density, plant percent cover, plant biomass, and ancillary data is provided as Appendix 1.

We identified 51 plant species (table 1) 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 (table 2). 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 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; Kenow et al. 2007). Common arrowhead (64.5 g/m^2), rice cutgrass (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 (table 2). 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) included in the analysis. However, plant biomass did not differ significantly between grazed (0 ± SE = 153.5 ± 43.5 g dry wt/m^2) and ungrazed (0 = 287.0 ± 23.9 g dry wt/m^2) plots (χ^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 aqaquatica*; 526.4 g/m^2), sandbar willow (218.0 g/m^2), purple loosestrife (*Lythrum salicaria*; 204.1 g/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) (table 2).

We observed a general pattern of increase 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 (table 3; Kenow et al. 2007). Figure 2 illustrates the change in frequency of occurrence of terrestrial/moist-soil, emergent, floating-leaved, and submersed aquatic vegetation between 2005 and 2006. 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 (table 3). 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., unpublished data).

A number of desirable plant species that were established on exposed substrates during the 2005 drawdown persisted, and in some cases flourished, in 2006. The dominant emergent species are recognized for their value as wildlife food and habitat structure for aquatic organisms (Cottam 1939, Martin and Uhler 1939, Bellrose and Anderson 1943, Weller 1978, Fredrickson and Reid 1988, Korschgen et al. 1988). River managers are particularly interested in the persistence of vegetation established with periodic drawdowns of varying duration, timing, spatial extent, and magnitude. This investigation further highlights the need for long-term evaluations of vegetation response to water level management strategies. The finding from studies in Pool 5 across multiple years, along with vegetation monitoring in other drawdown pools, contributes to an improved understanding of vegetation response to drawdowns on the Upper Mississippi River.

4 References

Bellrose, F. C., and H. G. Anderson. 1943. *Preferential Ratings of Duck Food Plants*. Illinois Natural History Survey Bulletin 22:417-433.

Cottam, C. 1939. *Food habits of North American Diving Ducks*. U.S. Department of Agriculture Technical Bulletin 6743. 139 pp.

Fredrickson, L. H., and F. A. Reid. 1988. *Nutritional Values of Waterfowl Foods*. In Cross, D. H., ed. Waterfowl Management Handbook, U. S. Fish and Wildlife Service Fish and Wildlife Leaflet 13, Washington, D.C.

Kenow, K. P., J. T. Rogala, and L. R. Robinson. 2007. *Vegetation Response to a Water Level Drawdown in Navigation Pool 5 of the Upper Mississippi River, 2005.* U. S. Geological Survey FY 2005 Eastern Region State Partnership Program Final Report.

Korschgen, C. E., L. S. George, and W. L. Green. 1988. *Feeding Ecology of Canvasbacks Staging on Pool 7 of the Upper Mississippi River.* In: Weller, M. W. (Ed.), Waterfowl in Winter, University of Minnesota Press, Minneapolis.

Martin, W. C., and F. M. Uhler. 1939. *Food of Game Ducks in the United States and Canada*. U.S. Department of Agriculture Technical Bulletin 634. 156 pp.

U.S. Army Corps of Engineers. 2005. *Pool Drawdown, Pool 5, Upper Mississippi River.* Final letter report and environmental assessment. Unpublished report. U.S. Army Corps of Engineers, St. Paul District, St. Paul, MN.

U.S. Department of Agriculture, National Resources Conservation Service. 2007. The PLANTS Database (http://plants.usda.gov). National Plant Data Center, Baton Rouge, LA 70874-4490 USA.

U.S. Geological Survey. 1999. *Ecological Status and Trends of the Upper Mississippi River System 1998: A report of the Long Term Resource Monitoring Program. LTRMP 99-T001.* USGS, Upper Midwest Environmental Sciences Center, La Crosse, WI.

Weller, M. W. 1978. *Management of Freshwater Marshes for Wildlife.* In Good, R. E., D. F. Whigham, and R. L. Simpson (eds.) Freshwater wetlands: Ecological processes and management potential. Academic Press, New York, NY.

Wiener, J. G., C. R. Fremling, C. E. Korschgen, K. P. Kenow, E. M. Kirsch, S. J. Rogers, Y. Yin, and J. S. Sauer. 1998. Mississippi River. Pages 351-384 in Mac, M.J., P. A. Opler, C.E. Puckett Haecker, and P.D. Doran, editors. *Status and Trends of the Nation's Biological Resources.* Biological Resources Division, U.S. Geological Survey, Reston, Va.

Wlosinski, J. 1999. Hydrology. Pages 6-1 to 6-8 in Lubinski, K., editor. *Ecological Status and Trends of the Upper Mississippi River System 1998: A Report of the Long Term Resource Monitoring Program. LTRMP 99-T001.* USGS, Upper Midwest Environmental Sciences Center, La Crosse, WI.

Table 1. List Of Plants That Were Found in the 217 Sites Sampled in 2006 on Pool 5 Substrates Exposed During the 2005 Drawdown [1]

Scientific Name	Common Name	Life Form [2]	USDA Symbol
	alga	F	2ALGA
Alisma plantago-aquatica	European water plantain	M	ALPL
Amaranthus tuberculatus	rough fruit amaranthus	M	AMTU
Azolla caroliniana	Carolina mosquito-fern	F	AZCA
Bidens cernua	nodding beggar-ticks	M	BICE
Cephalanthus occidentalis	buttonbush	Sh	CEOC2
Ceratophyllum demersum	coon's tail	S	CEDE4
Chara sp.	muskgrass	S	CHARA[3]
Cyperus erythrorhizos	redroot flatsedge	M	CYER2
Cyperus esculentus	chufa flatsedge	M	CYES
Cyperus rivularis	shining flatsedge	M	CYBI6
Echinochloa crusgalli	barnyard grass	M	ECCR
Echinochloa walteri	coast cock-spur grass	M	ECWA
Eleocharis obtusa	blunt spikerush	M	ELOBE2
Elodea canadensis	Canada waterweed	S	ELCA7
Heteranthera dubia	grassleaf mudplantain	S/M	ZODU
Leersia oryzoides	rice cutgrass	M	LEOR
Lindernia dubia	false pimpernel	M	LIDU
Ludwigia palustris	water purslane	M	LUPA
Lycopus uniflorus	northern bugleweed	M	LYUN
Lythrum salicaria	purple loosestrife	M	LYSA2
Mimulus ringens	Allegheny monkey flower	M	MIRI
Myriophyllum spicatum	Eurasian watermilfoil	S	MYSP2
Najas flexilis	bushy pondweed	S	NAFL
Nelumbo lutea	American lotus	F	NELU
Nymphaea odorata	white waterlily	F	NYTU
Penthorum sedoides	ditch stonecrop	M	PESE6
Phalaris arundinacea	reed canary grass	M	PHAR3
Phragmites australis	common reed grass	E	PHAU7
Polygonum amphibium	water knotweed	M	POAM8
Polygonum hydropeperiodes	swamp smartweed	M	POHY2
Polygonum lapathifolium	nodding smartweed	M	POLA4
Polygonum pensylvanicum	Pennsylvania smartweed	M	POPE2
Populus deltoides	eastern cottonwood	Tr	PODE3
Potamogeton crispus	curly-leafed pondweed	S	POCR3
Potamogeton foliosus	leafy pondweed	S	POFO3
Potamogeton nodosus	long-leaf pondweed	S	PONO2
Potamogeton pectinatus	sago pondweed	S	POPE6
Potamogeton richardsonii	Richardson's pondweed	S	PORI2
Potamogeton zosteriformis	flat-stem pondweed	S	POZO
Ranunculus trichophyllus	threadleaf crowfoot	S	RATR
Sagittaria latifolia	common arrowhead	E	SALA2
Sagittaria rigida	sessile fruit arrowhead	E	SARI
Salix exigua	sandbar willow	Tr	SAEX
Salix nigra	black willow	Tr	SANI
Schoenoplectus fluviatilis	river bulrush	E	SCFL11
Schoenoplectus tabernaemontani	soft-stem bulrush	E	SCTA2
Sparganium eurycarpum	broadfruit bur-reed	E	SPEU
Typha latifolia	broad leaf cattail	E	TYLA
Urtica dioica	stinging nettle	M	URDI
Vallisneria americana	wild celery	S	VAAM3
Zizania aquatica	wild rice	E	ZIAQ

[1] Naming convention and symbol after U.S. Department of Agriculture, National Resources Conservation Service (2007).
[2] Life fotegories are E=emergent, F=floating, M=moist-soil, S=submersed, Sh=shrub, and Tr=tree.
[3] Code used for *Chara sp*. does not conform to USDA/NRCS (2007) convention

Table 2. Frequency of Occurrence, Average Percent Cover, and Average Above-Ground Biomass for the Most Frequently Observed Species Among the 217sites Sampled in 2006 on Pool 5 Substrates Exposed During the 2005 Drawdown

			Mean (± SE) Above-ground Biomass (g/m^2 dw)	
Species	**Frequency of Occurrence (%)**	**Overall % Cover (Mean ± SE)**	**All Sample Quadrats**	**At Quadrats Where Species Occurred**
Coon's tail (*Ceratophyllum demersum*)	57	6.4 ± 0.9	-[1]	-
Common arrowhead (*Sagittaria latifolia*)	47	17.6 ± 1.9	64.5 ± 8.2	142.9 ± 14.6
Canada waterweed (*Elodea canadensis*)	46	4.5 ± 1.0	-	-
Grassleaf mudplantain (*Heteranthera dubia*)	45	8.2 ± 1.0	-	-
Rice cutgrass (*Leersia oryzoides*)	38	11.0 ± 1.5	53.8 ± 11.5	149.8 ± 29.0
White waterlily (*Nymphaea odorata*)	27	11.1 ± 1.7	29.0 ± 5.1	118.7 ± 15.6
Soft-stem bulrush (*Schoenoplectus tabernaemontani*)	23	2.7 ± 0.6	12.9 ± 3.8	80.2 ± 20.3
Eurasian watermilfoil (*Myriophyllum spicatum*)	20	1.0 ± 0.2	-	-
Sessile fruit arrowhead (*Sagittaria rigida*)	20	4.1 ± 0.9	11.0 ± 3.4	55.5 ± 15.5
Wild celery (*Vallisneria americana*)	17	2.4 ± 0.6	-	-
Broadfruit bur-reed (*Sparganium eurycarpum*)	15	3.4 ± 0.9	18.0 ± 5.6	126.2 ± 33.3
American lotus (*Nelumbo lutea*)	15	4.3 ± 1.0	12.5 ± 3.5	90.1 ± 20.4
Sago pondweed (*Potamogeton pectinatus*)	13	2.2 ± 0.6	-	-
Sandbar willow (*Salix exigua*)	12	2.4 ± 0.7	23.1 ± 8.8	218.0 ± 72.5
Reed canary grass (*Phalaris arundinacea*)	10	2.9 ± 0.9	19.3 ± 8.6	199.1 ± 80.2
Curly-leafed pondweed (*Potamogeton crispus*)	7	0.3 ± 0.1	-	-
Black willow (*Salix nigra*)	7	1.0 ± 0.4	7.4 ± 2.8	114.4 ± 33.2
Long-leaf pondweed (*Potamogeton nodosus*)	7	0.9 ± 0.4	-	12.4 ± 4.4
Purple loosestrife (*Lythrum salicaria*)	6	1.6 ± 0.6	11.3 ± 5.9	204.1 ± 93.5
Cattail (*Typha spp.*)	5	0.6 ± 0.3	4.4 ± 2.3	86.5 ± 40.1
Coast cock-spur grass (*Echinochloa walteri*)	5	0.3 ± 0.1	0.7 ± 0.3	21.2 ± 6.1
Nodding smartweed (*Polygonum lapathifolium*)	5	0.7 ± 0.3	1.1 ± 0.7	24.1 ± 12.9

[1] Biomass not determined for submersed aquatic species.

Table 3. Frequency of Occurrence and Average Above-Ground Biomass for 2005 (N=166) and 2006 (N=217) for the Most Frequently Observed Species on Exposed Sites Sampled During the 2005 Drawdown of Navigation Pool 5, Upper Mississippi River

	2005		2006	
	Frequency of Occurrence (%)	**Mean (± SE) Aboveground Biomass (g/m^2 dw)**	**Frequency of Occurrence (%)**	**Mean (± SE) Above-ground Biomass (g/m^2 dw)**
Rice cutgrass (*Leersia oryzoides*)	45	11.4 ± 2.3	38	53.8 ± 11.5
Common arrowhead (*Sagittaria latifolia*)	45	9.8 ± 3.0	47	64.5 ± 8.2
Sandbar willow (*Salix exigua*)	42	7.4 ± 1.8	12	23.1 ± 8.8
Grassleaf mudplantain (*Heteranthera dubia*)	42	-	45	-[1]
Chufa flatsedge (*Cyperus esculetnus*)	37	6.3 ± 1.4	1	0.1 ± 0.1
Black willow (*Salix nigra*)	34	2.2 ± 0.7	7	7.4 ± 2.8
Canada waterweed (*Elodea canadensis*)	34	-	46	-
False pimpernel (*Lindernia dubia*)	32	2.5 ± 1.3	1	< 0.1
Redroot flatsedge (*Cyperus erythrorhizos*)	29	6.6 ± 2.0	1	0.2 ± 0.2
Soft-stem bulrush (*Schoenoplectus tabernaemontani*)	27	0.5 ± 0.1	23	12.9 ± 3.8
Nodding smartweed (*Polygonum lapathifolium*)	27	3.5 ± 1.1	5	1.1 ± 0.7
Teal lovegrass (*Eragrostis hypnoides*)	27	11.6 ± 4.0	0	0
Rough fruit amaranthus (*Amaranthus tuberculatus*)	25	3.5 ± 1.1	0	0
Reed canary grass (*Phalaris arundinacea*)	24	1.2 ± 0.4	10	19.3 ± 8.6
Coon’s tail (*Ceratophyllum demersum*)	24	-	57	-
American lotus (*Nelumbo lutea*)	23	18.3 ± 52	15	12.5 ± 3.5
White waterlily (*Nymphaea odorata*)	22	12.4 ± 40	27	29.0 ± 5.1
Blunt spikerush (*Eleocharis obtusa*)	21	0.3 ± 1.2	4	1.4 ± 1.3

[1] Biomass not determined for submersed aquatic species.

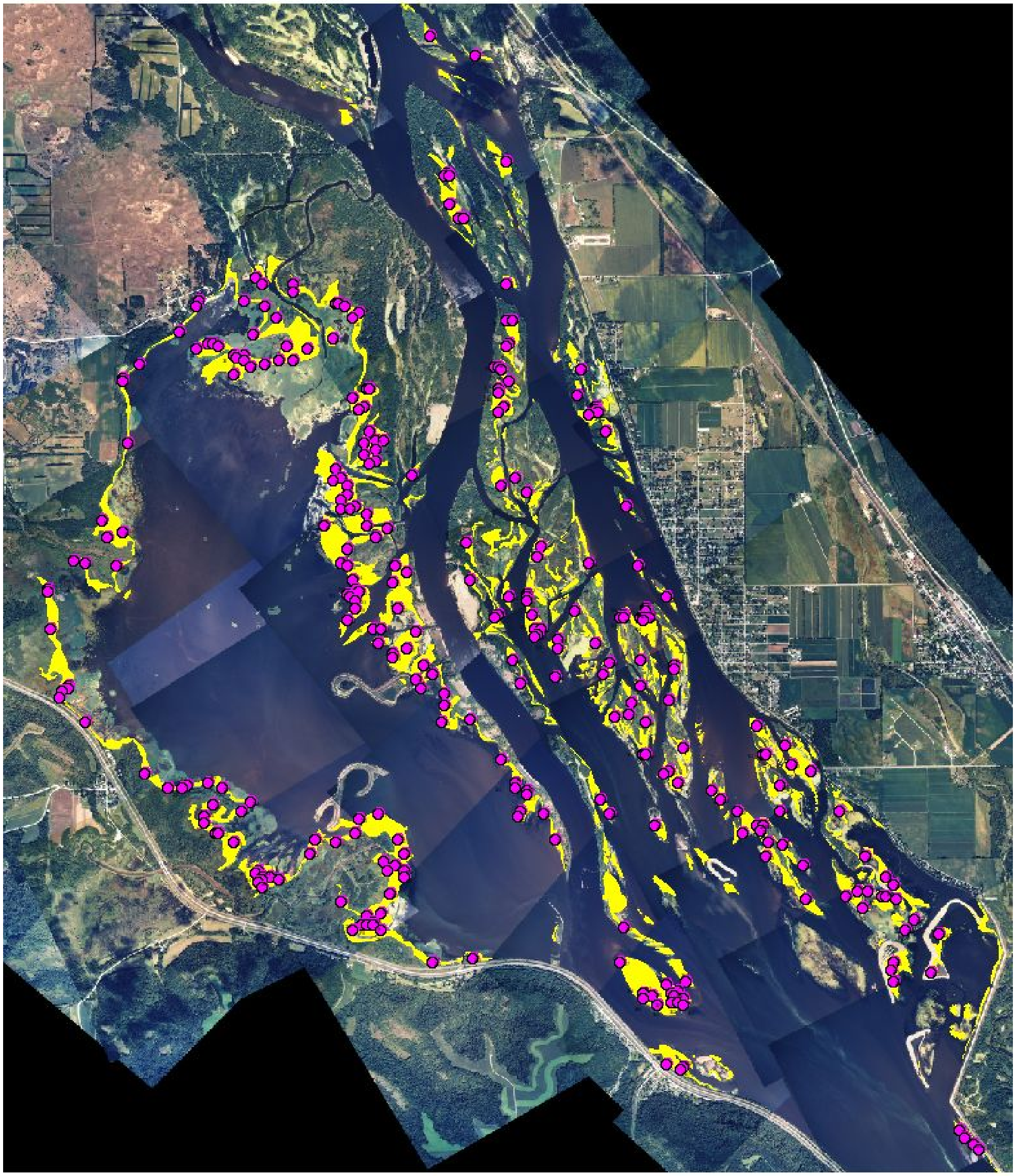

Figure 1. Location of sample sites (purple dots) for evaluating 2006 vegetation response on substrates exposed (indicated in yellow) during the 2005 drawdown of Navigation Pool 5, Upper Mississippi River (random distribution based on exposed area depicted on 15 July 2005 photography). Exposed substrate ArcView shapefile was developed by on-screen digitizing the exposed substrate visible on a 15 July 2005 aerial photo mosaic and projected in UTM Zone 15, NAD83. The extent of substrate exposed was determined to be approximately 1,002 acres.

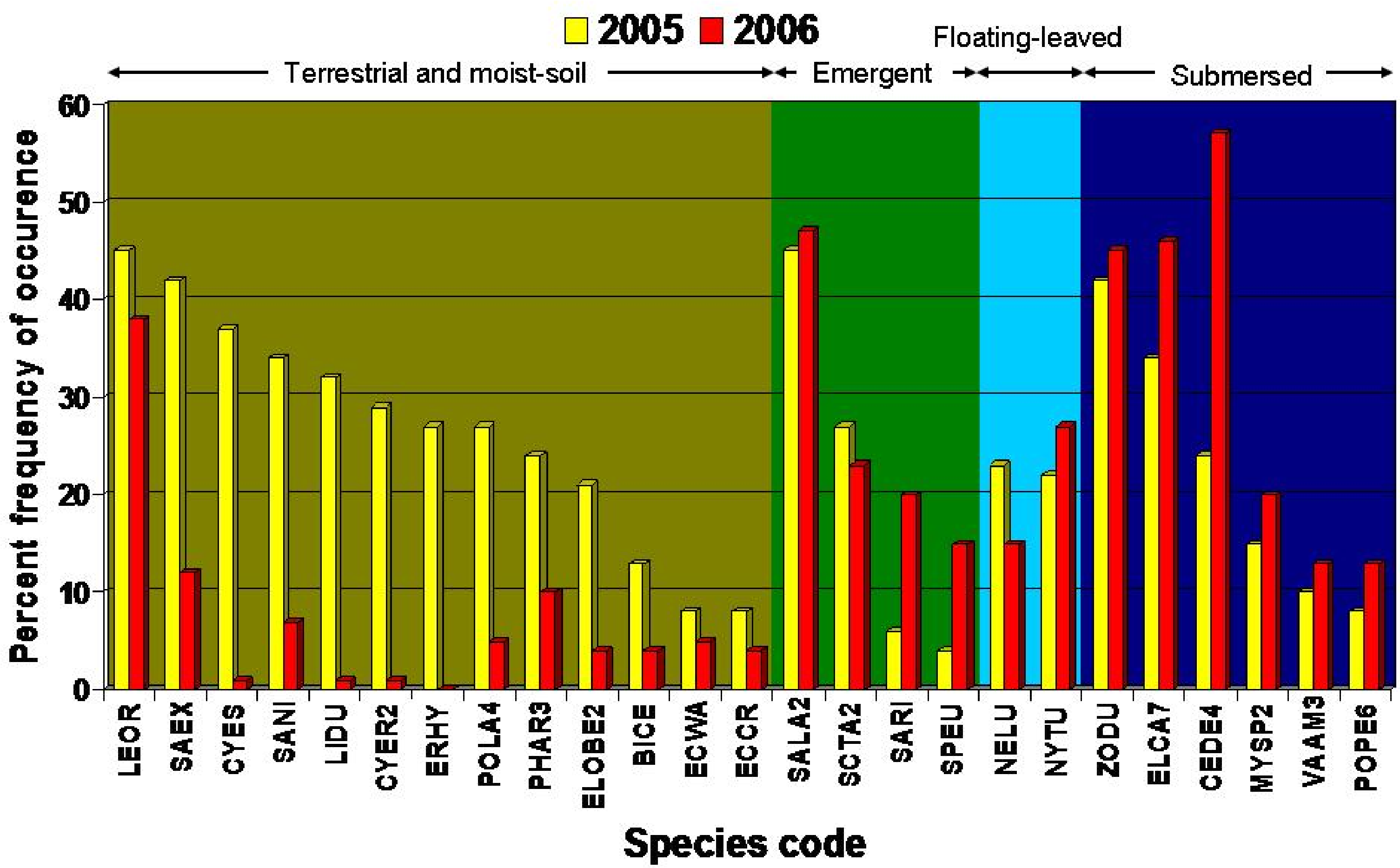

Figure 2. Frequency of occurrence of dominant terrestrial/moist-soil, emergent, floating-leaved, and submersed aquatic species in 2005 (yellow) and 2006 (red) found among Pool 5 sites that were exposed during the 2005 drawdown. Species codes are defined in table 1 (‘ERHY’ = *Eragrostis hypnoides*).