Prepared in cooperation with the U.S. Fish and Wildlife Service

Effects of a Drawdown on Plant Communities in a Freshwater Impoundment at Lacassine National Wildlife Refuge, Louisiana

Scientific Investigations Report 2012–5221

U.S. Department of the Interior
U.S. Geological Survey

Front cover:

Top, Coot (*Fulica americana*) in Unit D subimpoundment, Lacassine National Wildlife Refuge, Louisiana, March 2012.

Bottom, Outflow gate for Unit D subimpoundment, Lacassine National Wildlife Refuge, Louisiana, March 2012.

Background, Unit D subimpoundment, Lacassine National Wildlife Refuge, Louisiana, March 2012.

Back cover:

Top, Unit D subimpoundment, Lacassine National Wildlife Refuge, Louisiana, March 2012.

Bottom, Sign on a levee at Unit D subimpoundment, Lacassine National Wildlife Refuge, Louisiana, March 2012.

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Conversion Factors

Inch/Pound to SI

Multiply	By	To obtain
	Length	
inch (in.)	2.54	centimeter (cm)
foot (ft)	0.3048	meter (m)
	Area	
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
	Mass	
ounce, avoirdupois (oz)	28.35	gram (g)

Temperature in degrees Fahrenheit (°F) may be converted to degrees Celsius (°C) as follows:

$$°C=(°F-32)/1.8$$

Vertical coordinate information is referenced to the North American Vertical Datum of 1988 (NAVD 88).

Effects of a Drawdown on Plant Communities in a Freshwater Impoundment at Lacassine National Wildlife Refuge, Louisiana

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Abstract

Disturbance is an important natural process in the creation and maintenance of wetlands. Water depth manipulation and prescribed fire are two types of disturbance commonly used by humans to influence vegetation succession and composition in wetlands with the intention of improving wildlife habitat value. A 6,475-hectare (ha) impoundment was constructed in 1943 on Lacassine National Wildlife Refuge in southwest Louisiana to create freshwater wetlands as wintering waterfowl habitat. Ten years after construction of the impoundment, called Lacassine pool, was completed, refuge staff began expressing concerns about increasing emergent vegetation cover, organic matter accumulation, and decreasing area of open water within the pool. Because the presence of permanent standing water impedes actions that can address these concerns, a small impoundment within the pool where it was possible to manipulate water depth was created. The 283-ha subimpoundment called Unit D was constructed in 1989. Water was pumped from Unit D in 1990, and the unit was permanently reflooded about 3 years later. Four prescribed fires were applied during the drawdown. A study was initiated in 1990 to investigate the effect of the experimental drawdown on vegetation and soils in Unit D. Four plant community types were described, and cores were collected to measure the depth of the soil organic layer. A second study of Unit D was conducted in 1997, 4 years after the unit was reflooded, by using the same plots and similar sampling methods. This report presents an analysis and synthesis of the data from the two studies and provides an evaluation of the impact of the management techniques applied.

We found that plant community characteristics often differed among the four communities and varied with time. Species richness increased in two of the communities, and total aboveground biomass increased in all four during the drawdown. These changes, however, did not persist when Unit D was reflooded; by 1997, species richness and aboveground biomass were equivalent to values before the drawdown. The change in waterfowl food value of the plant communities during the drawdown varied; it did not change in two communities, increased in one, and decreased in one. A consistent pattern noted was that waterfowl food value was higher in communities that contained open water than in those dominated by emergent plants, both soon after the drawdown was initiated in Unit D and 4 years after reflooding. A reduction in depth of the soil organic layer became apparent 20 months after drawdown was initiated, and this reduction persisted in 1997, 4 years after reflooding. A separate 2003 study on soil characteristics in Lacassine pool found that the depth to the clay layer was lower in Unit D than in the rest of the pool. We were not able to establish a cause-and-effect relation between any changes noted and the fact water levels in the unit were drawn down because the initial study in 1990 did not include control plots. Changes in vegetation and soil organic layer depth identified in Unit D may have occurred in the surrounding Lacassine pool habitat as well. Similarly, we were unable to form any conclusions about the effect of the prescribed fire treatments because there was no information on which plots were burned. Because of the known relation between anaerobic soil conditions and reduced decomposition of organic matter, however, it is likely that the drawdown in Unit D resulted in an increased decomposition rate and a reduction in the depth of the soil organic layer.

Introduction

Wetland impoundments designed to provide high-quality waterfowl habitat have been constructed on State-owned lands in coastal Louisiana since the early 1950s (Chabreck, 1960). At that time impoundments were viewed as a means to protect wetlands from destruction due to conversion to agricultural land and to prevent more gradual wetland loss resulting from the tidal erosion and salt water intrusion associated with channelization for navigation and oil and gas pipeline placement (Chabreck, 1960). Impoundments are often actively managed to vary water levels seasonally. Because levees and weirs limit hydrologic exchange between these managed marshes and the surrounding environment, the sustainability of some impounded marshes has been questioned. For example, one study documented that some brackish marsh impoundments in coastal Louisiana had lower vertical accretion, lower soil bulk density and mineral matter content, and higher organic matter content compared to unmanaged reference marshes (Cahoon, 1994). These findings suggested that reduced sediment deposition in the impounded marshes would result in a shorter life expectancy for those marshes. Other studies have also identified lower sedimentation and lower surface elevation in impounded marshes compared to marshes that retained hydrologic connectivity (Reed and others, 1997; Bryant and Chabreck, 1998; Gabrey and Afton, 2001). Bryant and Chabreck (1998), however, found that a permanently flooded freshwater impoundment (that is, no active water management was applied) had greater accretion than did a nearby natural marsh. Cowan and others (1988) noted that the success of marsh management in Louisiana appears to be inversely related to salinity. Freshwater wetlands without tidal influence may be able to sustain adequate accretion through organic matter production and thereby maintain vigorous plant communities. The freshwater impoundment at Lacassine National Wildlife Refuge in southwest Louisiana is an example of such a wetland system, and is characterized by highly organic soils and abundant cover of emergent wetland plant species.

Lacassine National Wildlife Refuge (NWR) was established in 1937 with the primary objective of preserving high-quality habitat for wintering waterfowl species (U.S. Fish and Wildlife Service [USFWS], 2007); the refuge supports peak wintering populations of more than 300,000 ducks and 80,000 geese (USFWS, 2010). Soon after the refuge was established construction began of a 6,475-hectare (ha) freshwater impoundment called Lacassine pool. The pool, completed in 1943, is enclosed by earthen dikes formed by using materials dredged from within and adjacent to the impoundment. Precipitation is the normal water source for the pool. Although pool water levels can be lowered by gravitational flow through a system of three spillways with stop-log structures, complete drainage cannot be achieved by using these structures. The only option for completely draining the pool is to use pumps to actively remove the water.

By 1953 refuge personnel noted that vegetation cover within Lacassine pool was increasing while open water, an important habitat for wintering waterfowl, was decreasing (USFWS, 2007). Focus centered on the increased cover of the emergent species *Panicum hemitomon* and *Sagittaria lancifolia* because they are considered low quality as waterfowl food sources and resting areas. Because of the indications that waterfowl and fisheries habitat values have decreased over time in conjunction with the increased cover of emergent vegetation, concerns over the current condition of the pool remain. Concurrent with the noted increase in vegetation cover was the perceived increase in organic matter accumulation and a resulting increase in sediment surface elevation within the pool, limiting the extent of open water. Succession toward a primarily palustrine scrub/shrub habitat in the pool is thought to be likely.

Vertical accretion in wetlands results from the accumulation of both organic matter and mineral sediment (Hatton and others, 1983; Callaway and others, 1996). Because there are no inflows to Lacassine pool, little mineral sediment enters the system; such material can be introduced, however, when water is pushed over the pool levees during storm events. Organic matter originating from plants growing in the pool is therefore the primary factor influencing sediment accretion. Wetland plant growth and production are influenced by several factors, including herbivory, nutrient supply, flooding duration and depth, and salinity level. Accumulation of the organic matter produced by plants is affected by compaction and decomposition rate, which is in turn influenced by temperature, flooding, nutrient availability to decomposing organisms, and the quality of plant material (Mitsch and Gosselink, 2007). The feedback loop between plant production, flooding, and vertical accretion has been described by Nyman and others (1993). To influence plant species composition and cover, which in turn influence plant productivity, prescribed fire is a traditional management technique that has been applied in coastal marshes for decades (Lynch, 1941; Givens, 1962; Hoffpauer, 1968). Fire acts to release nutrients for plant growth and to remove litter and standing live plants (Faulkner and de la Cruz, 1982; Laubhan, 1995). As noted by Nyman and Chabreck (1995), burning may reduce vertical accretion if peat is destroyed, but it may enhance vertical accretion if root production is stimulated. Burning season and fire frequency and intensity will determine if prescribed fire has a negative or positive effect on vegetation and marsh accretion.

The current comprehensive conservation plan for Lacassine NWR includes an objective for the pool to "… achieve a habitat mosaic in an approximate emergent vegetation to open water ratio of 50:50, with plants of high waterfowl food value and extensive beds of submerged aquatic vegetation, so as to provide roosting and foraging habitat and sanctuary from disturbance for migratory birds, fish, and other wildlife compatible with the purposes of the refuge" (USFWS, 2007, p. 58). Actions taken to control emergent plant cover and increase the occurrence of preferred waterfowl food species in the pool include maintaining water levels at full pool level (depth of 0.4 meters [m] above mean sea level, referenced to the North American Datum of 1988 [NAVD 88]) during the spring and summer and lowering levels in the fall and winter to make food more readily available to waterfowl.

Prescribed fire has been used to influence plant species composition in Lacassine NWR since 1939 (Bass, 2004). In recent years sections of Lacassine pool have been burned during the fall or winter on a 3-year or longer rotation (USFWS, 2007, p. 67). Because spillway structures do not allow complete draining of the entire pool, the soil remains saturated during the prescribed burns in the fall. Under these conditions (that is, with standing water present), the prescribed fire is called a cover burn (Lynch, 1941); these fires typically remove dense vegetation but do not alter plant community composition. The fire type described by Lynch (1941) as a root burn requires a dry substrate and has the potential to kill belowground plant tissues and thereby alter plant community structure and composition. Because pumping water from the entire pool is not economically feasible, a smaller subimpoundment called Unit D was constructed in 1989 to remove all standing water from a smaller area. Water was pumped from the unit in 1990, and periodic prescribed fires were applied over 3 years (see "Methods—Management Actions") before the unit was permanently reflooded in 1993.

Two studies were conducted in Unit D during the 1990s to document any change in vegetation and soil characteristics that may have occurred during the drawdown period (March 1990 to January 1993) and subsequent reflooding. Data on plant community composition and soil characteristics were recorded, but this information was not consolidated to provide an overall summary of management effects. The objectives of this report are to analyze and synthesize data from the two 1990s studies and to provide an evaluation of the impact of the management techniques applied in Unit D on plant communities and soil organic matter accumulation.

Methods

Study Area

Lacassine NWR (fig. 1) is located in Cameron Parish in the Mermentau River Basin of southwestern Louisiana and encompasses about 14,200 ha of freshwater marshes, bayous, and interspersed uplands. Common wetland plant species found in Lacassine pool include *Panicum hemitomon*, *Eleocharis flavescens*, *Eleocharis elongata*, *Hydrocotyle* spp., and *Sacciolepis striata* in emergent marshes and *Nymphaea odorata* and *Utricularia* sp. in areas with open water (Howard and others, 2011). The vegetation assemblage of the pool is typical of the fresh maidencane (*Panicum hemitomon*) type (Visser and others, 2000) that covers about 17 percent of the marsh area in the Chenier Plain. Unit D, with an area of 283 ha, supports vegetation typical of the larger pool. It contains both vegetated and open-water areas when flooded, and water depth ranges from 0.9 to 1.2 m (USFWS, 2007). Soils of Unit D consist of about equal coverage of Allemands muck and Ged mucky clay (U.S. Department of Agriculture [USDA], 1995). Allemands muck is a very poorly drained organic soil that is characteristic of freshwater wetlands. It typically has an organic layer of very fluid muck up to 76 centimeters (cm) deep that overlays a fluid mucky clay layer to a depth of about 94 cm; the underlying material of clay above silty clay loam extends to a depth of about 168 cm (USDA, 1995). Ged mucky clay is a poorly drained mineral soil in freshwater wetlands. The surface layer of this soil is a fluid mucky clay about 10 cm deep with a fluid clay subsurface layer about 25 cm thick; a firm clay subsoil layer extends to a depth of about 152 cm (USDA, 1995).

Management Actions

Refuge records indicate that water was pumped from Unit D beginning in mid-March 1990 and continued through early November 1990. At that time the unit was reflooded and water was maintained at the prepumped level through January 1991, when pumping was reinitiated. Pumping then continued from January 1991 through August 1992; the unit was reflooded in January 1993 (W. Syron, Lacassine National Wildlife Refuge, oral commun., December 16, 2010). Any accumulation from precipitation was allowed to remain from the time that pumping stopped until January 1993, when a gate was opened to allow water from the pool to flood the unit. During the time between the initial drawdown and final reflooding (that is, March 1990 through January 1993), four prescribed fires were applied in the unit (table 1). The vegetation plots affected by the fires, however, were not noted.

Past Studies

This report focuses primarily on two studies conducted in the 1990s on Unit D. In the first study, staff of the USDA Soil Conservation Service (SCS, currently the Natural Resources Conservation Service) designed a plan to investigate the effect of the experimental drawdown initiated in 1990 on vegetation and soils within the unit. In this study (hereinafter called the SCS study), the following four plant communities were designated in Unit D prior to the drawdown: (1) an emergent plant community at the northern end of the unit, called the northern prairie community; (2) a central region characterized by floating-leaved species, called the brasenia/lily shallow community; (3) a deeper water area within this central region, called the brasenia/lily deep community; and (4) an emergent community at the south end of the unit, called the southern maidencane community. The SCS study plant species list for the northern prairie community indicated that this area was dominated by *Panicum hemitomon*, as was the southern maidencane community. For clarity in this report, we have renamed the four communities as follows: (1) north panicum (NP), (2) shallow water (SW), (3) deep water (DW), and (4) south panicum (SP).

Ten sampling plots each were located in the NP, SW, and SP communities, and five plots were located in the DW community. No control plots outside Unit D were established. The 35 plots were marked by posts to allow repeated measurements over time. In May 1990, about two months after the drawdown was initiated, vegetation growing in a 1-square-meter (m^2) quadrat at each plot was clipped to the soil surface and bagged. The number of stems by species was counted, and fresh and dry biomass amounts were measured. This procedure was repeated two subsequent times, between June and October 1991 and between August and September 1992. Soil cores were also taken near the vegetation plots at four sites in SP, three sites in SW, and two sites in DW. A core was collected on two separate occasions at a site in the NP community, but the data from these cores indicated that they were collected in an upland area, perhaps on a levee (that is, no organic soil layer was indicated); these cores are excluded from our analyses. The cores were collected by using a McCauley soil auger inserted to the depth where the clay layer was reached. The division between the organic and mineral layers was determined by visual examination, and the depth of

Figure 1. Lacassine National Wildlife Refuge, Louisiana, indicating the location of the Unit D subimpoundment.

each layer was measured. Soil samples were collected on six occasions: May 14, 1990; October 16, 1990; March 14, 1991; November 13, 1991; October 20, 1992; and November 23, 1993. It was noted that there was standing water at the sites in May 1990, March 1991, and November 1993. Original soil data from the SCS study was not available in computer files or as hardcopy. We used hard copies of line graphs, which were provided to the refuge at the conclusion of the SCS study, to extract data on the depth of the soil to the underlying clay layer. The graphs showed the depth of water and depth of organic and mineral soil layers at each of the six sampling times. The graphs were of poor quality (see example in fig. 2), making it difficult to determine organic layer depth. The figure legends were difficult to follow and the gray shadings used in the legend to indicate layers were not distinct. The graphs often illustrated two organic soil layers, but the difference between the layers was not defined. We assumed the upper layer contained living and dead plant roots and rhizomes and

Table 1. Dates of prescribed fires in Unit D of Lacassine pool, Lacassine National Wildlife Refuge, Louisiana.

[The approximate area burned, plant communities affected (NP, north panicum; SP, south panicum; DW, deep water; SW, shallow water), and a description of the burn location are indicated. Information is from hand-drawn maps provided in unpublished U.S. Department of Interior Individual Fire Reports. ha, hectare; %, percent]

Date	Area burned (ha)	Communities affected	Description of location
August 22, 1990	20.2	SP	Southwest corner of Unit D
August 2, 1991	5.9	NP	Northeast section of Unit D
November 14, 1991	212.5	SP, SW, DW, NP	About 75% of Unit D; excludes the northwest section
January 25, 1993	212.5	Not available	Not available

the lower contained decomposed organic material. The two layers were added to obtain a single value for our analyses (table 2). Each of the graphs provided by the SCS had a lower limit of 102 cm below the sediment surface; the soil at this depth was described as being a slightly fluid gray clay.

The second study (hereinafter referred to as the Chabreck study) was conducted in August 1997 by Dr. Robert Chabreck of the Louisiana State University Agriculture Center. He sampled the same plots used in the SCS study and replicated the techniques used. The locations of the plots were recorded by using a Global Positioning System (GPS) (table 3). Unit D was flooded to a depth of 0.9 to 1.2 m during this study. Stems of *Panicum hemitomon* and other emergent species were clipped, but the stems of submersed and floating-leaved species were collected by using a rake (Wayne Syron, Lacassine National Wildlife Refuge, oral commun., October 28, 2010). Soil samples were also collected at the same 10 sites as in the SCS study; soils were cored to a depth described as the “mineral soil hard pan” (Chabreck, 1997, p. 4).

To facilitate analyses of plant community change and assess the possible impacts of such change on wildlife habitat value, we assigned four categorical designations to the plant species identified in the SCS and Chabreck studies. The plant life history category was assigned as annual, biennial, or perennial. Plant life form was indicated as emergent, floating-leaved, or submersed. A wildlife index value (WIV) representing the quality of each species as a waterfowl food source was assigned as follows: (1) high value, (2) moderate

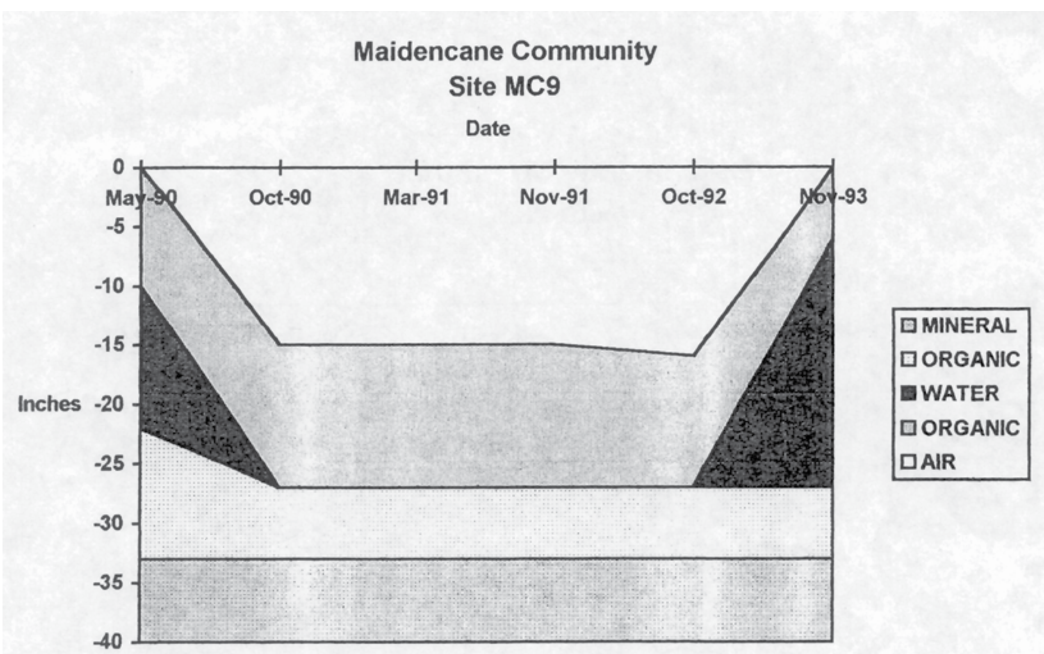

Figure 2. Scan of a figure provided at the conclusion of the study conducted by the Soil Conservation Service in the early 1990s showing the depth of soil layers at a site in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana. This site was designated as community SP, plot 9 in our analyses. One graph indicating all six sampling times was provided for each of nine sites.

Table 2. Depth of the organic soil layer at nine plots in Unit D, Lacassine National Wildlife Refuge, Louisiana.

[Depths are given in centimeters. Plant communities are south panicum (SP), shallow water (SW), and deep water (DW). Plot numbers correspond to those for vegetation sampling (table 3). Data for 1997 are from Chabreck, 1997]

Community	Plot	Date						
		1990		1991		1992	1993	1997
		May	October	March	November	October	November	August
SP	1	61.0	40.6	40.6	40.6	40.6	53.3	27.9
SP	3	43.2	43.2	40.6	38.1	38.1	30.5	25.4
SP	7	91.4	86.4	86.4	78.7	58.4	53.3	15.2
SP	9	50.8	43.2	43.2	43.2	38.1	27.9	20.3
SW	1A	50.8	25.4	25.4	38.1	38.1	35.6	20.3
SW	7A	45.7	33.0	30.5	17.8	17.8	15.2	7.6
SW	10A	86.4	43.2	43.2	30.5	26.7	26.7	12.7
DW	1AD	35.6	30.5	30.5	30.5	25.4	25.4	25.4
DW	5AD	20.3	22.9	10.2	10.2	10.2	10.2	12.7

value, and (3) low value. The WIV were determined by Wayne Syron, Lacassine National Wildlife Refuge, on the basis of information provided in Stutzenbaker (1999). We determined a weighted WIV for each plot by multiplying the value for each plant species by the number of stems for that species, adding the weighted values of all species, and then dividing by the total number of stems in the plot. Finally, a wetness coefficient (WC) between -5 and 5 (table 4) was designated for each plant on the basis of indicator categories as assigned by Reed (1988). Indicator categories reflect the estimated probability of a species occurring in wetland versus nonwetland (upland) areas. The WCs are negative for species with a high frequency of occurrence in wetlands and positive for species with a high frequency of occurrence in uplands (Herman and others, 1996; Allain, 2007). The sum of the coefficients of wetness for species found at a given site is the wetness index and indicates the general wetness of the site. We determined a weighted WC for each plot by using the same method applied to determine the weighted WIV.

A third study on the soils of Lacassine pool was conducted in 2003 (Howard, 2005), and data from that study will be examined herein to determine if soil differences between Unit D and the rest of the pool existed 10 years following the reflooding of Unit D. In the 2003 study, 91 sites selected in a systematic manner to cover the entire pool were sampled and included some sites located in Unit D. The sampling sites were classified into one of two groups: emergent (EM) sites were characterized by the dominance of emergent plants, and sites with permanent standing water (PSW) included those sites with no vegetation, floating-leaved plants, or submersed plants. Soil samples were collected at each site between June and September 2003 by using a McCauley core (50-cm depth, 5-cm diameter; also called a Macauley corer or a Russian peat corer) in 50-cm depth intervals until the clay layer was reached. The presence of the clay layer within a core sample was verified by examining the soil to ensure that an obstacle such as a thick root was not interfering with core placement. Immediately after collection, the depths of two transition zones within the soil column were determined by visual assessment; these measurements were made by the same person at all sites to reduce variation. The transition from organic to mineral soil, distinguished by the change from a dark brown soil color with a watery texture to a lighter brown color with a distinct grainy texture, and the transition to a predominately clay layer, distinguished by a grey color and smooth texture, were recorded. Cores were then cut into 10-cm increments, placed in labeled plastic bags, stored on ice, and refrigerated upon return to the laboratory, where they were placed in a forced-air oven at 80 °C and dried to a constant weight. Among other analyses, organic matter content of each core section was determined. The soil was ground in a commercial mill, and percent organic matter (loss on ignition) was determined by using a method modified from Ben-Dor and Banin (1989). Organic soil was described by Mitsch and Gosselink (2007, p. 164) as soils with more than 20 to 35 percent organic matter. In this study, the organic soil layer was defined as soil with more than 36 percent organic matter. The bottom of the organic soil layer was defined as the midpoint of the first 10-cm soil section encountered at each site that contained less than 36 percent organic matter.

Statistical Analyses

Differences among the four plant community types used in the SCS and Chabreck studies (north panicum, south panicum, deep water, shallow water) were examined by applying a mixed model two-way repeated measures analysis of variance. Community type and year were the independent

Table 3. Locations of sampling plots by community type in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana.

[Data from Chabreck, 1997; the locations of sampling plots in the north panicum (NP) community were not recorded]

Plot number	Latitude	Longitude
South panicum (SP) community		
1	29° 59′ 33.2″ N	92° 53′ 37.6″ W
2	29° 59′ 34.9″ N	92° 53′ 38.5″ W
3	29° 59′ 19.3″ N	92° 53′ 35.8″ W
4	29° 59′ 14.5″ N	92° 52′ 35.7″ W
5	29° 59′ 20.7″ N	92° 53′ 23.6″ W
6	29° 59′ 03.6″ N	92° 53′ 34.3″ W
7	29° 59′ 09.7″ N	92° 53′ 14.7″ W
8	29° 59′ 11.3″ N	92° 53′ 14.7″ W
9	29° 59′ 02.9″ N	92° 52′ 55.1″ W
10	29° 59′ 09.7″ N	92° 52′ 53.1″ W
Shallow water (SW) community		
1A	29° 59′ 17.1″ N	92° 52′ 57.3″ W
2A	29° 59′ 16.8″ N	92° 53′ 04.8″ W
3A	29° 59′ 15.8″ N	92° 53′ 09.1″ W
4A	29° 59′ 24.7″ N	92° 52′ 59.6″ W
5A	29° 59′ 35.5″ N	92° 52′ 41.0″ W
6A	29° 59′ 53.8″ N	92° 52′ 44.8″ W
7A	29° 59′ 45.7″ N	92° 52′ 50.1″ W
8A	29° 59′ 51.7″ N	92° 53′ 01.1″ W
9A	29° 59′ 58.3″ N	92° 52′ 09.5″ W
10A	29° 59′ 54.8″ N	92° 53′ 23.9″ W
Deep water (DW) community		
1AD	29° 59′ 24.7″ N	92° 53′ 30.3″ W
2AD	29° 59′ 26.5″ N	92° 53′ 25.7″ W
3AD	29° 59′ 27.2″ N	92° 53′ 21.1″ W
4AD	29° 59′ 30.8″ N	92° 53′ 24.2″ W
5AD	29° 59′ 28.5″ N	92° 53′ 26.1″ W

variables in the analyses. The response variables were species richness (number of species per plot), total stem number, total aboveground biomass, waterfowl food value, number of emergent species, and wetness indicator value. Because *Panicum hemitomon* is the dominant emergent species in Lacassine pool and is of particular concern to refuge staff, total biomass of this species per plot was also included as a response variable. Information on *Panicum hemitomon* biomass was not available for 1997, so 3 years of data (1990, 1991, 1992) were used. Analysis of variance was applied to the 2003 data with habitat type (Unit D, EM, or PSW) as the independent variable. Response variables were organic layer depth as determined by percent organic content and depth to the clay layer. Residuals in each model were checked for homogeneity and normality, and data were transformed when necessary. The significance level used was $\alpha = 0.05$; this level was adjusted for the number of mean comparisons when needed (for example, 48 comparisons if community type and year interacted to affect a response variable) by using the Bonferroni method. All analyses were conducted by using SAS ver. 9.1 (SAS Institute, Cary, N.C.).

Table 4. Plant indicator categories, codes, and coefficients as applied to plants growing in Unit D of Lacassine pool, Lacassine National Wildlife Refuge, Louisiana.

[Plant indicator categories are from Reed, 1988. Within a category, a positive sign following the code designation indicates a higher frequency of occurrence in wetlands, and a negative sign indicates a lower frequency]

Indicator category	Wetness code	Wetness coefficient
Obligate wetland species	OBL	-5
Facultative wetland species	FACW+	-4
	FACW	-3
	FACW-	-2
Facultative species	FAC+	-1
	FAC	0
	FAC-	1
Facultative upland species	FACU+	2
	FACU	3
	FACU-	4
Upland	UPL	5

Results

The species list from the combined SCS and Chabreck studies comprised 105 species (app. 1). The species count by year was 24 in 1990, 48 in 1991, 55 in 1992, and 16 in 1997. Many species were encountered infrequently; only 27 of the 105 species were found on five or more plots in any given year (frequency greater than or equal to 0.14; table 5). The number of annual (A) species, including those that can function either as annuals or perennials (A/P) or annuals or biennials (A/B), increased during the drawdown years, with 6 such species in 1990, 15 in 1991, 16 in 1992, and 4 in 1997. The percentage of total species in these three categories, however, did not change to a great extent by year and was 25 percent, 31 percent, 29 percent and 25 percent in 1990, 1991, 1992, and 1997, respectively.

Table 5. Plant species found in the Unit D impoundment at Lacassine National Wildlife Refuge, Louisiana, in 1990, 1991, 1992, and 1997.

[Scientific names follow Flora of North America Editorial Committee (http://www.efloras.org). For names not included in Flora of North America Editorial Committee, Tropicos (http://www.tropicos.org, Missouri Botanical Garden) and the Integrated Taxonomic Information System (http://www.itis.gov) were referenced. Wildlife indicator value (na, not available), species life history (A, annual; P, perennial; B, biennial), number of plots in which each species was found by year, and species frequency of occurrence by year are indicated. Species names in bold font occurred in 14 percent or more (that is, 5 plots or more) of the 35 plots]

Species	Wildlife value	Life history	Number of plots by year				Frequency by year			
			1990	1991	1992	1997	1990	1991	1992	1997
Alopecurus carolinianus	na	A		1			0.00	0.03	0.00	0.00
Alternanthera philoxeroides	3	P	1	1			0.03	0.03	0.00	0.00
Ambrosia artemisiifolia	3	A			1		0.00	0.00	0.03	0.00
Andropogon glomeratus	3	P		2	1		0.00	0.06	0.03	0.00
Andropogon virginicus	2	P			3		0.00	0.00	0.09	0.00
Baccharis halimifolia	3	P			4		0.00	0.00	0.11	0.00
Bacopa caroliniana	2	P	5	1			0.14	0.03	0.00	0.00
Bidens laevis	3	A/P		12	6		0.00	0.34	0.17	0.00
Boltonia asteroides	3	P		1			0.00	0.03	0.00	0.00
Brasenia schreberi	1	P	6			6	0.17	0.00	0.00	0.17
Cabomba caroliniana	3	P				7	0.00	0.00	0.00	0.20
Carex albolutescens	2	P			2		0.00	0.00	0.06	0.00
Centella asiatica	1	P	1	6	3		0.03	0.17	0.09	0.00
Cephalanthus occidentalis	1	P		2	1		0.00	0.06	0.03	0.00
Ceratophyllum demersum	1	P	4			11	0.11	0.00	0.00	0.31
Chamaecrista fasciculata	1	P			2		0.00	0.00	0.06	0.00
Chaptalia tomentosa	3	A		1			0.00	0.03	0.00	0.00
Cirsium horridulum	3	B		3	5		0.00	0.09	0.14	0.00
Conoclinium coelestinum	3	P			4		0.00	0.00	0.11	0.00
Cornus foemina	3	P	1				0.03	0.00	0.00	0.00
Crinum americanum	3	P	2				0.06	0.00	0.00	0.00
Croton capitatus	1	A		1			0.00	0.03	0.00	0.00
Cuphea carthagenensis	2	A/P	1				0.03	0.00	0.00	0.00
Cynosciadium digitatum	2	A			1		0.00	0.00	0.03	0.00
Cyperus compressus	1	A/P		2	1		0.00	0.06	0.03	0.00
Cyperus erythrorhizos	1	A/P			2		0.00	0.00	0.06	0.00
Cyperus esculentus	1	P		2			0.00	0.06	0.00	0.00
Cyperus haspan	1	P	1		1		0.03	0.00	0.03	0.00
Cyperus odoratus	1	A/P		3	2		0.00	0.09	0.06	0.00
Decodon verticillatus	1	P		1			0.00	0.03	0.00	0.00
Didiplis diandra (Peplis)	3	A		1			0.00	0.03	0.00	0.00
Digitaria ciliaris	2	A		1			0.00	0.03	0.00	0.00
Diodia virginiana	1	A/P			1		0.00	0.00	0.03	0.00
Eleocharis elongata	1	P		1	2		0.00	0.03	0.06	0.00
Eleocharis equisetoides	1	P	3		2		0.09	0.00	0.06	0.00

Table 5. Plant species found in the Unit D impoundment at Lacassine National Wildlife Refuge, Louisiana, in 1990, 1991, 1992, and 1997.—Continued

[Scientific names follow Flora of North America Editorial Committee (http://www.efloras.org). For names not included in Flora of North America Editorial Committee, Tropicos (http://www.tropicos.org, Missouri Botanical Garden) and the Integrated Taxonomic Information System (http://www.itis.gov) were referenced. Wildlife indicator value (na, not available), species life history (A, annual; P, perennial; B, biennial), number of plots in which each species was found by year, and species frequency of occurrence by year are indicated. Species names in bold font occurred in 14 percent or more (that is, 5 plots or more) of the 35 plots]

Species	Wildlife value	Life history	Number of plots by year				Frequency by year			
			1990	1991	1992	1997	1990	1991	1992	1997
Eleocharis flavescens	1	P		3			0.00	0.09	0.00	0.00
Eleocharis obtusa	1	A/P	9				0.26	0.00	0.00	0.00
Eleocharis parvula	1	A/P	1				0.03	0.00	0.00	0.00
Eleocharis quadrangulata	1	P				1	0.00	0.00	0.00	0.03
Eupatorium capillifolium	3	P		15	24		0.00	0.43	0.69	0.00
Fimbristylis autumnalis	3	A		7			0.00	0.20	0.00	0.00
Fimbristylis dichotoma	3	A/P		2			0.00	0.06	0.00	0.00
Fimbristylis miliacea	3	A		1	4		0.00	0.03	0.11	0.00
Fuirena pumila	2	A			3		0.00	0.00	0.09	0.00
Helianthus angustifolius	2	P			2		0.00	0.00	0.06	0.00
Hibiscus laevis	2	P		3			0.00	0.09	0.00	0.00
Hibiscus moscheutos ssp. *lasiocarpos*	2	A/P	1				0.03	0.00	0.00	0.00
Hibiscus moscheutos	2	A/P			2		0.00	0.00	0.06	0.00
Hydrocotyle umbellata	3	P	2	1			0.06	0.03	0.00	0.00
Hypericum gymnanthum	2	P		1	10		0.00	0.03	0.29	0.00
Juncus megacephalus	2	P			1		0.00	0.00	0.03	0.00
Justicia ovata	3	P			1		0.00	0.00	0.03	0.00
Lactuca floridana	2	B		1			0.00	0.03	0.00	0.00
Leersia oryzoides	1	B		3	6	1	0.00	0.09	0.17	0.03
Limnobium spongia	1	P	4				0.11	0.00	0.00	0.00
Limnosciadium pinnatum	2	A		1			0.00	0.03	0.00	0.00
Ludwigia decurrens	1	A/P	4		1		0.11	0.00	0.03	0.00
Ludwigia leptocarpa	1	A/P		8	2	1	0.00	0.23	0.06	0.03
Ludwigia peploides	1	P			2		0.00	0.00	0.06	0.00
Ludwigia sphaerocarpa	2	P		3	8		0.00	0.09	0.23	0.00
Ludwigia grandiflora	2	P	3	4			0.09	0.11	0.00	0.00
Mimosa microphylla	3	P		1			0.00	0.03	0.00	0.00
Najas guadalupensis	1	A				1	0.00	0.00	0.00	0.03
Nelumbo lutea	2	P				14	0.00	0.00	0.00	0.40
Nymphaea odorata	2	P	9			2	0.26	0.00	0.00	0.06
Nymphoides cordata	2	P	10				0.29	0.00	0.00	0.00
Oplismenus hirtellus	2	P		2			0.00	0.06	0.00	0.00
Panicum dichotomiflorum	1	A			1		0.00	0.00	0.03	0.00
Panicum hemitomon	3	P	22	22	35	22	0.63	0.63	1.00	0.63
Passiflora incarnata	3	P		1			0.00	0.03	0.00	0.00

Table 5. Plant species found in the Unit D impoundment at Lacassine National Wildlife Refuge, Louisiana, in 1990, 1991, 1992, and 1997.—Continued

[Scientific names follow Flora of North America Editorial Committee (http://www.efloras.org). For names not included in Flora of North America Editorial Committee, Tropicos (http://www.tropicos.org, Missouri Botanical Garden) and the Integrated Taxonomic Information System (http://www.itis.gov) were referenced. Wildlife indicator value (na, not available), species life history (A, annual; P, perennial; B, biennial), number of plots in which each species was found by year, and species frequency of occurrence by year are indicated. Species names in bold font occurred in 14 percent or more (that is, 5 plots or more) of the 35 plots]

Species	Wildlife value	Life history	Number of plots by year				Frequency by year			
			1990	1991	1992	1997	1990	1991	1992	1997
Persicaria hydropiperoides	1	P			1		0.00	0.00	0.03	0.00
Persicaria punctatum	1	A/P			5		0.00	0.00	0.14	0.00
Persicaria virginianum	1	A/P			1		0.00	0.00	0.03	0.00
Rhexia mariana	2	P		1	1		0.00	0.03	0.03	0.00
Rhynchospora caduca	2	P			2		0.00	0.00	0.06	0.00
Rhynchospora chalarocephala	2	P			1		0.00	0.00	0.03	0.00
Rhynchospora globularis	2	P			1		0.00	0.00	0.03	0.00
Rhynchospora nitens	2	P			7		0.00	0.00	0.20	0.00
Rhynchospora rariflora	2	P			2		0.00	0.00	0.06	0.00
Rubus trivialis	2	P		3			0.00	0.09	0.00	0.00
Rumex verticillatus	2	P			1		0.00	0.00	0.03	0.00
Sacciolepis striata	1	P		4	6	3	0.00	0.11	0.17	0.09
Sagittaria lancifolia	3	P	7				0.20	0.00	0.00	0.00
Sagittaria latifolia	2	P		1			0.00	0.03	0.00	0.00
Sagittaria montevidensis	2	P			1		0.00	0.00	0.03	0.00
Sagittaria papillosa	2	P		1			0.00	0.03	0.00	0.00
Salvinia rotundifolia	3	P				1	0.00	0.00	0.00	0.03
Saururus cernuus	3	P	1			1	0.03	0.00	0.00	0.03
Schizachyrium scoparium	3	P			6		0.00	0.00	0.17	0.00
Scirpus lineatus	2	P			1		0.00	0.00	0.03	0.00
Setaria pumila	1	P			2		0.00	0.00	0.06	0.00
Solidago sempervirens	3	P		1			0.00	0.03	0.00	0.00
Spartina patens	1	P		5	4		0.00	0.14	0.11	0.00
Steinchisma hians	2	P			2		0.00	0.00	0.06	0.00
Stellaria media	1	A/P		2			0.00	0.06	0.00	0.00
Stuckenia pectinata	1	P		1			0.00	0.03	0.00	0.00
Symphyotrichum subulatum	3	A/B		9	6		0.00	0.26	0.17	0.00
Symphyotrichum tenuifolium	3	P			3		0.00	0.00	0.09	0.00
Triadenum virginicum	3	P	2	6			0.06	0.17	0.00	0.00
Triadica sebifera	3	P		1			0.00	0.03	0.00	0.00
Typha angustifolia	2	P				1	0.00	0.00	0.00	0.03
Utricularia cornuta	3	A/P				8	0.00	0.00	0.00	0.23
Utricularia radiata	2	A/P	1			7	0.03	0.00	0.00	0.20
Vernonia gigantea	3	P			4		0.00	0.00	0.11	0.00
Xyris difformis	2	P			4		0.00	0.00	0.11	0.00

Analyses indicated that there was an interactive effect of plant community type and year on most of the measured response variables (table 6); the exception was the wetness coefficient, where year alone was significant. Species richness significantly increased in the NP and DW communities during two years of the drawdown (1991, 1992) but did not change in the other two communities (fig. 3). Total aboveground biomass per plot showed a significant increase in all communities at some point during the drawdown, but the pattern varied (fig. 4). *Panicum hemitomon* biomass in the NP community was significantly lower in 1991 compared to 1990, but biomass increased in 1992 to become equivalent to 1990 (fig. 5). In 1990, *Panicum hemitomon* was represented by a total of just nine stems (total dry biomass = 0.89 grams [g]) growing in three plots in SW and was absent from DW. Total biomass for this species was less than 5 grams in both SW and DW in 1991; in 1992, however, *Panicum hemitomon* biomass was 175.7 g ± 44.7 g (all data presented as mean ± 1 standard error) in SW and 173.9 g ± 34.9 g in DW (fig. 5). Whereas biomass of this species was significantly lower in DW and SW compared to NP and SP in 1990 and 1991, there was no significant difference in *Panicum hemitomon* biomass between communities in 1992 (data not shown). The percent of total aboveground biomass that consisted of *Panicum hemitomon* decreased from 1990 to 1992 in the NP community, decreased and then increased in the SP community, and increased in both the SW and DW communities (fig. 6). The total number of stems of all species was significantly higher in 1992 in NP and was significantly lower in 1997 in SW compared to other years, but no significant difference in stem number by year was found for the other communities (fig. 7).

Table 6. Results of a repeated measures analysis of variance of the effect of plant community type and year on seven response measures in Unit D, Lacassine National Wildlife Refuge, Louisiana.

[The significant P value for the model source of variation examined is in bold font. Num df, the numerator degrees of freedom; Den df, the denominator degrees of freedom; EM, the number of plants with an emergent life form; Pahe, *Panicum hemitomon*]

Response	Source	Num df	Den df	F value	P
Richness	Community	3	31	2.58	0.0711
	Year	3	31	20.01	<0.0001
	Community * year	9	31	6.90	**<0.0001**
Total biomass	Community	3	31	23.33	<0.0001
	Year	3	31	52.24	<0.0001
	Community * year	9	31	12.14	**<0.0001**
Total stem number	Community	3	31	19.31	<0.0001
	Year	3	87	7.35	0.0002
	Community * year	9	87	3.90	**0.0003**
Wildlife indicator	Community	3	31	17.18	<0.0001
	Year	3	31	2.32	0.0946
	Community * year	9	31	6.33	**<0.0001**
EM	Community	3	34	6.99	0.0009
	Year	3	34	45.60	<0.0001
	Community * year	9	34	4.92	**0.0003**
Wetness coefficient	Community	3	31	2.61	0.0687
	Year	3	87	12.35	**<0.0001**
	Community * year	9	87	1.76	0.088
Pahe biomass	Community	3	31	18.84	<0.0001
	Year	2	31	42.29	<0.0001
	Community * year	6	31	6.29	**0.0002**

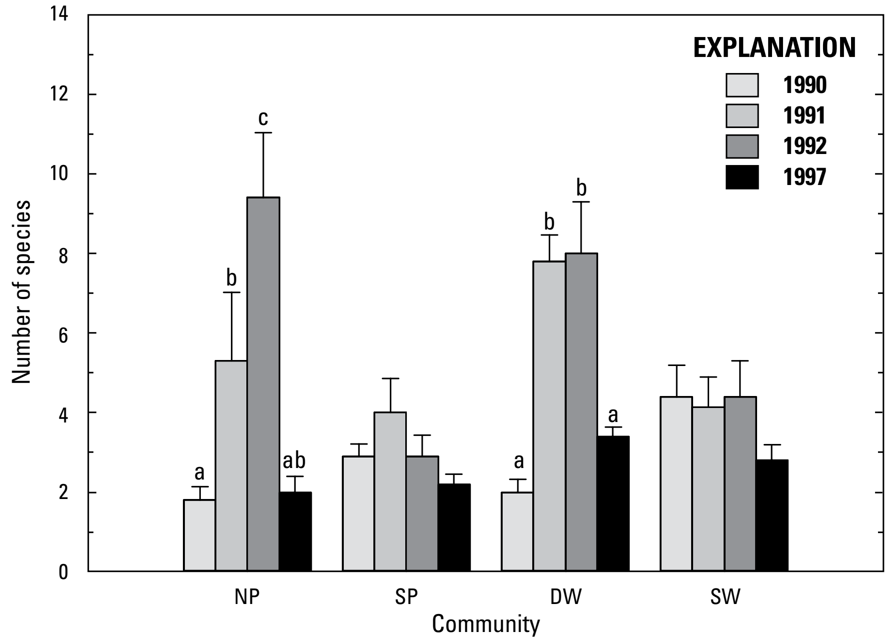

Figure 3. Mean species richness (number of species) by year in four plant communities in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana. Community abbreviations are NP, north panicum; SP, south panicum; DW, deep water; and SW, shallow water. Error bars indicate one standard error. Different letters indicate significant differences ($P < 0.05$) between years within a community.

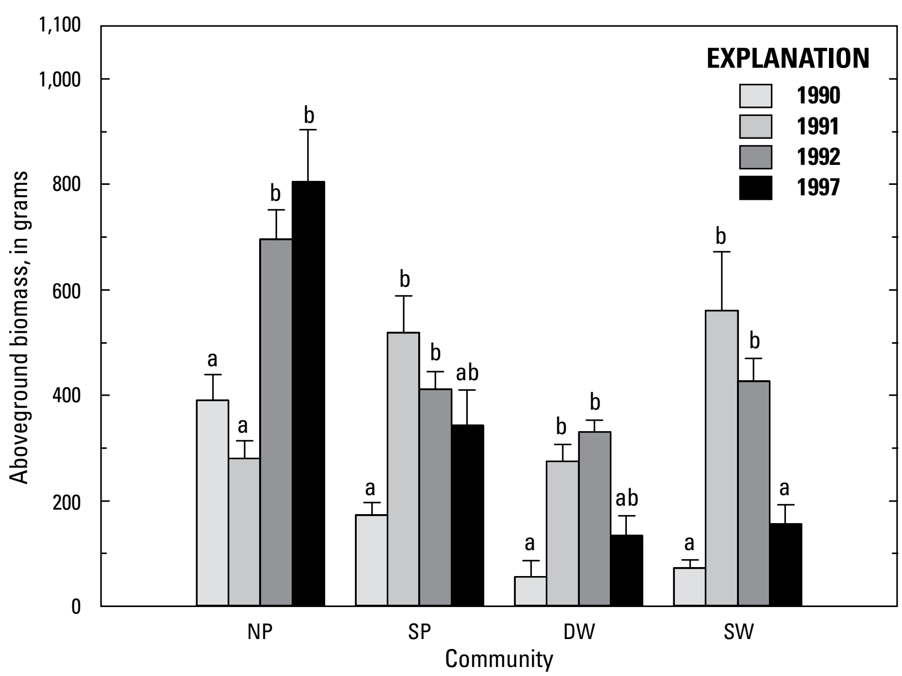

Figure 4. Mean aboveground biomass by year in four plant communities in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana. Community abbreviations are NP, north panicum; SP, south panicum; DW, deep water; and SW, shallow water. Error bars indicate one standard error. Different letters indicate significant differences ($P < 0.05$) between years within a community.

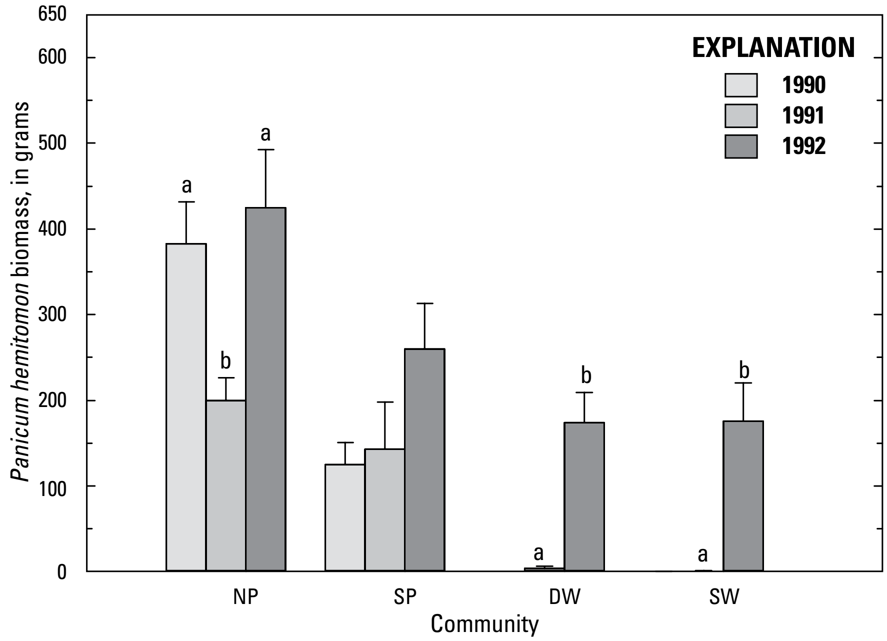

Figure 5. Mean aboveground biomass of *Panicum hemitomon* by year in four plant communities in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana. Community abbreviations are NP, north panicum; SP, south panicum; DW, deep water; and SW, shallow water. Error bars indicate one standard error. Different letters indicate significant differences ($P < 0.05$) between years within a community.

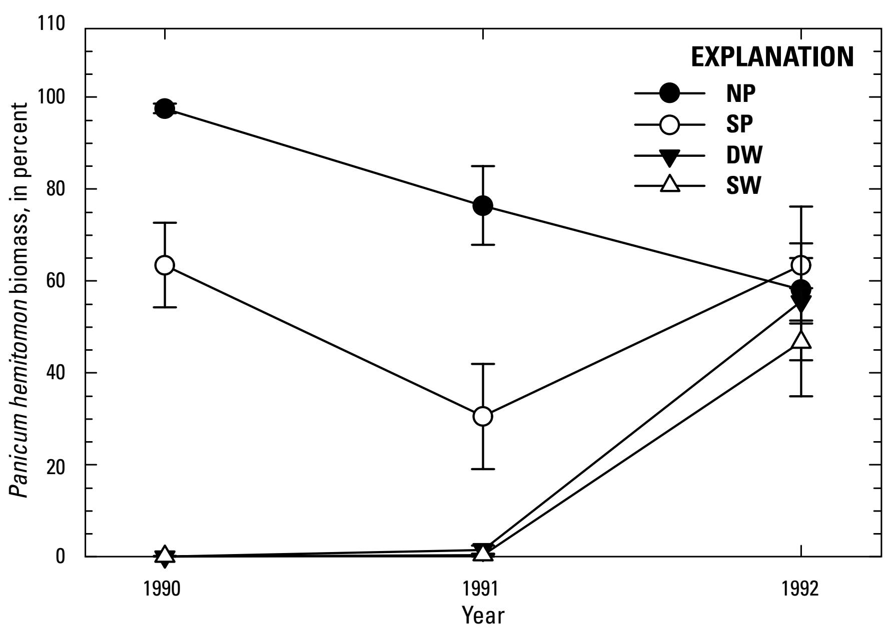

Figure 6. Percent of total aboveground biomass composed of *Panicum hemitomon* biomass by year in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana. Community abbreviations are NP, north panicum; SP, south panicum; DW, deep water; and SW, shallow water. Error bars indicate one standard error.

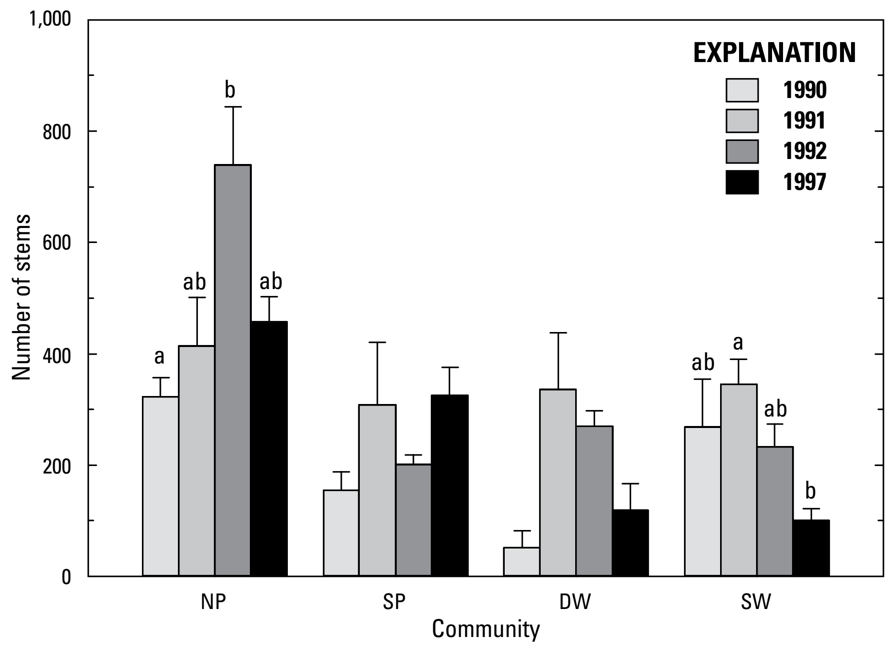

Figure 7. Mean number of stems by year in four plant communities in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana. Community abbreviations are NP, north panicum; SP, south panicum; DW, deep water; and SW, shallow water. Error bars indicate one standard error. Different letters indicate significant differences ($P < 0.05$) between years within a community.

The number of emergent species increased in NP, DW, and SW but not in SP (fig. 8) in 1991 and 1992 during the drawdown. There was little difference in wildlife food values within the communities over years, with the exceptions of a significant increase in value (that is, lower WVI) in NP in 1992 compared to 1990 and a significant decrease in value (that is, higher WVI) in SW for the same years (fig. 9*A*). Differences within year for wildlife food value indicate that the value was significantly greater in communities with standing water (DW, SW) than in the panicum communities (NP, SP) in 1990, about two months after the drawdown was initiated (fig. 9*B*). The wildlife food value did not vary significantly between communities in 1991 and 1992 during the drawdown, but the value in SW was significantly lower than that in NP again in 1997 (fig. 9*B*). The weighted WC for vegetation was significantly higher during two drawdown years (-4.1 ± 0.25 in 1991 and -3.6 ± 0.28 in 1992) than in the other years (-4.9 ± 0.03 in 1990 and -5.0 ± 0.0 in 1997).

The depth of the organic soil layer was affected by community type ($P = 0.0209$) and sample time ($P < 0.0001$); the interaction between these factors was not significant ($P = 0.0892$). Depth of the organic layer was significantly less in DW (21.4 ± 2.43 cm) than in SP (46.4 ± 3.67 cm). Depth of this layer in SW (31.9 ± 3.71 cm) did not differ significantly from that in either DW or SP. The depth of the organic layer during the drawdown significantly decreased after the first three sampling events, with depth measured in November 1991 lower than that measured in May 1990 (fig. 10). The depth of the organic soil layer in August 1997 was significantly less than that measured at all previous dates, with the exception of November 1993.

Data from the 2003 study included 4 sites in Unit D, all of which were classified as PSW; an additional 46 PSW sites and 41 EM sites were distributed across the rest of Lacassine pool. Analyses indicated no significance difference ($P = 0.0769$) in depth of the organic soil layer for the three groups. There was, however, a significant ($P < 0.001$) difference in depth to the clay layer. Depth to clay in Unit D (47.0 ± 1.47 cm) was significantly lower than that in PSW sites outside the unit (72.6 ± 4.17 cm) and EM sites (113.5± 3.44 cm); the depth to the clay layer in PSW sites outside the unit was also significantly lower than that in EM sites.

Discussion

The intent of the management actions taken in Unit D was to decrease the cover of undesirable plant species, primarily *Panicum hemitomon*; increase the abundance of desirable waterfowl food plants; increase the amount of open water habitat; and reduce the accumulation of organic material in the soil. Water depth manipulation (that is, drawdown) in the impoundment and prescribed fire were

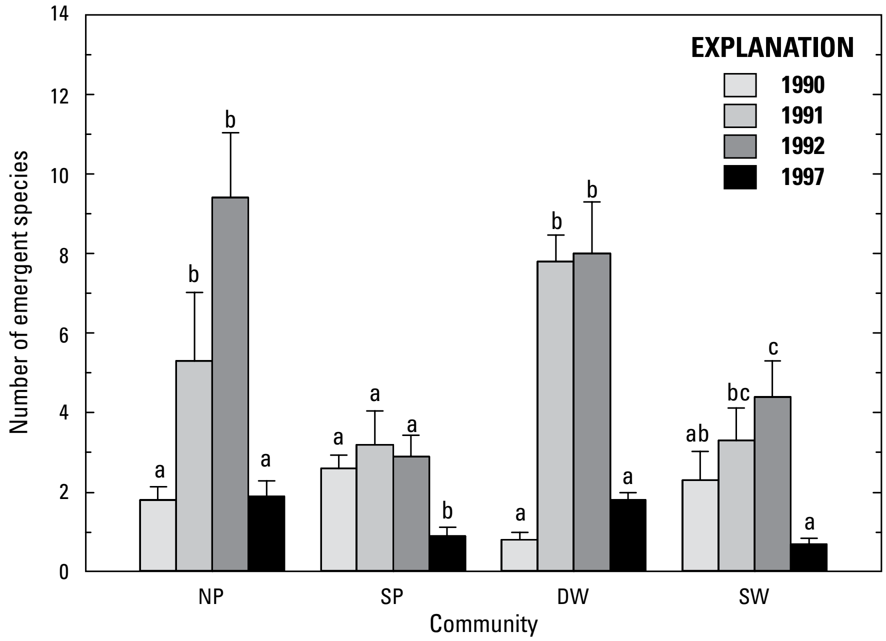

Figure 8. Mean number of species with an emergent growth form by year in four plant communities in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana. Community abbreviations are NP, north panicum; SP, south panicum; DW, deep water; and SW, shallow water. Error bars indicate one standard error. Different letters indicate significant differences ($P < 0.05$) between years within a community.

disturbances applied to achieve the desired outcomes. Whereas impoundment drawdowns have been shown to result in increased plant species diversity (Keddy and Reznicek, 1982; DeBerry and Perry, 2005; Howard and Wells, 2009), the effectiveness of using prescribed fire to increase the abundance of wildlife food plants has recently been questioned (Flores and others, 2011). Our ability to attribute any detected changes in vegetation and soil to the effects of the drawdown or fire are hindered by the limitations of the SCS study, which were the absence of control plots that had not been affected by the drawdown and the lack of information on which plots were actually burned. Nevertheless, we address in the succeeding paragraphs how the disturbances applied to Unit D appeared to affect the intended management goals.

Unit D supported a relatively diverse plant community with 105 species identified during the two studies conducted in the 1990s. It should be noted, however, that two of the species found in the SCS study, *Chaptalia tomentosa* and *Scirpus lineatus*, had not been recorded for Cameron Parish through the mid-1990s (Thomas and Allen, 1993, 1996). Voucher specimens apparently were not collected during the SCS study, and no record was made of who determined plant identity; therefore, the presence of these species on Lacassine NWR cannot be verified. It is also important to point out that different conditions in Unit D during the SCS and Chabreck studies affected the methods used to collect data. Because water as deep as 1.2 m was present in the DW and SW habitat during the Chabreck study in 1997, stems of emergent species in these areas were clipped at the water surface, and submerged vegetation was collected by using a rake. These methods differ from those used in the SCS study, when all vegetation was clipped at the soil surface. It is difficult to ensure that submerged vegetation in a 1-m^2 area is accurately sampled with the rake technique. Therefore, comparison of 1997 stem count and total biomass data to those collected in the SCS study are somewhat suspect.

We identified changes in plant community attributes in Unit D by using data from the SCS and Chabreck studies. The effect of disturbance in wetland systems varies depending on many factors, including the type, rate, and magnitude of the disturbance, and disturbance can influence processes such as competitive interactions, species diversity, and succession (McKee and Baldwin, 1999). The management techniques applied in Unit D apparently affected plant community structure primarily through changes in species richness, total aboveground biomass, and aboveground biomass of *Panicum hemitomon*, but the community types often responded differently. Species richness was not affected in either the SP or SW communities but increased in the NP and DW communities during the drawdown (fig. 3). The increase in the number of species in the NP community was probably a result of decreased competition from *Panicum hemitomon* since biomass of this species was reduced in 1991. In conflict with the desired outcome, however, *Panicum hemitomon* biomass

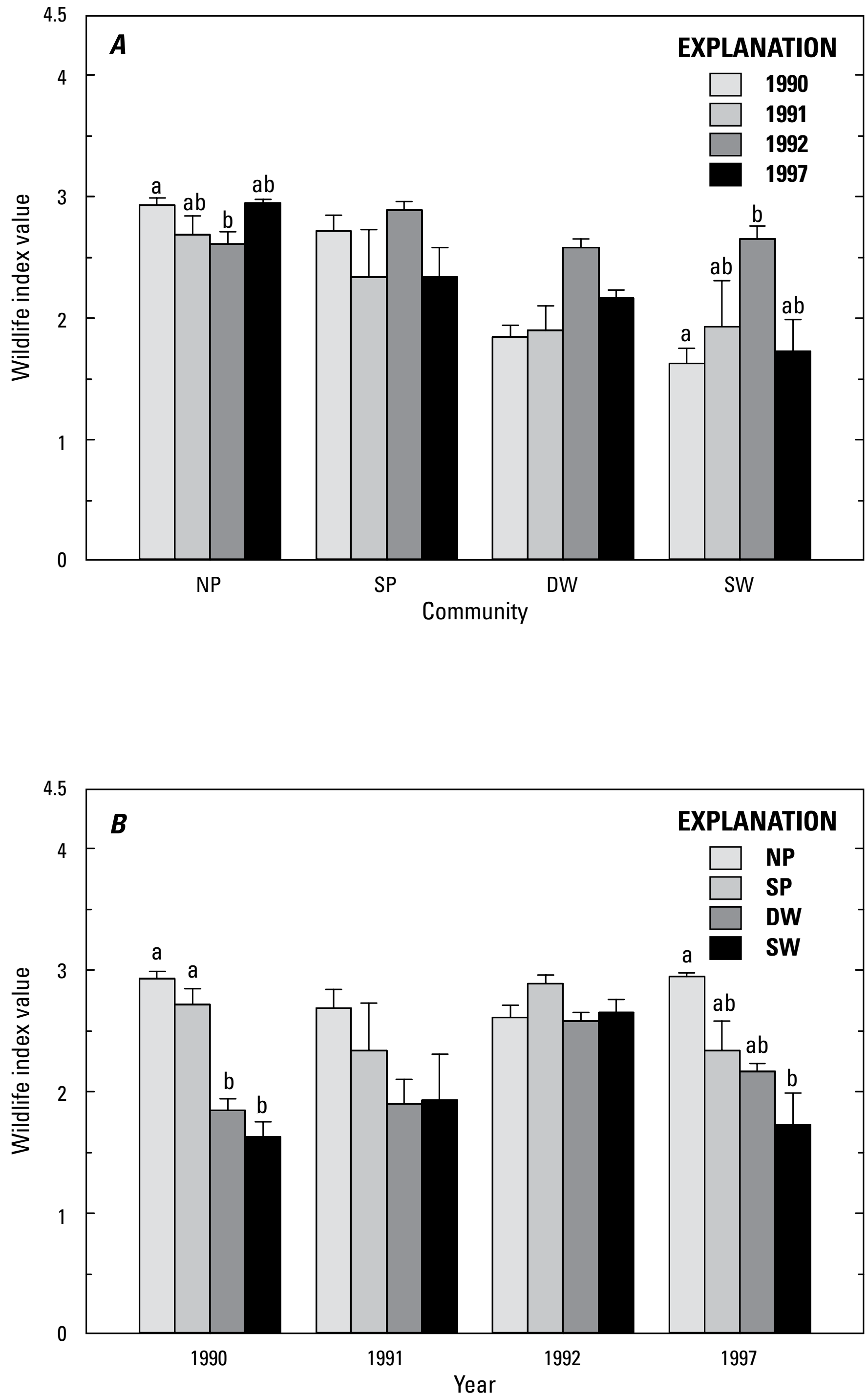

Figure 9. Mean wildlife index value in *A*, four plant communities by year and *B*, by year in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana. Community abbreviations are NP, north panicum; SP, south panicum; DW, deep water; and SW, shallow water. Error bars indicate one standard error. Different letters indicate significant differences ($P < 0.05$) between years within a community.

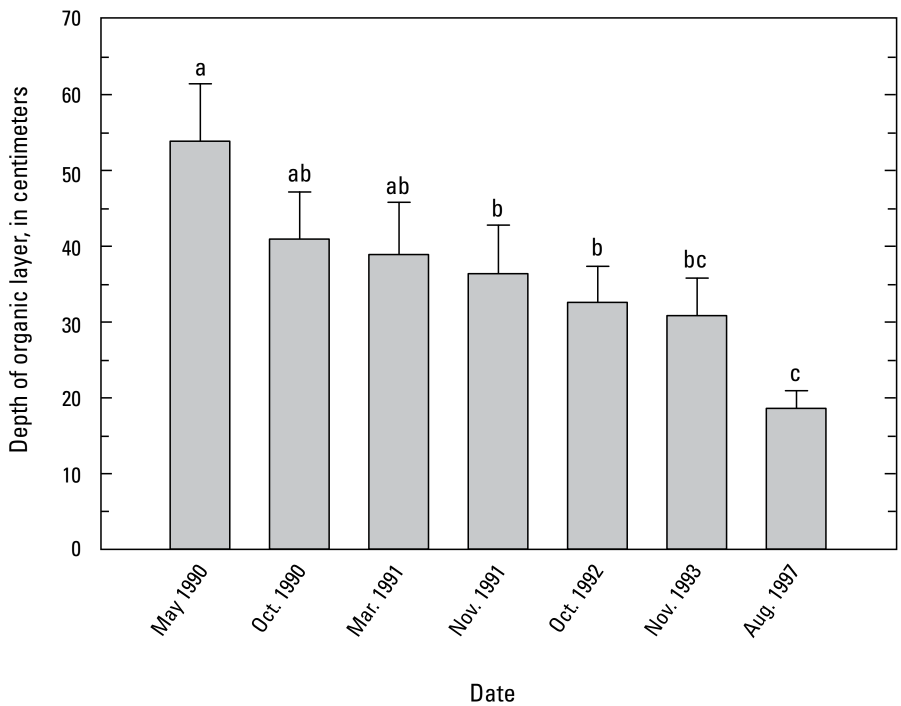

Figure 10. Mean depth of the organic soil layer by sample date in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana. Error bars indicate one standard error. Different letters indicate significant differences ($P < 0.05$) between sample dates.

was not affected in the SP community and actually increased in the DW and SW communities by 1992 (fig. 5). *Panicum hemitomon* remained present in all of the DW plots in 1997, but it was absent in the SW plots (table 7). In the DW and SW communities, which had permanent standing water before the drawdown occurred, it is likely that drop in water level exposed unvegetated soil and provided an open substrate for *Panicum hemitomon* expansion and (or) germination of seeds of other species. In these communities, submersed aquatic species such as *Ceratophyllum demersum* and *Utricularia* sp. were eliminated during the drawdown, as were some common floating-leaved species, including *Brasenia schreberi*, *Nymphaea odorata*, and *Nymphoides cordata*. In addition to *Panicum hemitomon*, emergent species that frequently moved into DW and SW plots during the drawdown included *Bidens laevis*, *Eupatorium capillifolium*, *Sacciolepis striata*, and *Symphyotrichum subulatum*. With the exception of *Sacciolepis striata*, these emergent species were rated as low-value food plants for waterfowl. The management actions had little effect on the overall WIV in Unit D (fig. 9*A*, *B*). The WIV decrease (that is, higher food value) identified in the NP community in 1992 compared to 1990 was due to the presence of new species with high food value, including *Centella asiatica*, *Cyperus erythrorhizos*, *Leersia oryzoides*, *Sacciolepis striata*, and *Spartina patens*; these species had greatly reduced stem numbers or were absent in NP in 1997. The WIV increase (lower food value) in the SW community in 1992 was due to the predominance of *Panicum hemitomon*. The WIV was significantly lower in both the DW and SW communities compared to the panicum communities in 1990, about two months after the drawdown was initiated; it is likely that invasion of these communities by *Panicum hemitomon* and other emergent species was minimal at this time. By 1997, however, the value in the DW community was equivalent

Table 7. Frequency of occurrence of *Panicum hemitomon* in plots by community type in Unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana.

[Occurrence in all plots sampled in a community is indicated by “1.” The total number of plots in which *Panicum hemitomon* occurred was 22 in 1990, 1991, and 1997 and 35 in 1992. NP, north panicum; SP, south panicum; DW, deep water; SW, shallow water]

Community	Number of plots	Year			
		1990	1991	1992	1997
NP	10	1	1	1	1
SP	10	0.9	0.8	1	0.7
DW	5	0	0.6	1	1
SW	10	0.3	0.1	1	0

to that in the two panicum communities and only the SW community had significantly more species of high food value to waterfowl (fig. 9*B*). Without information on control plots, it is not possible to ascertain if the management actions influenced this reduction in food habitat value for DW.

Review of the data collected during the SCS and Chabreck studies revealed other vegetation changes in Unit D that appear to be consistent with change in the larger Lacassine pool. Two species are of special note—*Sagittaria lancifolia* and *Brasenia schreberi*. *Sagittaria lancifolia* is an emergent species that, secondary to *Panicum hemitomon*, has traditionally been a species of concern to refuge personnel. It was believed that this species, which has low waterfowl habitat value, was increasing in abundance along with *Panicum hemitomon*. *Sagittaria lancifolia* occurred in 7 of the 35 plots in 1990, and all of these plots were in the SP community. The number of stems per plot ranged from 23 to 45. *Sagittaria lancifolia* disappeared from the plots during the drawdown and had not reestablished by 1997 (table 5). *Brasenia schreberi* is a floating-leaved species that has high value as a waterfowl food plant. Unpublished refuge records indicated that it was planted in Lacassine pool in 1943, and subsequent reports through the mid-1970s indicated that there was abundant cover of this species. *Brasenia schreberi* was present in 6 of the 35 plots in 1990, was eliminated during the drawdown, but was present again in 6 plots in 1997 (table 5). By 2007, however, *Sagittaria lancifolia* was a minor component of the Lacassine pool vegetation assemblage, and *Brasenia schreberi* did not occur in any vegetation plots sampled at that time (Howard and others, 2011). *Nelumbo lutea* is a floating-leaved plant that was absent in 1990–92 but quite common in 1997. Whether the shifts in frequency of occurrence for these three species represent temporary changes in distribution or a long-term trend is not known.

Research has demonstrated that prescribed fires can have positive effects on some plant species and negative effects on others (McWilliams and others, 2007; Flores and others, 2011). We were not able to assess the impact of the prescribed fire on plant species in Unit D because it was not clear which plots actually burned and because the experimental design did not include control plots that were not burned. We can speculate, however, on how *Panicum hemitomon* may respond to prescribed fire. This species is perennial and propagates primarily through the clonal growth mechanism of spreading by rhizomes. The rhizomes and roots of *Panicum hemitomon* can extend deep within the soil, and the depth of rooting will influence how it responds to drawdown and fire. Flinn and Wein (1977) noted that plant species that survive fire because they support deep subterranean tissues will have a competitive advantage over plants that must establish from seeds. Studies in Florida have noted that *Panicum hemitomon* is a fire-tolerant species that resprouts readily after fire and rapidly attains preburn vigor (Loveless, 1959; Wade and others, 1980; Lowe, 1986). Kirkman and Sharitz (1993) reported that winter fire alone had no effect on stem number and height of *Panicum hemitomon* the following growing season, but winter fire followed by inundation with water 13 cm deep reduced both stem number and height. Three of the prescribed fires in Unit D were not followed by reflooding. It is therefore likely that those fires, especially the fires in August 1990 and August 1991, either had little effect on the vigor of *Panicum hemitomon* stands or actually stimulated growth. The January 1993 fire was set when the unit was either close to or at full water depth and would have had minimal impact on the SW and DW communities. The SW and DW communities had little or no cover of *Panicum hemitomon* at the start of the study but were invaded by this species by 1992, when it composed about 50 percent of the total aboveground biomass (fig. 6). The overall frequency of *Panicum hemitomon* was 0.63 in 1990, 1992, and 1997, when it was present in 22 of the 35 plots; this species occurred in all plots in 1992 (table 7).

Soil changes in Unit D were also detected in the data. Anaerobic conditions in soils during flooding inhibit the decomposition of organic matter, and material can accumulate over time. Change in the depth of the soil organic layer in Unit D was first noted 20 months after the drawdown began in March 1990. In November 1991 the depth of the organic layer was significantly less than that measured the first time, in May 1990 (fig. 10). This reduction in the soil organic layer, as compared to initial conditions, remained throughout the SCS study, and a further reduction was detected 4 years later in the Chabreck study. Two processes were involved in the reduction of the organic layer depth in Unit D. First, soon after the drawdown was initiated there was compaction resulting from the removal of interstitial soil water. Second, subsequent prevalence of aerobic conditions during the drawdown and high temperatures during summer months increased organic matter decomposition and thereby further reduced the depth of the organic layer. There are inconsistencies in the definition of the limits of the organic soil layer as applied in the SCS and Chabreck studies and the 2003 study. Regardless, in 2003, 10 years after Unit D was reflooded, the depth to the underlying clay layer (which, by definition, was overlain by organic and mineral layers) in Unit D was lower than that in the surrounding pool.

Determination that the depth of the organic soil layer was less in Unit D compared to the rest of Lacassine pool is consistent with the results of an additional study (conducted in 1994, about 18 months after Unit D was reflooded) that examined soil accretion. In that study, Bryant (1996) sampled soils in Unit D, in Lacassine pool, and in a nearby marsh that was not impounded. The cesium-137 (^{137}Cs) method described by DeLaune and others (1978) was used to estimate accretion. The depth of the layer in a soil core with the highest ^{137}Cs concentration indicates the soil surface layer in 1963, the year of peak fallout of this element from nuclear testing. A limitation of Bryant's (1996) study was the low sample size of just two cores per marsh type. For the 31 years between 1963 and 1994, mean accretion was measured as 34 cm in Lacassine pool and 5 cm in both Unit D and the unimpounded marsh. The 27-cm lower accretion in Unit D compared to Lacassine pool was attributed to the water level manipulations (Bryant, 1996).

Summary

We analyzed data collected during the 1990s in the Unit D subimpoundment of Lacassine pool to determine the effects of a drawdown in water levels and fire on plant community composition and the depth of the soil organic layer. Four plant community types were designated in 1990 within Unit D—north panicum (NP), south panicum (SP), deep water (DW), and shallow water (SW)—and differences in plant response to the drawdown were detected among them. Species richness increased in two of the communities, and total aboveground biomass increased in all four during the drawdown. We attributed the changes in the NP community to a temporary decrease in dominance of *Panicum hemitomon*, which may have allowed the establishment of new species, and to exposure of sediment surface that had previously been submerged in the DW and SW communities. These exposed sediments were probably readily colonized by seeds or invaded by vegetative propagules from perennial species, including *Panicum hemitomon*. The increase in total aboveground biomass in SP and SW that was not accompanied by an increase in species richness may have been the result of either increased productivity of the suite of species present before the drawdown or substitution of predrawdown species with species of higher productivity. The elimination of submersed and floating-leaved species in the DW and SW communities led to an increase in the number of emergent species. The number of emergent species also increased in the NP community, again presumably because of the decreased competition from *Panicum hemitomon*. There was no apparent long-term reduction in *Panicum hemitomon* biomass, and in fact, the data document the spread of this species into plots where it was absent at the beginning of the study. The change in waterfowl food value of the communities was not consistent. During 2 years of the drawdown this value was not affected in SP and DW, decreased in SW because of the loss of high-quality floating-leaved species such as *Brasenia schreberi*, and increased in NP because of the reduction in *Panicum hemitomon* dominance. The consistent pattern noted in waterfowl food value was that under flooded conditions it was higher in the open water communities (SW and DW) than in the panicum communities (NP and SP).

While it is evident that the death of submersed and floating-leaved species was a result of drawing down water levels in the impoundment, we were not able to establish a definite cause-and-effect relation between the drawdown and other vegetation changes because of the lack of control plots. That is, changes in species richness, aboveground biomass, stem density, and the number of emergent species that we identified in Unit D may have occurred in the surrounding Lacassine pool habitat as well. We were unable to make any conclusions about the effect of the prescribed fire treatments because there was no information on which plots were burned. Because of the known relation between anaerobic soil conditions and reduced decomposition of organic matter, however, we can reasonably conclude that the drawdown in Unit D resulted in a reduction of the depth of the soil organic layer.

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Appendix 1.—Checklist of Plants Identified in 1.0-Square-Meter Quadrats in Unit D of Lacassine Pool, Lacassine National Wildlife Refuge, Louisiana, During Studies Conducted in 1990, 1991, 1992, and 1997

Table 1–1. Plants identified in 1.0-square-meter quadrats in unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana, in 1990, 1991, 1992, or 1997.

[Families are arranged alphabetically within group (ferns, monocots, and then dicots). Scientific names follow Flora of North America Editorial Committee (http://www.efloras.org). For names not included in Flora of North America Editorial Committee, Tropicos (http://www.tropicos.org, Missouri Botanical Garden) and the Integrated Taxonomic Information System (http://www.itis.gov) were referenced. The most complete listings and the shortest abbreviations of authors were used]

Scientific name	Family	Common name
Ferns		
	Salviniaceae	
Salvinia minima Baker		water spangles
Monocots		
	Alismataceae	
Sagittaria lancifolia L.		bulltongue arrowhead
Sagittaria latifolia Willd.		broadleaf arrowhead
Sagittaria montevidensis Cham. & Schltdl.		hooded arrowhead
Sagittaria papillosa Buchenau		nipple bract arrowhead
	Cyperaceae	
Carex albolutescens Schwein.		eastern sedge
Cyperus compressus L.		poorland flatsedge
Cyperus erythrorhizos Muhl.		redroot flatsedge
Cyperus esculentus L.		yellow nut flatsedge
Cyperus haspan L.		shethed flatsedge
Cyperus odoratus L.		fragrant flatsedge
Eleocharis elongata Chapm.		water spikerush
Eleocharis equisetoides (Elliott) Torr.		jointed spikerush
Eleocharis flavescens (Poir.) Urb.		yellow spikerush
Eleocharis obtusa (Willd.) Schult.		blunt spikerush
Eleocharis parvula (Roem. & Schult.) Link ex Bluff, Nees & Schauer		dwarf spikerush
Eleocharis quadrangulata (Michx.) Roem. & Schult.		squarestem spikerush
Fimbristylis autumnalis (L.) Roem. & Schult.		slender fimbristylis
Fimbristylis dichotoma (L.) Vahl		fimbristylis
Fimbristylis miliacea (L.) Vahl		globe fimbristylis
Fuirena pumila (Torr.) Spreng.		dwarf umbrellasedge
Rhynchospora nitens (Vahl) A. Gray		short beak baldrush
Rhynchospora caduca Elliott		anglestem beakrush
Rhynchospora chalarocephala Fernald & Gale		horned rush
Rhynchospora globularis (Chapm.) Small		horned rush
Rhynchospora rariflora (Michx.) Elliott		horned rush
Scirpus lineatus Michx.		rusty bulrush
	Hydrocharitaceae	
Limnobium spongia (Bosc) Rich. ex Steud.		American frogbit
	Juncaceae	
Juncus megacephalus M.A. Curtis		bighead rush
	Amaryllidaceae	
Crinum americanum L.		swamplily
	Hydrocharitaceae	
Najas guadalupensis (Spreng.) Magnus		southern waternymph

Table 1–1. Plants identified in 1.0-square-meter quadrats in unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana, in 1990, 1991, 1992, or 1997.—Continued

[Families are arranged alphabetically within group (ferns, monocots, and then dicots). Scientific names follow Flora of North America Editorial Committee (http://www.efloras.org). For names not included in Flora of North America Editorial Committee, Tropicos (http://www.tropicos.org, Missouri Botanical Garden) and the Integrated Taxonomic Information System (http://www.itis.gov) were referenced. The most complete listings and the shortest abbreviations of authors were used]

Scientific name	Family	Common name
Monocots—Continued		
	Poaceae	
Alopecurus carolinianus Walter		Carolina foxtail
Andropogon glomeratus (Walter) Britton, Sterns & Poggenb.		bushy bearded bluestem
Andropogon virginicus L.		broomsedge
Digitaria ciliaris (Retz.) Koeler		southern crabgrass
Leersia oryzoides (L.) Sw.		rice cutgrass
Oplismenus hirtellus (L.) P. Beauv.		basketgrass
Panicum dichotomiflorum Michx.		fall panicgrass
Panicum hemitomon Schult.		maidencane panicgrass
Steinchisma hians (Elliott) Nash		gaping panicgrass
Sacciolepis striata (L.) Nash		american cupscale
Schizachyrium scoparium (Michx.) Nash		little bluestem
Setaria pumila (Poir.) Roem. & Schult.		yellow bristlegrass
Spartina patens (Aiton) Muhl.		marshhay cordgrass
	Potamogetonaceae	
Stuckenia pectinata (L.) Börner		sago pondweed
	Typhaceae	
Typha angustifolia L.		narrowleaf cattail
	Xyridaceae	
Xyris difformis Chapm.		southern yellow-eyed grass
Dicots		
	Acanthaceae	
Justicia ovata (Walter) Lindau		water willow
	Amaranthaceae	
Alternanthera philoxeroides (Mart.) Griseb.		alligator weed
	Apiaceae	
Centella asiatica (L.) Urb.		spadeleaf
Cynosciadium digitatum DC.		finger dogshade
Limnosciadium pinnatum (DC.) Mathias & Constance		pinnate-cynosciadium
	Araliaceae	
Hydrocotyle umbellata L.		umbrella pennywort
	Asteraceae	
Ambrosia artemisiifolia L.		common ragweed
Symphyotrichum subulatum (Michx.) G.L. Nesom		annual aster
Symphyotrichum tenuifolium (L.) G.L. Nesom		saline aster
Baccharis halimifolia L.		eastern baccharis
Bidens laevis (L.) Britton, Sterns & Poggenb.		smooth beggarticks
Boltonia asteroides (L.) L'Hér.		marsh boltonia
Chaptalia tomentosa Vent.		sunbonnets
Cirsium horridulum Michx.		yellow thistle

Table 1–1. Plants identified in 1.0-square-meter quadrats in unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana, in 1990, 1991, 1992, or 1997.—Continued

[Families are arranged alphabetically within group (ferns, monocots, and then dicots). Scientific names follow Flora of North America Editorial Committee (http://www.efloras.org). For names not included in Flora of North America Editorial Committee, Tropicos (http://www.tropicos.org, Missouri Botanical Garden) and the Integrated Taxonomic Information System (http://www.itis.gov) were referenced. The most complete listings and the shortest abbreviations of authors were used]

Scientific name	Family	Common name
Dicots—Continued		
Eupatorium capillifolium (Lam.) Small		cypress weed/dog fennel
Conoclinium coelestinum (L.) DC.		mistflower
Helianthus angustifolius L.		narrow-leaf sunflower
Lactuca floridana (L.) Gaertn.		wild lettuce
Solidago sempervirens L.		seaside goldenrod
Vernonia gigantea (Walter) Trel.		ironweed
	Cabombaceae	
*Brasenia schreber*i J.F. Gmel.		Schreber watershield
Cabomba caroliniana A. Gray		Carolina fanwort
	Caryophyllaceae	
Stellaria media (L.) Vill.		chickweed starwort
Ceratophyllum demersum L.		common coontail
	Clusiaceae	
Hypericum gymnanthum Engelm. & A. Gray		clasping St. John’s wort
Triadenum virginicum (L.) Raf.		marsh St. John’s wort
	Cornaceae	
Cornus foemina Mill.		stiff dogwood
	Euphorbiaceae	
Croton capitatus Michx.		woolly croton
Triadica sebifera (L.) Small		Chinese tallowtree
	Fabaceae	
Chamaecrista fasciculata (Michx.) Greene		partridge pea
Mimosa microphylla Dryand.		littleleaf sensitivebriar
	Lentibulariaceae	
Utricularia cornuta Michx.		horned bladderwort
Utricularia radiata Small		whorled bladderpod
	Lythraceae	
Cuphea carthagenensis (Jacq.) J.F. Macbr.		waxseed cuphea
Decodon verticillatus (L.) Elliott		swamp loosestrife
Didiplis diandra (Nutt. ex DC.) Alph. Wood		water purslane
	Malvaceae	
Hibiscus moscheutos ssp. lasiocarpos (Cav). O.J. Blanch.		wooly rosemallow
Hibiscus laevis All.		halberd-leaf rosemallow
Hibiscus moscheutos L.		marsh mallow
	Melastomataceae	
Rhexia mariana L.		Maryland meadow beauty
	Menyanthaceae	
Nymphoides cordata (Ell.) Fern.		little floating heart
	Nelumbonaceae	
Nelumbo lutea Willd.		American lotus

Table 1–1. Plants identified in 1.0-square-meter quadrats in unit D, Lacassine pool, Lacassine National Wildlife Refuge, Louisiana, in 1990, 1991, 1992, or 1997.—Continued

[Families are arranged alphabetically within group (ferns, monocots, and then dicots). Scientific names follow Flora of North America Editorial Committee (http://www.efloras.org). For names not included in Flora of North America Editorial Committee, Tropicos (http://www.tropicos.org, Missouri Botanical Garden) and the Integrated Taxonomic Information System (http://www.itis.gov) were referenced. The most complete listings and the shortest abbreviations of authors were used]

Scientific name	Family	Common name
Dicots—Continued		
	Nymphaeaceae	
Nymphaea odorata Ait.		white waterlily
	Onagraceae	
Ludwigia decurrens (DC.)Walter		willow water primrose
Ludwigia leptocarpa (Nutt.) H. Hara		anglestem water primrose
Ludwigia peploides (Kunth) P.H. Raven		floating water primrose
Ludwigia sphaerocarpa Elliott		spherical fruit water primrose
Ludwigia grandiflora ssp. *grandiflora* (Michx.) Greuter & Burdet		Uruguay water primrose
	Passifloraceae	
Passiflora incarnata L.		maypop passionflower
	Polygonaceae	
Persicaria hydropiperoides (Michx.) Small		swamp smartweed
Persicaria punctatum (Elliott) Small		dotted smartweed
Persicaria virginianum (L.) Gaertner		jumpseed smartweed
Rumex verticillatus L.		swamp dock
	Rosaceae	
Rubus trivialis Michx.		southern dewberry
	Rubiaceae	
Cephalanthus occidentalis L.		button bush
Diodia virginiana L.		poor joe
	Saururaceae	
Saururus cernuus L.		lizardtail
	Plantaginaceae	
Bacopa caroliniana (Walter) B.L. Rob.		lemon hyssop

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