Date: 30 September 2011
Mary Stefanski
Upper Mississippi River National Wildlife and Fish Refuge
Winona District
51 East 4th Street, Room 203
Winona, MN 55987

Dear Mary,

This report summarizes the initial results of our investigation of the vegetation response on areas exposed during the 2010 drawdown of Navigation Pool 6, Upper Mississippi River. It is submitted in partial fulfillment of the Scope of Work entitled "Vegetation response on areas exposed during a pool-wide water level reduction of Upper Mississippi River Navigation Pool 6"; U.S. Fish and Wildlife Service, Upper Mississippi River National Wildlife and Fish Refuge – Winona District, USDI Inter/Intra-Agency Agreement (August 2009).

If you have any questions regarding this report, please do not hesitate to contact me.

Sincerely,

Kevin Kenow
Research Wildlife Biologist

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

Background

The U.S. Army Corps of Engineers (USACE) has implemented experimental water level reductions (drawdowns) on the Upper Mississippi River (UMR) during the summer growing season under deviations from approved pool regulation plans. These drawdowns were recommended by the Water Level Management Task Force (WLMTF) of the River Resources Forum, an advisory group to the St. Paul District, USACE, for the primary purpose of enhancing aquatic plant production and habitat diversity. The experimental water level management techniques provide for seasonal water level reductions, while simultaneously permitting commercial navigation (i.e., barge passage) on this large multi-use system. Information is needed on the biotic response to these water level manipulations to inform resource managers of the efficacy of such a strategy.

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

UMESC and state partners monitored vegetation response to past drawdowns of Pool 8 and Pool 5 (Kenow et al. 2007, Kenow et al. 2007, Kenow and Lyon 2008). A number of vegetation characteristics were monitored in the drawdown zone, including above ground biomass, species composition, frequency of occurrence, stem density, and cover. Based on this previous work, it was anticipated that the Pool 6 summer drawdown would increase diversity, abundance, and distribution of emergent and submersed aquatic vegetation during the year of the drawdown. Resource agencies are committed to continuing evaluation of drawdown effects on vegetation in order to document the anticipated benefits of this water management technique.

Methods

Vegetation above-ground biomass was measured at 303 randomly selected locations within areas delineated as exposed substrate during the drawdown that were 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 27 July 2010 (Lock and Dam 6 Discharge- 40,200 cubic feet per second (cfs), Lock and Dam 6 Pool Elevation – 643.60 feet above mean sea level (ft msl), Winona Elevation – 646.14 ft msl). The drawdown was initiated on 18 June and a full one-foot drawdown (at Lock and Dam 6) was achieved on about 01 July. 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.

Vegetation sampling was conducted between 18 August and 8 September 2010. Clusters of sites to be sampled each day were randomly selected to avoid any spatial bias, as plants potentially were still germinating, growing, and senescing during the three week sampling period. Field crews located the sampling sites using a Garmin GPS receiver.

At each sample location, cover class (Daubenmire 1959) was determined by species, and stem counts obtained for most emergent, moist-soil, and terrestrial species occurring within 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*], reed canary grass [*Phalaris arundinacea*]). 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 48 hrs) 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 2010 drawdown period for each sample site, using estimates of site bed elevation and water level estimates obtained from gages. This information was used to determine the likelihood that a given sample site was dewatered. Water levels were determined within the Pool 6 study area by linear interpolation between data from U.S. Army Corps of Engineers gages at Lock and Dam 6 and Winona, Minnesota. Water surface slope laterally across the floodplain was assumed to be zero. Water elevation was calculated for each river mile for each day based on the 8:00 AM gage data. Using a GIS, vegetation sampling sites were assigned a river mile within the study area. Bed elevations for 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.

Descriptive statistics concerning frequency of occurrence, average percent cover, and average above-ground biomass were generated using SAS® software. 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.

Results

The drawdown initiated on 18 June was maintained through 26 August, when the Pool level was gradually raised to normal level by 3 September (Figure 2). An area of about 286 acres were 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. We sampled 303 sites within the 'exposed' areas, but only 46.5% (141) of the sites fell on substrates exposed with drawdown based on estimates of bed elevation at each site and a GIS model of water surface profile during the drawdown. We were unable to locate photographic coverage collected earlier in July. Consequently, our best estimate of substrate exposed as a result of the drawdown is 133 acres (286*0.465=133 acres).

Data collected at the 141 sample sites regarded to have been exposed during the drawdown was used in the subsequent analyses. At these 141 sites, the average length of exposure was 22 days, and ranged from 1 to 66 days. These sites were dominated by submersed, moist-soil, emergent, and floating-leaved aquatic species. Researchers identified about 66 plant species (Table 1). 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 crispu*s), 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 (Table 2).

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 (Table 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 ($P > 0.12$). 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)(Table 2).

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 (Table 3, Figure 3). 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.

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 (Cottam 1939, Martin and Uhler 1939, Bellrose and Anderson 1943, Weller 1978, Fredrickson and Reid 1988, Korschgen et al. 1988). The finding from this study, coupled with investigations in Pools 8 and 5 across multiple years, contributes to an improved understanding of vegetation response to drawdowns on the Upper Mississippi River.

Acknowledgements

Steve Houdek, Pete Boma, and Luke Fara supervised field crews, processed vegetation in the laboratory, and contributed to the production of this report. Mark Roth provided field assistance. Jim Rogala modeled water surface elevation relative to bed elevation for each sample site. Jenny Hanson and Larry Robinson mosaicked and interpreted the aerial photography, and developed the exposed substrate shapefile used to select sample locations.

Literature Cited

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.

Daubenmire, R. F. 1959. A canopy-coverage method of vegetational analysis. Northwest Science 33:43-64.

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., and J.E. Lyon. 2008. Composition of the seed bank in drawdown areas of Navigation Pool 8 of the Upper Mississippi River. River Research and Applications (2008) , DOI: 10.1002/rra.

Kenow, K. P., J. T. Rogala, and L. R. Robinson. 2007a. 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.

Kenow, K. P., J. T. Rogala, and P. J. Boma. 2007b. Evaluation of 2006 vegetation response on areas exposed during the 2005 drawdown of Navigation Pool 5, Upper Mississippi River. Submitted to St. Paul District, US Army Corps of Engineers.

Korschgen, CE, LS George, and WL Green. 1988. Feeding ecology of canvasbacks staging on Pool 7 of the Upper Mississippi River. In: Weller, MW (Ed.), Waterfowl in Winter, University of Minnesota Press, Minneapolis.

Martin, WC and FM Uhler. 1939. Food of game ducks in the United States and Canada. U.S. Department of Agriculture Technical Bulletin 634. 156 pp.

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.

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

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Table 1. List of plants that were found in the 141 sites sampled on Pool 6 substrates exposed during the 2010 drawdown. Naming convention and symbol after U.S. Department of Agriculture, National Resources Conservation Service (2007). Life form categories are E=emergent, F=floating, M=moist-soil, S=submersed, Sh=shrub, and Tr=tree.

Scientific Name	Common name	Life form	USDA symbol
	Alga	F	2ALGA
Acer saccharinum	silver maple	Tr	ACSA2
Amaranthus retroflexus	redroot amaranth	M	AMRE
Amaranthus tuberculatus	rough fruit amaranthus	M	AMTU
Azolla caroliniana	Carolina mosquito-fern	F	AZCA
Betula nigra	river birch	Tr	BENI
Bidens cernua	nodding beggar-ticks	M	BICE
Bidens coronata	crowned beggar-ticks	M	BICO
Boehmeria cylindrica	smallspike false nettle	M	BOCY
Carex spp.	sedge	M	CAREX
Ceratophyllum demersum	coon's tail	S	CEDE4
Cyperus erythrorhizos	redroot flatsedge	M	CYER2
Cyperus esculentus	chufa flatsedge	M	CYES
Cyperus rivularis	shining flatsedge	M	CYBI6
Cyperus squarrosus	bearded flatsedge	M	CYSQ
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
Eragrostis hypnoides	teal lovegrass	M	ERHY
Heteranthera dubia	grassleaf mudplantain	S/M	ZODU
Impatiens sp.	touch-me-not	M	IMPAT
Juncus sp.	Rush	M	JUNCU
Laportea canadensis	Canadian woodnettle	M	LACA3
Leersia oryzoides	rice cutgrass	M	LEOR
Lindernia dubia	false pimpernel	M	LIDU
Ludwigia palustris	water purslane	M	LUPA
Lycopus americanus	American water horehound	M	LYAM
Lycopus uniflorus	northern bugleweed	M	LYUN
Lysimachia hybrida	lowland yellow loosestrife	M	LYHY
Lysimachia sp.	yellow loosestrife	M	LYSIM
Lythrum salicaria	purple loosestrife	M	LYSA2
Mentha arvensis	wild mint	M	MEAR4
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
Nettle sp.[a]	nettle	M	
Nymphaea odorata	white waterlily	F	NYTU
Panicum capillare	witchgrass	M	PACA6
Phalaris arundinacea	reed canary grass	M	PHAR3
Pontederia cordata	pickerelweed	E	POCO14

Polygonum lapathifolium	nodding smartweed	M	POLA4
Populus deltoides	eastern cottonwood	Tr	PODE3
Potamogeton crispus	curly-leafed pondweed	S	POCR3
Potamogeton foliosus	leafy pondweed	S	POFO3
Potamogeton pectinatus	sago pondweed	S	POPE6
Potamogeton zosteriformis	flat-stem pondweed	S	POZO
Ranunculus trichophyllus	threadleaf crowfoot	S	RATR
Rorippa islandica	northern marsh yellowcress	M	ROIS2
Rumex sp.	dock	M	RUMEX
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
Scutellaria lateriflora	blue skullcap	M	SCLA2
Sparganium eurycarpum	broadfruit bur-reed	E	SPEU
Stachys tenuifolia	smooth hedgenettle	M	STTE
Typha sp.	cattail	E	TYPHA
Urtica dioica	stinging nettle	M	URDI
Vallisneria americana	wild celery	S	VAAM3
Veronica americana	American speedwell	M	VEAM2
Verbena hastata	swamp verbena	M	VEHA2
Zizania aquatica	wild rice	E	ZIAQ

[a]Likely *Urtica, Boehmeria,* or *Pilea spp*.

Table 2. Frequency of occurrence, average percent cover, and average above-ground biomass for the most frequently observed species among the 141[a] sites sampled on Upper Mississippi River Navigation Pool 6 substrates exposed during the 2010 drawdown.

			Mean (± SE) aboveground biomass (g/m^2 dw)	
Species	Percent frequency of occurrence	Overall percent cover (Mean ± SE)	All sample quadrats	At quadrats where species occurred
Grassleaf mudplantain (*Heteranthera dubia*)	44	8.2 ± 1.7	9.60 ± 3.62	21.32 ± 8.00
Canada waterweed (*Elodea canadensis*)	43	3.4 ± 0.9	1.90 ± 0.54	4.01 ± 1.14
Coon's tail (*Ceratophyllum demersum*)	41	6.5 ± 1.4	5.85 ± 2.55	14.15 ± 6.07
Rice cutgrass (*Leersia oryzoides*)	38	10.4 ± 1.8	16.04 ± 3.75	42.66 ± 8.89
Curly-leaved pondweed (*Potamogeton crispus*)	31	1.8 ± 0.6	0.57 ± 0.22	1.74 ±0.67
Reed canary grass (*Phalaris arundinacea*)	28	4.1 ± 1.0	4.03 ± 1.56	14.03 ± 5.23
White waterlily (*Nymphaea odorata*)	23	5.6 ± 1.3	4.66 ± 1.48	20.54 ± 5.75
Redroot flatsedge (*Cyperus erythrorhizos*)	22	4.4 ± 1.1	9.59 ± 2.54	43.60 ± 9.35
Chufa flatsedge (*Cyperus esculentus*)	21	6.6 ± 1.5	12.19 ± 3.26	57.30 ± 12.30
Nodding smartweed (*Polygonum lapathifolium*)	21	2.4 ± 0.6	3.15 ± 0.91	15.33 ± 3.67
False pimpernel (*Lindernia dubia*)	18	0.9 ± 0.4	0.19 ± 0.10	0.59 ± 0.26
Wild celery (*Vallisneria americana*)	17	1.9 ± 0.8	0.42 ± 0.24	2.46 ± 1.35
Sandbar willow (*Salix exigua*)	17	0.8 ± 0.2	0.41 ± 0.13	2.42 ± 0.66
Sessile fruit arrowhead (*Sagittaria rigida*)	15	2.5 ± 0.8	3.00 ± 1.28	20.13 ± 7.72
Sago pondweed (*Potamogeton pectinatus*)	15	1.0 ± 0.3	0.25 ± 0.10	1.68 ± 0.59
Common arrowhead (*Sagittaria latifolia*)	14	0.8 ± 0.3	1.36 ± 1.12	9.57 ± 7.82
Broadfruit bur-reed (*Sparganium eurycarpum*)	14	4.6 ± 1.4	23.44 ± 8.31	165.23 ± 48.56
Teal lovegrass (*Eragrostis hypnoides*)	12	1.6 ± 0.7	3.62 ± 2.68	30.03 ± 21.73
Eurasian watermilfoil (*Myriophyllum spicatum*)	12	0.3 ± 0.1	0.11 ± 0.04	0.89 ± 0.24
Rough fruit amaranthus (*Amaranthus tuberculatus*)	10	0.5 ± 0.3	0.91 ± 0.67	9.14 ± 6.59
Flat-stem pondweed (*Potamogeton zosteriformis*)	10	0.2 ± 0.1	0.05 ± 0.02	0.46 ± 0.16
Blunt spikerush (*Eleocharis obtuse*)	10	0.4 ± 0.2	0.43 ± 0.21	4.35 ± 1.88
Pickerelweed (*Pontederia cordata*)	9	2.2 ± 0.9	5.88 ± 2.81	63.76 ± 26.24
Purple loosestrife (*Lythrum salicaria*)	8	0.7 ± 0.4	0.75 ± 0.58	9.51 ± 7.26
Barnyard grass (*Echinochloa crusgalli*)	7	1.9 ± 0.8	6.55 ± 3.29	92.40 ± 38.72

[a] 303 sites were visited, but many sites were not exposed with drawdown; 141 were retained for this analysis. Water surface elevation relative to bed elevation was used to define sample sites that were exposed during the drawdown.

Table 3. Frequency of occurrence and average above-ground biomass for the most frequently observed species on exposed sites (n=166) on Navigation Pool 5 during the 2005 drawdown and on exposed sites (n=141) on Navigation Pool 6 during the 2010 drawdown, Upper Mississippi River.

Taxa	Pool 5 (2005)		Pool 6 (2010)	
	Frequency of occurrence (%)	Mean (± SE) aboveground biomass (g/m^2 dw)	Frequency of occurrence (%)	Mean (± SE) aboveground biomass (g/m^2 dw)
Rice cutgrass (*Leersia oryzoides*)	45	11.4 ± 2.3	38	16.0 ± 3.8
Common arrowhead (*Sagittaria latifolia*)	45	9.8 ± 3.0	14	1.4 ± 1.1
Sandbar willow (*Salix exigua*)	42	7.4 ± 1.8	17	0.4 ± 0.1
Grassleaf mudplantain (*Heteranthera dubia*)	42	-[a]	44	9.6 ± 3.6
Chufa flatsedge (*Cyperus esculentus*)	37	6.3 ± 1.4	21	12.2 ± 3.3
Black willow (*Salix nigra*)	34	2.2 ± 0.7	1	<0.1
Canada waterweed (*Elodea canadensis*)	34	-	43	1.9 ± 0.5
False pimpernel (*Lindernia dubia*)	32	2.5 ± 1.3	18	0.2 ± 0.1
Redroot flatsedge (*Cyperus erythrorhizos*)	29	6.6 ± 2.0	22	9.6 ± 2.5
Soft-stem bulrush (*Schoenoplectus tabernaemontani*)	27	0.5 ± 0.1	6	0.1 ± 0.1
Nodding smartweed (*Polygonum lapathifolium*)	27	3.5 ± 1.1	21	3.2 ± 0.9
Teal lovegrass (*Eragrostis hypnoides*)	27	11.6 ± 4.0	12	3.6 ± 2.7
Rough fruit amaranthus (*Amaranthus tuberculatus*)	25	3.5 ± 1.1	10	0.9 ± 0.7
Reed canary grass (*Phalaris arundinacea*)	24	1.2 ± 0.4	28	4.0 ± 1.6
Coon's tail (*Ceratophyllum demersum*)	23	-	41	5.8 ± 2.6
American lotus (*Nelumbo lutea*)	23	18.3 ± 52	3	0.3 ± 0.2
White waterlily (*Nymphaea odorata*)	22	12.4 ± 40	23	4.7 ± 1.5
Blunt spikerush (*Eleocharis obtusa*)	21	0.3 ± 1.2	10	0.4 ± 0.2
Eurasian watermilfoil (*Myriophyllum spicatum*)	14	-	12	0.1 ± 0.04
Nodding beggartick (*Bidens cernua*)	13	1.4 ± 0.4	5	0.7 ± 0.5
Cattail (*Typha spp.)*	11	2.9 ± 2.9	2	0.1 ± 0.1
Marsh seedbox (*Ludwigia palustris*)	11	0.1 ± 0.05	1	<0.1
Northern marsh yellowcress (*Rorippa islandica*)	10	0.2 ± 0.1	4	<0.1
Wild celery (*Vallisneria americana*)	10	-	17	0.4 ± 0.2
Witchgrass (*Panicum capillare*)	10	0.4 ± 0.2	4	0.2 ± 0.1
Sago pondweed (*Potamogeton pectinatus*)	8	-	15	0.3 ± 0.1
Sessilefruit arrowhead (*Sagittaria rigida*)	6	0.7 ± 0.4	15	3.0 ± 1.3
Broadfruit bur-reed (*Sparganium eurycarpum*)	4	0.1 ± 0.03	14	23.4 ± 8.3

[a] Biomass not determined for submersed aquatic species at Pool 5 in 2005.

Figure 1. Location of sample sites (red dots) for evaluating vegetation response on substrates exposed (indicated in yellow) during the 2010 drawdown of Navigation Pool 6, Upper Mississippi River (random distribution based on exposed area depicted on 27 July 2010 photography). Exposed substrate ArcView shapefile was developed by on-screen digitizing the exposed substrate visible on a 27 July 2010 aerial photo mosaic and projected in UTM Zone 15, NAD83.

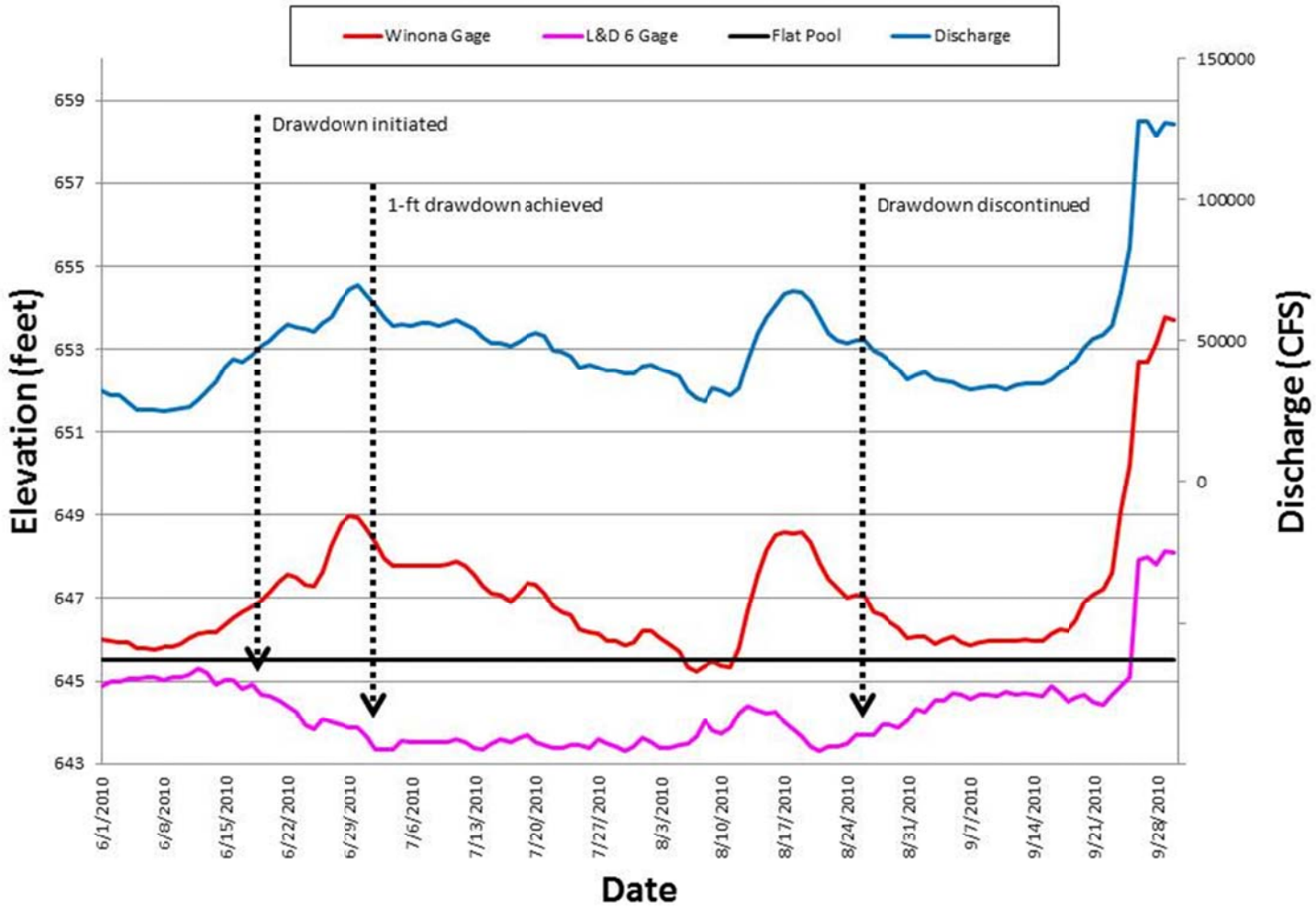

Figure 2. Upper Mississippi River Navigation Pool 6 water elevation (feet msl) at Lock & Dam 6 and Winona gages, and Lock & Dam 6 discharge (cfs) during June through September 2010.

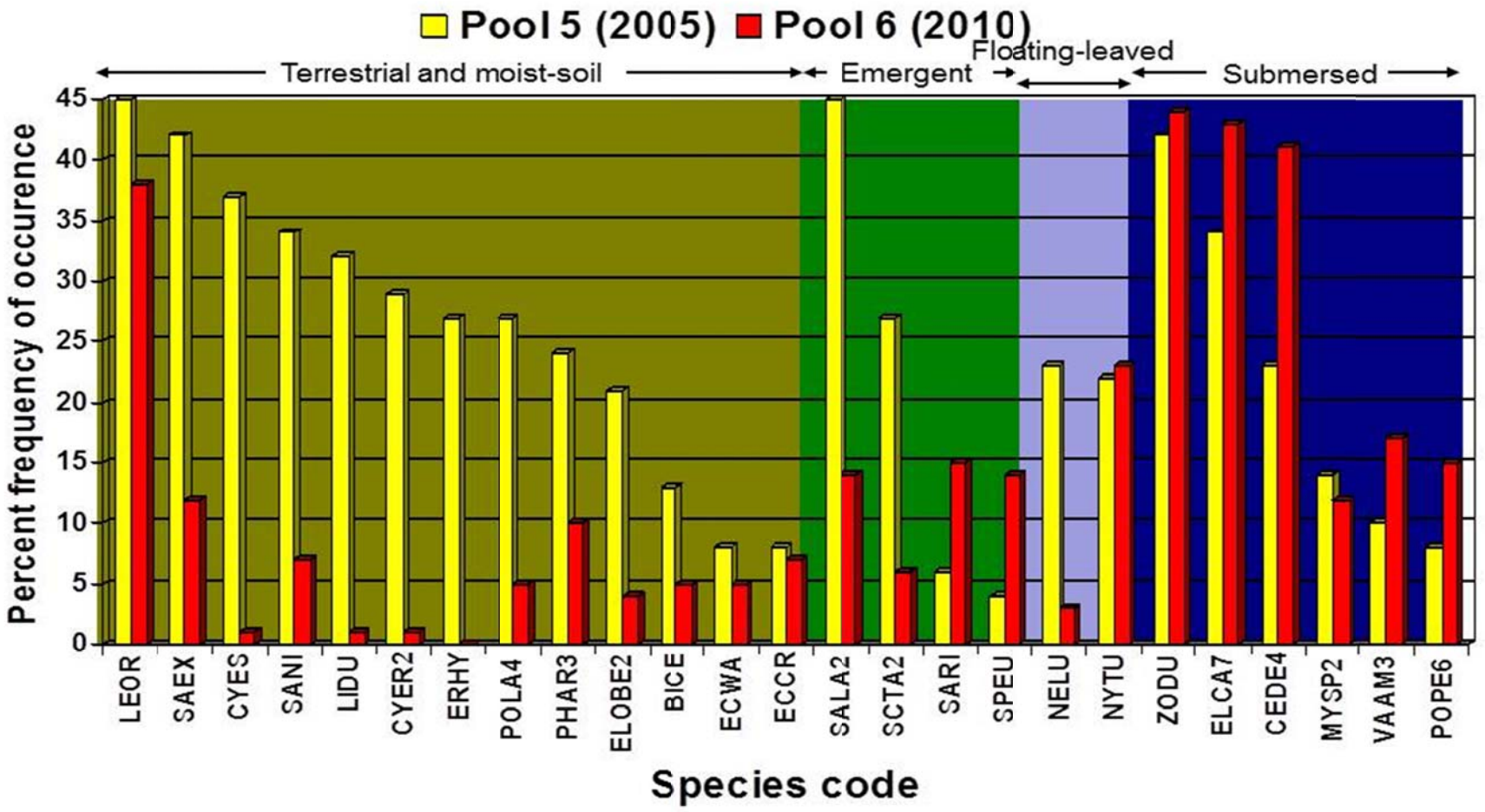

Figure 3. Frequency of occurrence of dominant terrestrial/moist-soil, emergent, floating-leaved, and submersed aquatic species in Pool 5 (2005; yellow) and Pool 6 (2010; red) found among sites that were exposed during the respective drawdowns. Species codes are defined in Table 1.