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THIN-MAT FLOATING MARSH ENHANCEMENT DEMONSTRATION PROJECT TE-36

Seventh Priority List Demonstration Project of the Coastal Wetlands Planning, Protection, and Restoration Act
(Public Law 101-646)

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INTRODUCTION

The Coastal Wetlands Planning, Protection, and Restoration Act (CWPPRA) of 28 November, 1990, House Document 646, 101st Congress, provides for the use of federal funds for planning and implementing projects that create, protect, restore, and enhance coastal wetlands of the United States, including Louisiana. As part of this effort, the Thin-Mat Floating Marsh Enhancement Demonstration Project (TE-36) was approved for funding and included on the Seventh Priority List which was transmitted to Congress in September 1998. Project sites will be located within the relatively fragile thin-mat floating marshes (flotant). The purpose of this project is to develop techniques that will prove helpful in restoring degraded freshwater wetlands, with the particular emphasis in this project to stimulate the development of thick-mat flotant marsh from thin-mat flotant marsh. Construction is authorized to begin in spring 2000, as soon as compliance with appropriate environmental laws and regulations are achieved. The CWPPRA specifies that projects be cost-shared with the State of Louisiana. Pursuant to the Louisiana Coastal Wetlands Conservation Plan, the federal government provides 85% of the project cost and the State of Louisiana provides the remaining 15%. The United States Department of Agriculture through NRCS acts as the federal sponsoring agency for this project. The State has indicated its willingness to cost share on the proposed action.

The project area is located in the Mississippi River Delta Plain (MRDP). This geomorphic region developed as a series of overlapping delta lobes, each with a well-described cycle of river-dominated growth and marine-dominated abandonment. Each part of this delta cycle is characterized by different forces and the development of different habitats (Gagliano and Van Beek 1970). The time period of an entire cycle lasts from approximately two to four thousand years for a major complex. Three major Holocene delta lobes (Maringouin, Teche, and Lafourche) built the study area, of which the Lafourche lobe is the most recent (Kolb and Van Lopik 1958).

Floating marshes probably form in the later stages of the delta cycle. A delta lobe is built by deposition of river sediments at the mouth of the river. As the delta lobe grows, vegetation invades the exposed mudflats, developing into increasingly larger vegetated fresh-water wetlands. As a delta matures and nears its maximum development, the river bypasses the fresh marshes in the portion of the delta lobe farthest removed from the Gulf of Mexico and organic peat begins to accumulate. When the distributary course is no longer hydraulically efficient, the main channel of the river changes to a more efficient route and the newly built delta lobe is slowly abandoned (Frazier 1967). Expansive freshwater marshes thrive in the abandoned upper delta lobe. Vegetative production and decomposition in these marshes accumulate deep layers of organic peat, which replace mineral sediment as the primary depositional material. It is during this stage in the delta cycle that formation of floating marshes is most likely to occur, as a result of submergence of natural attached organic marshes (O'Neil 1949). With increased submergence, a buoyant organic mat is subjected to increasing upward tension until it breaks free from its mineral substrate and floats. Other theories of floating marsh formation describe the formation of floating mats by encroachment into lakes from attached marshes (Russell 1942), establishment of a mat on concentrated free floating aquatics (Russell 1942), and/or the invasion of unvegetated organic mats that pop up from lake bottoms (Rich 1984).

Two major types of floating marshes that occur in the region are thick-mat maidencane (*Panicum hemitomon*) and thin-mat spikerush (*Eleocharis baldwinii*). Floating maidencane marshes consist of a thick (~50 cm) mat of tightly woven roots in a mostly organic matrix that floats continuously on a layer of usually clear water (Sasser et al. 1995a, 1996). In contrast, spikerush marshes grow on thin (<25 cm), seasonally floating mats that would not support the weight of a person during most of the growing season (Sasser et al. 1995a, 1996). Both the thick-mat maidencane and the thin-mat spikerush marshes are supported by substrates that contain very low mineral densities (<0.015 g/cc in the active root zone) and high (>78%) organic matter content (Sasser et al. 1996). The end-of-season biomass of thin-mat spikerush marsh (129 g/m2) is significantly lower than the end-of-season biomass of thick-mat maidencane marshes (524 g/m2) (Sasser et al. 1995a). A complete species list of species found in thin-mat spikerush and thick-mat maidencane floating marshes is provided in Table 1.

The marshes in the project area have remained fresh since the 1940's when they were first mapped by O'Neil (1949). Floating marshes historically were widely distributed in the freshwater areas of the Mississippi River Deltaic Plain (O'Neil, 1949), and their present distribution remains widespread in these areas (Sasser et al. 1994). However, in large parts of the project area vegetation associations have changed from thick-mat maidencane (*Panicum hemitomon*) dominated marsh to thin-mat spikerush (*Eleocharis baldwinii*) dominated marsh (Visser et al. 1999). The largest change occurred between 1968 and 1978 when maidencane dominated marsh dropped from 67% to 34% of the fresh and oligohaline marshes. The loss of maidencane marsh continued and only 19% remained in 1992 (Visser et al. 1999). At the same time, spikerush marsh increased from 3% in 1968 to 53% in 1992 (Visser et al. 1999). Potential causes of the dramatic change in fresh marsh vegetation and land loss in the area include: grazing by nutria, increased water levels, hydrologic modifications, and eutrophication.

Nutria (*Myocastor coypus*) is a rodent introduced to Louisiana in 1937 (Evans 1970). Since its introduction the nutria population has increased rapidly becoming the dominant grazer in fresh and oligohaline marshes (Lowery 1974, Condrey et al. 1995). Change in vegetative species composition due to nutria grazing has been shown in Louisiana for the nearby Atchafalaya delta (Shaffer et al 1992, Evers et al. 1998), oligohaline wiregrass marshes (Taylor et al. 1994), and mesohaline wiregrass marshes (Nyman et al. 1993). Nutria grazing has also been implicated in the decline of reed swamps (*Phragmites australis*) in England (Boorman and Fuller, 1981). However, the effect of nutria grazing on maidencane marshes has not yet been documented.

Kinler et al. (1980) attribute the die-back of maidencane marsh and the replacement with thin-mat marshes to the 1973 record flood and above-average rainfall in following years. Water level stages in the northwestern Penchant Basin have generally increased in the last 20 years due to the decreasing efficiency of the Lower Atchafalaya River. However, 92% of the maidencane marshes in the Terrebonne estuary are floating (Evers et al. 1996). Although attached *Panicum hemitomon* is negatively affected by increased water levels (McKee and Mendelssohn 1989), floating *Panicum hemitomon* biomass is positively correlated with higher water levels (Sasser et al. 1995b). The positive effect of increased water level on floating *Panicum hemitomon* is presumably due to higher nutrient levels associated with increased runoff (Sasser et al. 1995b). Some fragmentation of floating marsh mats occurs during high water events, resulting in the movement of small sections of marsh that drift downstream (Sasser et al. 1994).

Table 1. Plant species found in thin-mat spikerush and thick-mat maidencane marshes within the project area. Based on Sasser et al. (1994, 1995a) and Visser et al. (1999).

Scientific Name	Common Name	Marsh*
Aeschynomene indica L.	Sensitive Joint Vetch	S
Althernanthera philoxeroides (Mart.) Griseb.	Alligatorweed	M,S
Amaranthus australis (Gray) Sauer	Southern Waterhemp	M
Andropogon glomeratus (Walter) B.S.P.	Broomsedge	M,S
Bacopa monnieri (L.) Wettst.	Coastal Waterhyssop	M,S
Bidens laevis (L.) B.S.P.	Smooth Beggar-tick, Fouchet	S
Boehmeria cylindrica (L.) Sw.	False Nettle	M
Cephalanthus occidentalis L.	Buttonbush	M,S
Colocasia antiquorum (L.) Schot	Elephant-ear	M,S
Conoclinium coelestinum (L.) DC.	Mistflower	M,S
Cyperus odoratus L.	Fragrant Sedge	M,S
Cyperus polystachyos Rottb.	Sedge	M,S
Decodon verticillatus (L.) Elliott	Water-willow	M,S
Dichromena colorata (L.) Hitchc.	White-top Sedge	M,S
Echinochloa crusgalli (L.) Beauv.	Barnyard grass	M,S
Eleocharis albida Torr.	Spikerush	M,S
Eleocharis baldwinii (Torr.) Chapman.	Spikerush	S
Eleocharis macrostachya Britt	Largespike Spikerush	M
Eleocharis parvula (R.&S.) Link.	Dwarf Spikerush	M,S
Eupatorium capillifolium (Lam.) Small.	Dog-fennel	M,S
Fuirena pumila (Torr.) Spreng.	Umbrella Grass	S
Hibiscus lasciocarpus Cav.	Marsh Mallow	M,S
Hydrocotyle ranunculoides L.	Floating Pennywort	S
Hydrocotyle umbellata L.	Marsh Pennywort	M,S
Ipomoea sagittata Poir in Lam.	Saltmarsh Morningglory	M
Kosteletzkia virginica (L.) K. Presl ex Gray	Seashore Marshmallow	M
Leersia oryzoides (L.) Sw.	Rice Cutgrass	M,S
Limnobium spongia (Bosc.) Steud.	Common Frogbit	S
Ludwigia leptocarpa (Nutt.) Hara	False Loosestrife,	M,S
Myrica cerifera L.	Waxmyrtle	M,S
Panicum hemitomon Schult.	Maidencane, Paille Fine	M,S
Panicum sp.		M,S
Paspalum vaginatum Sw.	Seashore Paspalum	M,S
Phragmites australis (Cav.) Trin. ex Steud.	Common Reed, Roseau Cane	M,S
Phyla lanceolata (Michx.) Greene	Lance-leafed Frogfruit	M,S
Polygonum punctatum Ell.	Dotted Smartweed	M,S
Pontedaria cordata L.	Pickerelweed	M
Ptilimnium capillaceum (Michx.) Raf.	Mock Bishop's Weed	M
Sacciolepis striata (L.) Nash	Bagscale	M,S
Sagittaria lancifolia L.	Bulltongue	M,S
Sagittaria latifolia Wild.	Arrowhead, Wapato	M,S
Scirpus americanus Pers.	Three Square	M
Scirpus cubensis Poepp. & Kunth in Kunth	Sedge	S
Setaria geniculata (Lam.) Beauv.	Foxtail	M,S
Solidago sempervirens L.	Seaside Goldenrod	M,S
Thelypteris palustris Schott.	Marsh Fern	M,S
Triadenum virginicum (L.) Raf.	Marsh St. John's-wort	M,S
Typha latifolia L.	Cattail	M,S
Vigna luteola (Jacq.) Benth.	Deerpea	M

*M=Maidencane, S=Spikerush

A large number of oil and gas access canals have changed the hydrology of this region since the 1950s. This in combination with the construction of the Avoca Island Cutoff levee has changed the historical overland flooding in the project area. Aerial photographs taken during the spring flood of the Atchafalaya River show almost no sediment-laden waters entering the area of highest land loss in the center of the project area. The area is somewhat isolated from the major flows of the region, with lower flow rates and low suspended load (Sasser et al., 1995a). It is therefore plausible that the conversion of the high productivity maidencane floating marsh to a low productivity spikerush floating marsh could be a result of reduced nutrient input.

In contrast, some researchers believe that the demise of the maidencane marsh in the project area is due to eutrophication. Eutrophication has been indicated in the demise of reed swamps (*Phragmites australis* marshes) in Europe (Klötzli 1971). An increase in the nitrogen to potassium ratio in the environment results in less sclerenchymatous tissue in the *Phragmites australis* rhizomes as well as a decrease in belowground biomass of floating reed (Boar et al. 1989). Therefore, floating reed swamps are more prone to breakup and are lost from eutrophic waters, while attached marshes are unaffected (Boar et al. 1989). Although both nitrogen and phosphorus concentrations have significantly increased in the waters of the Mississippi and Atchafalaya rivers since the 1960s, the only water quality station near the project area (Bayou Black at Gibson) showed no significant trends in water quality (turbidity, dissolved oxygen, total nitrogen, nitrate and nitrite, total phosphorus and total carbon) between 1958 and 1991 (Rabalais et al. 1995). This in addition to the apparent lack of penetration of these sediment-laden waters into the project area make it seem unlikely that eutrophication is the driving factor in the observed demise of maidencane marsh.

Project Objectives

The objective of this demonstration project is to induce the development of thick-mat floating marsh in areas that are presently thin-mat floating marsh. This goal will be achieved by enhancing growth of the naturally vegetated mat in three ways: (1) transplanting plant species of existing *Panicum hemitomon*- dominated thick-mat floating marshes into the thin-mat areas, (2) induce growth through fertilization, and (3) induce growth through reduction of mammal grazing. The combinations of these management techniques will be evaluated, as outlined below:

- Convert existing spikerush thin-mat floating marsh to healthy maidencane floating-marsh.
- Evaluate transplanting of maidencane floating marsh as a tool for thin-mat to thick-mat marsh conversion.
- Evaluate fertilization as a tool for thin-mat to thick-mat marsh conversion.
- Evaluate grazing exclusion as a tool for thin-mat to thick-mat marsh conversion.
- Evaluate combinations of the three methods as a tool for thin-mat to thick-mat marsh conversion.

This report describes the work accomplished on the demonstration project in 1999, contains data collected during the fall and winter of 1999–2000, and describes the condition of the sites before implementation of the treatments.

METHODS

Site Layout

The Thin-Mat Enhancement Demonstration Project directly impacts approximately 4 acres of fresh marsh within the northwestern part of the Penchant Basin in Terrebonne Parish, southeast of Morgan City, LA. The project methods are replicated at four sites (coordinates are provided in Table 2) in an area bounded on the north by the Gulf Intracoastal Waterway (GIWW), on the east by Bayou Copesaw, on the south by Superior Canal, and on the west by Bayou Chene (Figure 1).

At each site, a T-shaped boardwalk was constructed in the summer of 1999 to minimize impacts on the existing vegetation during construction and monitoring. At each site eight 172 ft^2 (4 x 4 m) plots were assigned to one of the eight treatment combinations. Figure 2 shows the general layout for each site. Treatment assignment within each site was performed as follows. First, one arm of the boardwalk was randomly selected to receive the four fertilized treatments and the other arm received the non fertilized treatments. Four treatment combinations (A. grazed and planted, B. grazed and unplanted, C. not grazed and planted, and D. not grazed and unplanted) were randomly assigned to each plot within a fertilizer treatment (see Figure 2).

Table 2. Coordinates for the four project sites.

	TMA	TMB	TMC	TMD
Latitude:	29<34’50’’	29<33’32’’	29<33’15’’	29<28’36’’
Longitude:	91<04’12’’	91<01’09’’	91<09’12’’	91<05’28’’

Vegetation

Vegetation was sampled at the four sites in September 1999 to assess the existing vegetation condition prior to initiation of the project treatments in the spring of 2000.

We sampled five randomly selected 1.08 ft^2 (0.10 m^2) plots outside of the treatment plots to determine end-of-season biomass. Emergent vegetation was clipped within 1 inch (3 cm) of the substrate surface collected in a plastic bag and transported back to the laboratory. In the laboratory, the live material in the sample was separated from dead material and sorted by species. Both live and dead material were dried to constant weight in a 158 <F (70<C) oven.

Cover of all emergent plant species was estimated to the nearest 5% in a 10.76 ft^2 (1 m^2) plot within each of the eight treatment plots at each site. Because species sometimes overlap in coverage of the substrate the total cover for a plot can exceed 100%.

Figure 1. Location of the project sites.

Figure 2. Generalized layout of each site showing the eight treatments.

Hydrology

The primary goal of the water level and mat level data collection is to determine the buoyancy characteristics of examples of the major vegetated habitats in the basins, with particular focus on the seasonal dynamics of mat movement. To this end, the following parameters are being measured at each of the sites:

1. Open water (bayou or canal).
2. Inland Marsh water level (~160 ft or 50 m inland).
3. Inland marsh (~160 ft or 50 m inland) mat vertical movement (replicate sensors).

The inland data is being collected using a multi-channel data logger (Stevens Multiloggers®, Leupold and Stevens Inc., Beaverton, Oregon) which is located on a platform (~ 160 ft or 50 m inland) next to the boardwalk. The marsh water and mat levels are measured at this point. The marsh mat is measured at two points, one on each side of the gauge platform. The bayou (or canal) water levels are being measured with a single channel data logger (Stevens Type A/F®, Leupold and Stevens Inc., Beaverton, Oregon) deployed on a platform along the water's edge. The overall gauge deployment scheme for a site is shown in Figure 2.

The water levels are measured using a stilling well with a float and counterweight system. The cable attached to the float goes over the sensor pulley and is attached to a weight. Thus, as the float moved vertically (with the water), it moves the cable, which in turn rotates the sensor pulley attached to the digital shaft encoder. The rotation of the encoder shaft is converted to a digital signal which is recorded by the data logger. The mat levels are monitored by using a float-counterweight encoder, but without the float. The sensor is deployed on a single pipe (to minimize friction effects) with the counterweight located inside the pipe. The cable attached to the weight is placed over the sensor pulley and then attached to a dog leash anchor that has been augured into the mat. Thus, as the mat moves vertically, it moves the cable, which in turn rotates the sensor pulley attached to the digital shaft encoder. The rotation of the encoder shaft is converted to a digital signal which is recorded by the data logger onto solid state memory modules.

Gauge Calibration and Setup

The gauges used for the study were purchased on a previous project funded by the EPA in the Barataria and Terrebonne systems. Four of the original twelve gauges were re-furbished and re-calibrated for use in this study. Laboratory calibration consisted of checking the operation of the shaft encoders. The encoders were set up in the lab on a stand with a float and counterweight. The float was them moved over a distance from 0 to 3.28 ft at 0.66 ft intervals (0 to 1.0 meters at 0.20 meter intervals). A regression analysis was performed using the actual reading as the independent variable and the encoder reading as the dependent variable. The calibration check indicated that the encoders have accuracy's better then 0.03 ft (1 cm). In addition, the encoders are a digital measuring device and do not have a potential drift problem.

After all of the sensors were calibrated, the data loggers were configured. The data logger configuration consisted of:

1. Verify all of the switch settings on the interface boards.
2. Set the clock and calendar for the appropriate date and time.
3. Set the desired sampling interval for each channel.
4. Set the channel identification for each of the four channels.

The multi-channel loggers have been assigned numbers ranging from 9901 through 9904 (99 = year the project started, 01-04 = consecutive ID number). The consecutive ID number is set to correspond to the sample site location (01 = TMA, 02 = TMB, 03 = TMC, and 04 = TMD). The data channel ID consists of the logger ID plus a 2 digit code for the channel number (01 through 04). In all cases, channel 1 is the marsh water, channels 2 and 3 are the marsh mat sensors and channel 4 is the open water (bayou or canal). Thus, each data series has a unique ID code which is recorded as part of the data, eliminating the possibility of mixing up data if a data file is named incorrectly during processing.

Gauge Deployment

After all of the gauges were set-up and their operation was verified, field deployment began. The gauges were deployed in the following manner:

1. A platform with a float and counterweight well for water level measurements was installed in the open water along the waters edge.
2. The single channel data logger, and battery pack was installed on the platform.
3. A platform to hold the data logger and batteries was installed on the marsh surface next to the boardwalk. This platform also had a float and counterweight well for measurement of marsh water levels.
4. The multi-channel data logger, and battery pack was installed on the platform.
5. The mat sensors were installed in the marsh on each side of the gauge platform, and connected to the data logger with an armored cable.

After all connections were made and checked, the batteries were attached, the data cards were installed, and the gauges were set up to start recording. The gauges are checked by using the top of the mounting platform as a reference level. During installation the distance from the top of the data logger (or mat sensor) platform to the water (or mat) surface is measured. The gauges are set so that the top of the platform corresponds to a reading of 16.4 ft (5.0 m). Thus, if the distance from the platform to the water (or mat) was 6.6 ft (2.0 m), then the gauge should be reading 9.8 ft (3.0 m). This distance is measured on each servicing trip, and compared to the actual gauge reading.

Gauges were deployed at three of the sites (TMA, TMC, and TMD) in June, 1999 and at the forth site (TMB) in September, 1999. Table 3 summarizes the data return for each site. The gauges have been operating continuously since being deployed. There have been very few instances of data loss. The major data loss was from the marsh mat sensors at site TMD (44% during November, 1999). The sensor cable had come off of the encoder pulley at site TMD. It appeared as though the cable had been pulled off, possibly by a nutria becoming entangled in the cable. Should the problem persist, we will design some sort of guard to place around the sensor.

Data Retrieval

The gauges are serviced regularly at which time the memory modules are retrieved, the batteries replaced, and a new memory module installed. The data stored on the memory module is recovered upon return to LSU using a memory module reader interfaced with a laptop computer. The raw data files are converted into time series format using the manufacturers supplied software. The time series data files are saved on a desktop computer for analysis using "Statistical Analysis System" (SAS 1990 a, b, c, d, e). Since all of the data is in time series format, the same techniques are used for all sites. A preliminary analysis, to check the data for missing data points and/or outliers is performed. During this check any needed correction factors are applied and any suspect data is set to missing. The data are then ready for final analysis.

Table 3. Percent data return over the time period from June 10, 1999 through February 29, 2000. Indicated for each sample site and sensor is the percent recovery of valid data.

			Data Recovery (percent)			
Site	Year	Month	Marsh Water	Marsh Mat 1	Marsh Mat 2	Open Water
TMA	1999	6	100.0	100.0	100.0	93.1
TMA	1999	7	100.0	100.0	100.0	99.9
TMA	1999	8	100.0	100.0	100.0	100.0
TMA	1999	9	100.0	100.0	100.0	100.0
TMA	1999	10	100.0	100.0	100.0	100.0
TMA	1999	11	100.0	100.0	100.0	100.0
TMA	1999	12	100.0	100.0	100.0	100.0
TMA	2000	1	100.0	100.0	100.0	100.0
TMA	2000	2	100.0	100.0	100.0	100.0
TMB	1999	9	100.0	100.0	100.0	100.0
TMB	1999	10	100.0	100.0	100.0	100.0
TMB	1999	11	100.0	100.0	100.0	99.7
TMB	1999	12	100.0	100.0	100.0	100.0
TMB	2000	1	100.0	100.0	100.0	100.0
TMB	2000	2	100.0	100.0	100.0	100.0
TMC	1999	6	100.0	100.0	100.0	100.0
TMC	1999	7	100.0	100.0	100.0	99.9
TMC	1999	8	100.0	100.0	100.0	100.0
TMC	1999	9	100.0	100.0	100.0	100.0
TMC	1999	10	100.0	100.0	100.0	100.0
TMC	1999	11	100.0	100.0	100.0	99.9
TMC	1999	12	100.0	100.0	100.0	100.0
TMC	2000	1	100.0	100.0	100.0	100.0
TMC	2000	2	100.0	100.0	100.0	100.0
TMD	1999	6	100.0	100.0	100.0	100.0
TMD	1999	7	100.0	100.0	100.0	100.0
TMD	1999	8	100.0	100.0	100.0	100.0
TMD	1999	9	99.9	99.9	99.9	100.0
TMD	1999	10	100.0	100.0	100.0	100.0
TMD	1999	11	99.9	99.9	43.9	100.0
TMD	1999	12	100.0	100.0	100.0	100.0
TMD	2000	1	100.0	100.0	100.0	100.0
TMD	2000	2	100.0	100.0	100.0	100.0

Suspended Matter

Suspended matter was determined from water samples taken at locations near the project sites and waterways in the project area. Water samples were collected in clean nalgene® sample containers. The bottles were rinsed with ambient water, then filled, capped and placed in an ice chest. The samples were returned to the laboratory for total suspended load and percent organic analysis. Samples were collected along an open water transect which included two locations in the vicinity to the project sites (TMA, TMB, TMC, TMD) as well as samples from the waterways between the sites for a total of 18 sample stations. The transect was sampled twice, the first time in February, 1999 and the second in May, 1999 to verify that the sample sites were along a suspended load gradient.

Suspended load was determined by filtering a known volume of water through a pre-combusted at 1022 <F (550 <C) and pre-weighed glass fiber filter (Whatman Type GF/F or equivalent). The filters are dried at 140 <F (60 <C) then re-weighed to determine total suspended load in mg/l. The filters are then combusted at 1022 <F (550 <C), cooled, then re-weighed to estimate percent organic by loss on ignition (APHA, 1992).

Substrate

At each experimental plot across the four study sites, we collected porewater nutrient concentrations (2 replicates per plot) at 2 inch (5 cm) and 9.8 inch (25 cm) depths in late September and early October 1999. During this same time period, we extracted two (3 inch or 7.62 cm diameter) cores from each experimental plot for substrate nutrient concentration analysis and bulk properties; the cores were sectioned every 3.9 inch (10 cm) comprising a total depth of 15.7 inch (40 cm).

The porewater nutrients—phosphate, nitrate, and ammonium—were analyzed by the LSU Coastal Ecology Institute with a Technicon Autoanalyzer. These inorganic nutrient concentrations were measured at :g atoms l^{-1}. Moist soil samples were analyzed for total extractable phosphorous, pH, and exchangeable cations (Ca, K, Na) at the Soil Testing Lab in the LSU Agronomy Department. The soil phosphorous and cation concentrations are in the process of being converted from a moist-to-dry volume basis. Dry soil samples are awaiting analysis for carbon and nitrogen concentrations with a CHN analyzer at the Coastal Ecology Institute.

RESULTS

Vegetation

Biomass

Total biomass was not significantly different among sites (ANOVA, "=0.05, Figure 3). However, there was a large difference in species composition (Table 4). Only three species occurred in the samples at all four sites. These species are *Eleocharis baldwinii*, *Hydrocotyle umbellata*, and *Phyla lanceolata*. At TMA, *Eleocharis baldwinii* contributed 59% of the end-of-season biomass. While, *Sacciolepis striata* contributes 52% to the biomass at TMB. TMC had the highest number of species (14) that contributed to the biomass, however the largest percentage (32%) was contributed by *Eichornia crassipes*. *Eichornia crassipes* is normally a free floating aquatic, however at TMC this species was growing in the floating mat substrate and therefore was considered part of the emergent vegetation at this site. TMD had the second highest number of species (11) contributing to the total biomass, with *Aeschynomene indica* as the largest contributor at 39%.

Figure 3. Live-biomass harvested from the 4 sites in September 1999. Only those species that occurred at all sites or contributed more than 30% at one of the sites are shown separately. Data for all species are presented in Table 4.

Table 4. Biomass harvested from the four sites. Data presented is the average determined from five samples.

	Mean Biomass ± Standard Error (g/m^2)			
Scientific name	TMA	TMB	TMC	TMD
Aeschynomene indica			40 ± 26	124 ± 82
Bacopa monnieri			10 ± 4	12 ± 4
Bidens laevis	6 ± 2	17 ± 12		2 ± 1
Cyperus haspan			9 ± 8	
Cyperus polystachyos				8 ± 3
Eichornia crassipes			136 ± 94	
Eleocharis baldwinii	236 ± 60	77 ± 28	22 ± 10	52 ± 13
Eleocharis quadrangulata			31 ± 8	
Fuirena pumila		1 ± 1	3 ± 3	12 ± 6
Hydrocotyle ranunculoides			1 ± 1	
Hydrocotyle umbellata	10 ± 3	16 ± 3	10 ± 4	14 ± 4
Leersia oryzoides			24 ± 18	
Ludwigia leptocarpa		10 ± 10	85 ± 48	
Ludwigia peploides	101 ± 40			
Phyla lanceolata	43 ± 27	100 ± 22	22 ± 13	4 ± 2
Sacciolepis striata		259 ± 47	4 ± 4	17 ± 13
Sagittaria latifolia		15 ± 9	22 ± 11	74 ± 9
Unidentified Grass	3 ± 1	3 ± 2		2 ± 1
Dead Biomass	110 ± 25	52 ± 9	134 ± 16	83 ± 8
Live Biomass	400 ± 50	498 ± 52	419 ± 57	321 ± 87
Number of Species	6	9	14	11

Cover

Significant differences in total cover were detected among the 4 sites (ANOVA, " =0.05, Figure 4). The highest cover (192 ± 7) was found at TMD. This site had two different layers of vegetation. The bottom layer was dominated by *Eleocharis baldwinii* and *Hydrocotyle umbelata* and the top layer was dominated by *Sagittaria latifolia* and *Aeschynomene indica*. TMC had the lowest cover (104 ± 3) and was dominated by *Ludwigia leptocarpa* and *Eichornia crassipes*. TMA and TMB had intermediate cover and were dominated by *Eleocharis baldwinii*.

Figure 4. Percentage cover estimated at the 4 sites in September 1999. Only those species that occurred at all sites or contributed more than 20% at one of the sites are shown separately. Data for all species are presented in Table 5.

Hydrology

Plots of the half-hourly open water levels, the marsh water levels and the marsh mat levels for each of the four gauge sites are shown in Figures 5 through 8. In all cases the horizontal axis is the date, and the vertical axis is water (or mat) level, in meters. The 25-hour diurnal tidal signal which is superimposed upon other longer-term fluctuations can be seen on the open water data at all of the stations. This type of open water level signal has been shown to be typical for the Louisiana Deltaic Plain Intermediate, Brackish, and Salt marshes (Byrne et al. 1976, Adams and Baumann 1980, Chuang and Swenson, 1981, Swenson and Turner 1987, Sasser et al, 1994). The marsh water levels at sites TMA, TMB, and TMD track the open water levels but without the tidal fluctuations. The marsh water at site TMC tracks the open water levels including the tidal fluctuations, especially at the higher water levels. The marsh mat movement at sites TMA, TMB, and TMC track the marsh water level signal but do not respond to all of the marsh water level pulses. The marsh mat at site TMC closely follows the marsh water levels.

Table 5. Cover estimated at the four sites. Data presented is the average determined from eight samples and the standard error.

	Mean Percentage Cover ± Standard Error			
Scientific Name	TMA	TMB	TMC	TMD
Aeschynomene indica		10.00 ± 4.53	1.25 ± 0.82	24.38 ± 3.46
Althernanthera philoxeroides		1.25 ± 0.82	1.88 ± 0.91	
Bacopa monnieri	6.25 ± 6.25		1.25 ± 0.82	6.88 ± 1.32
Bidens laevis	6.25 ± 2.95	4.38 ± 1.13	2.50 ± 1.34	2.50 ± 1.34
Cyperaceae	0.63 ± 0.63		0.63 ± 0.63	
Cyperus haspan		5.63 ± 3.71		1.25 ± 0.82
Cyperus odoratus			0.63 ± 0.63	0.63 ± 0.63
Cyperus polystachyos		0.63 ± 0.63		5.00 ± 1.34
Echinochloa walteri				0.63 ± 0.63
Eichornia crassipes			20.00 ± 5.09	
Eleocharis baldwinii	55.00 ± 6.27	36.25 ± 5.41	14.38 ± 5.30	57.50 ± 7.20
Eleocharis quadrangulata			3.13 ± 0.91	0.63 ± 0.63
Fuirena pumila		0.63 ± 0.63	4.38 ± 1.48	6.88 ± 2.49
Hydrocotyle ranunculoides			2.50 ± 0.94	0.63 ± 0.63
Hydrocotyle umbellata	24.38 ± 4.95	13.75 ± 3.50	10.00 ± 1.89	34.38 ± 3.05
Kosteletzkya virginica			0.63 ± 0.63	
Leersia oryzoides			3.13 ± 0.91	
Ludwigia leptocarpa		0.63 ± 0.63	25.00 ± 5.09	2.50 ± 1.34
Ludwigia peploides	32.50 ± 8.66			
Phyla lanceolata	16.25 ± 2.06	10.63 ± 2.90	3.13 ± 0.91	2.50 ± 0.94
Sacciolepis striata		38.13 ± 6.61	3.13 ± 1.32	3.75 ± 1.57
Sagittaria latifolia		13.75 ± 5.07	5.63 ± 1.75	41.88 ± 3.89
Scirpus cubensis		0.63 ± 0.63	0.63 ± 0.63	
Number of Species	7	13	19	16

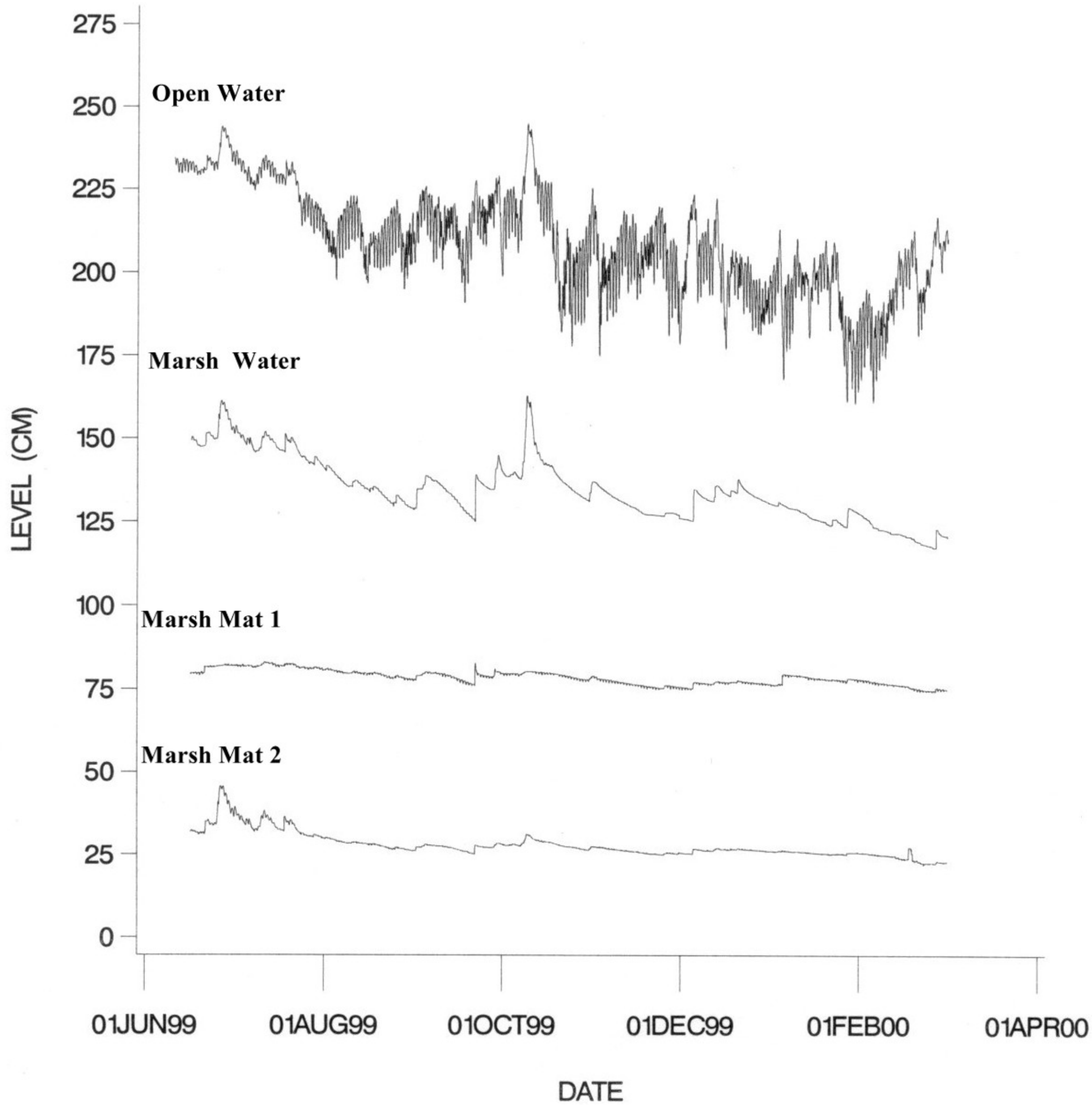

Figure 5. Time series plots of (top to bottom) half-hourly values of Open Water Levels, Marsh Water Levels, Marsh Mat Sensor 1, and Marsh Mat Sensor 2 from TMA (Turtle Bayou). All values are in centimeters relative to an arbitrary datum.

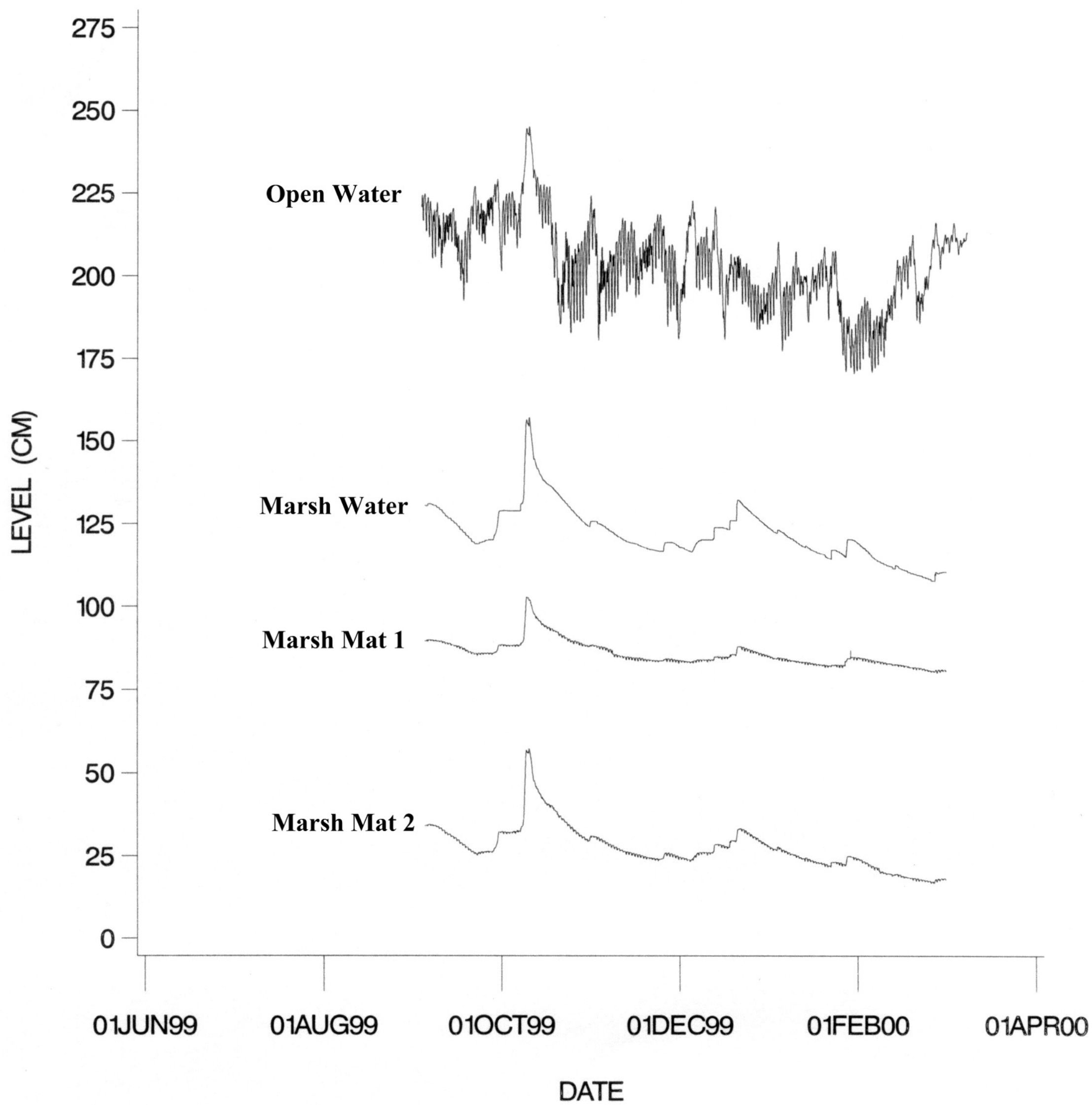

Figure 6. Time series plots of (top to bottom) half-hourly values of Open Water Levels, Marsh Water Levels, Marsh Mat Sensor 1, and Marsh Mat Sensor 2 from TMB (Louisiana Mud Canal). All values are in centimeters relative to an arbitrary datum.

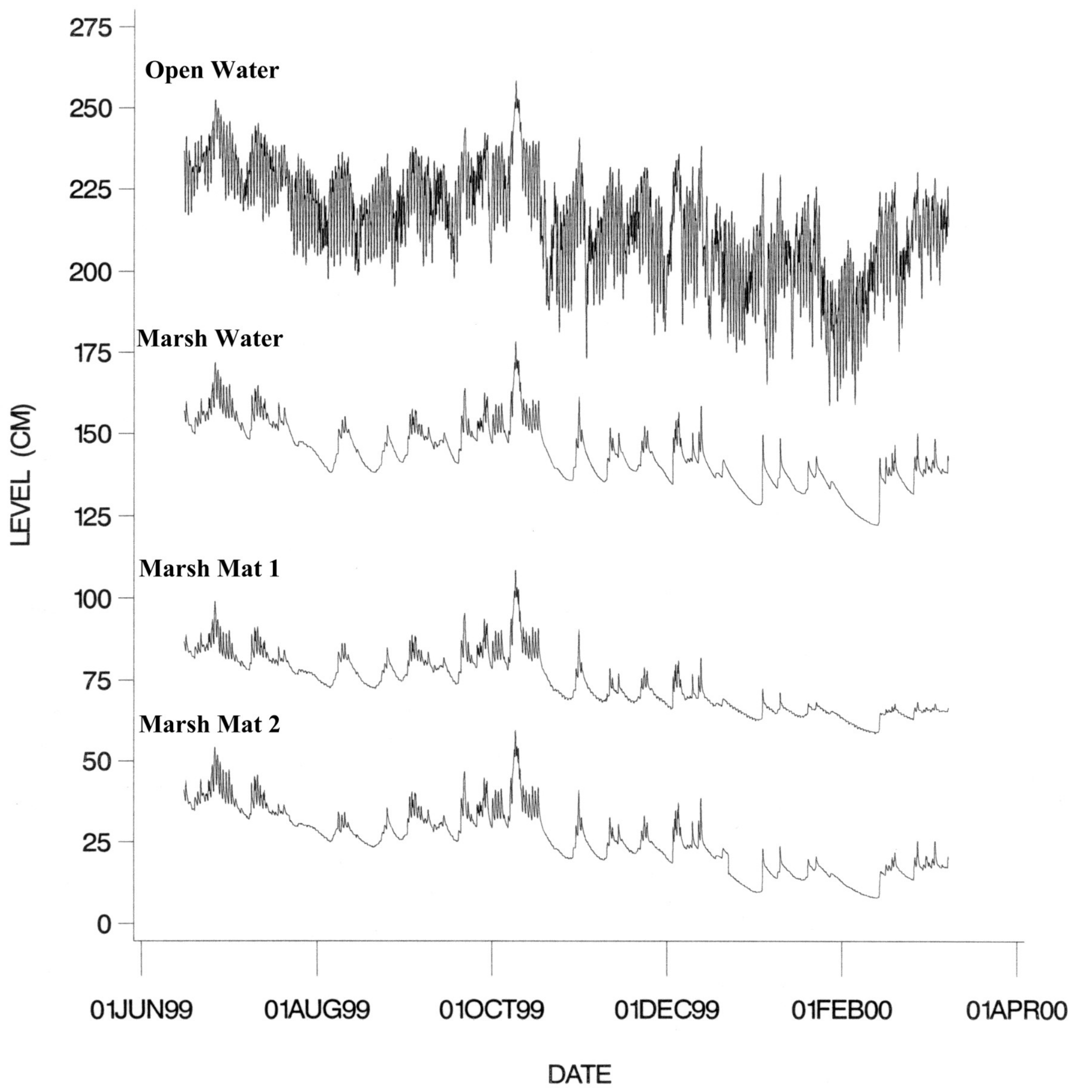

Figure 7. Time series plots of (top to bottom) half-hourly values of Open Water Levels, Marsh Water Levels, Marsh Mat Sensor 1, and Marsh Mat Sensor 2 from TMC (Texaco Canal). All values are in centimeters relative to an arbitrary datum.

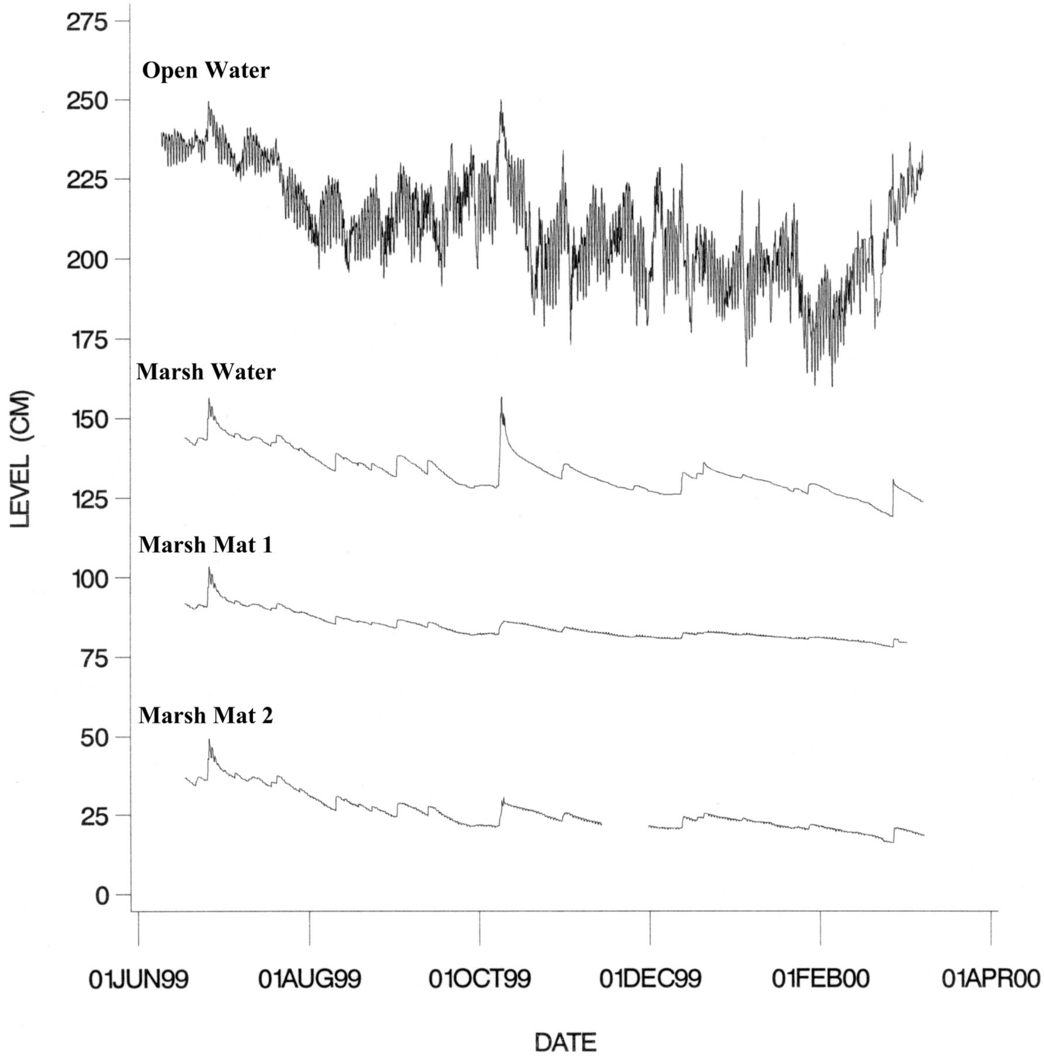

Figure 8. Time series plots of (top to bottom) half-hourly values of Open Water Levels, Marsh Water Levels, Marsh Mat Sensor 1, and Marsh Mat Sensor 2 from TMD (Towhead Bayou). All values are in centimeters relative to an arbitrary datum.

Suspended Matter

Total suspended sediment load in the project area was significantly higher in February than in May (ANOVA, "=0.05, Table 6). But a large range of values were found in both February (6 to 128 mg/l) and May (7.7 to 62.4 mg/l). Both suspended organic and inorganic matter were also significantly higher in February than in May. However, the range of suspended organic matter in the project area is relatively small compared to the range of suspended inorganic matter. Suspended organic matter in the project area ranged from 5.6 to 21.0 mg/l in February and from 4.2 to 11.6 mg/l in May. In contrast, suspended inorganic matter ranged from 0.4 to 109.5 mg/l in February and from 3.5 to 50.8 mg/l in May. On both dates the lowest suspended inorganic matter was found in Turtle Bayou adjacent to TMA. The highest suspended inorganic matter concentrations were found in the Intracoastal Waterway on the northern border of the project area as well as Kent and Superior Canal, which are connected directly to Bayou Penchant.

Table 6. Suspended Material composition observed in the waterways throughout the project area. Data shown are average and standard error for 18 stations.

Date	Suspended Organic Matter (mg/l)	Suspended Inorganic Matter (mg/l)	Total Suspended Solids (mg/l)
February 4, 1999	13.3 ± 1.1	56.3 ± 9.0	69.6 ± 10.1
May 6, 1999	7.8 ± 0.5	23.5 ± 3.4	31.3 ± 3.8

Measurements of suspended sediment load in the open water adjacent to each site show that total suspended sediment in the water bodies adjacent to the project sites differ, however these differences were not statistically significant most likely due to the small sample size (ANOVA, "=0.05, Figure 9). Most of the difference in total suspended material among the sites is due to differences in suspended inorganic material, while suspended organic matter seemed to have similar concentrations throughout the project area (Figure 9). TMA has the lowest inorganic suspended load; TMB and TMC have intermediate inorganic suspended load; and TMD has the highest inorganic suspended load.

Figure 9. Suspended Load and Percent Organic Matter in the suspended load measured in the open water (canal or bayou) adjacent to each site on February 4 and May 6, 1999.

Substrate

The soil and porewater nutrient data presented in this section were collected in the fall of 1999 at all experimental sites. These samples provide a synopsis of the differences in soil bulk properties (bulk density and percentage organic matter) and porewater nutrients prior to project construction. At present, we are still in the process of converting substrate nutrient concentrations (phosphorous and cations) to a standard volume basis and analyzing the nitrogen concentration of soil tissues (CHN analysis). Thus the data in the results section contain only the data we have analyzed to date.

The soil at each of the study sites is similar in organic matter content (Figure 10). TMA and PMB have the highest percentages of organic matter; concomitantly, these sites exhibit low bulk density. The sites closest to the Atchafalaya River, TMD and TMC, have relatively greater soil bulk density than those removed from the sediment influence of the river (TMA, TMB). At all sites, the organic matter content, in general, decreases with depth (Figure 11). The southern-most site (TMC) contains high variability in organic matter content between plots at depths below 20 cm. Variability in soil bulk properties at the three other sites is low.

Porewater nutrient concentrations contain high amounts of ammonium at greater depths (25 cm) in the soil profile (Figure 12). TMD contained significantly lower amounts of ammonium and phosphate compared to other sites. Nitrate levels were low at all study sites, since this form of nitrogen is quickly sequestered in flooded soil conditions. Porewater nutrient samples at the one donor site sampled (D1) showed that this area is either more actively assimilating ammonium and phosphate, or more limited than the project sites.

Figure 10.   Bulk density and organic matter for the study sites and two donor sites.

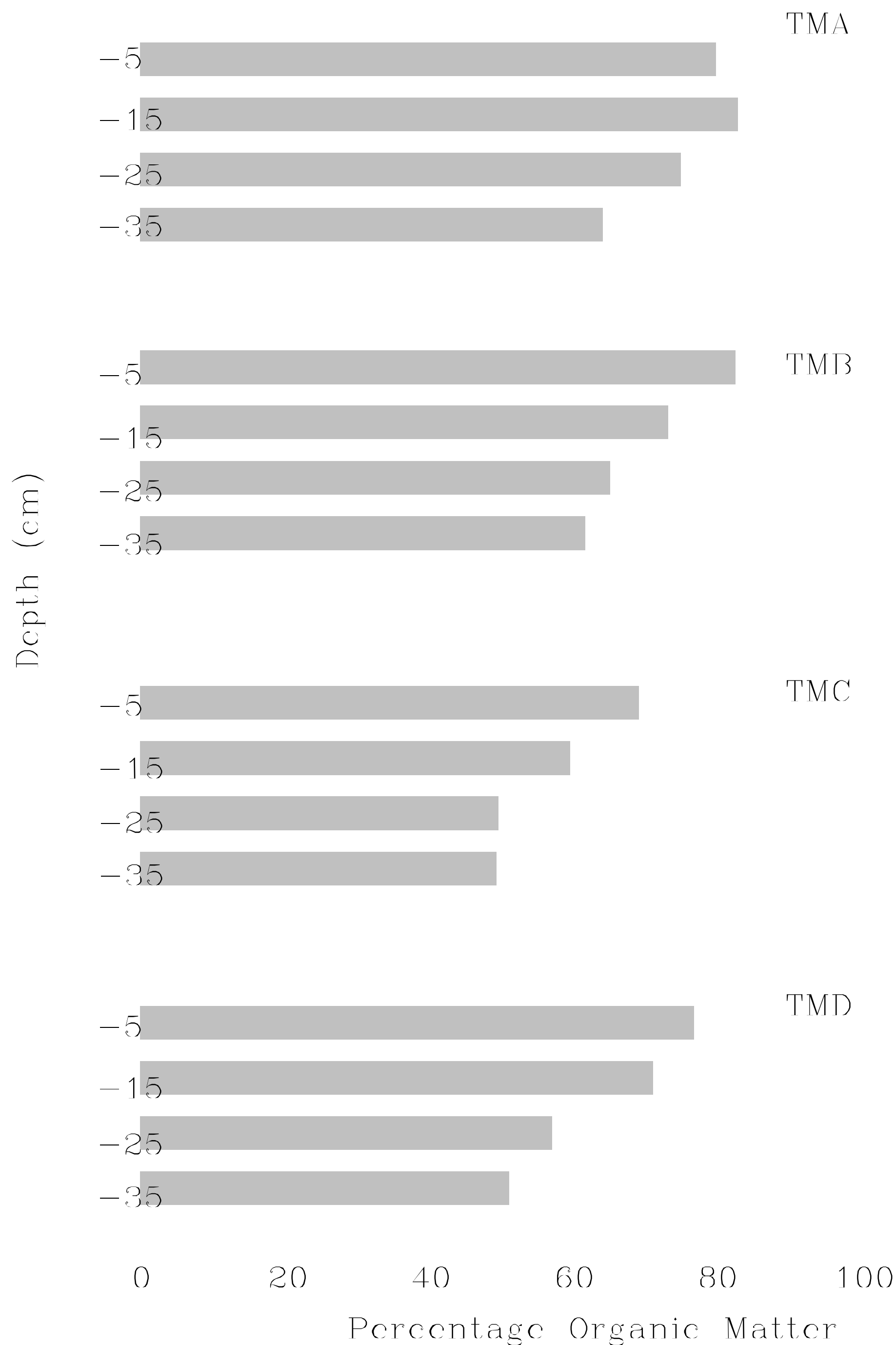

Figure 11. Organic matter percentages by depth for the four project sites.

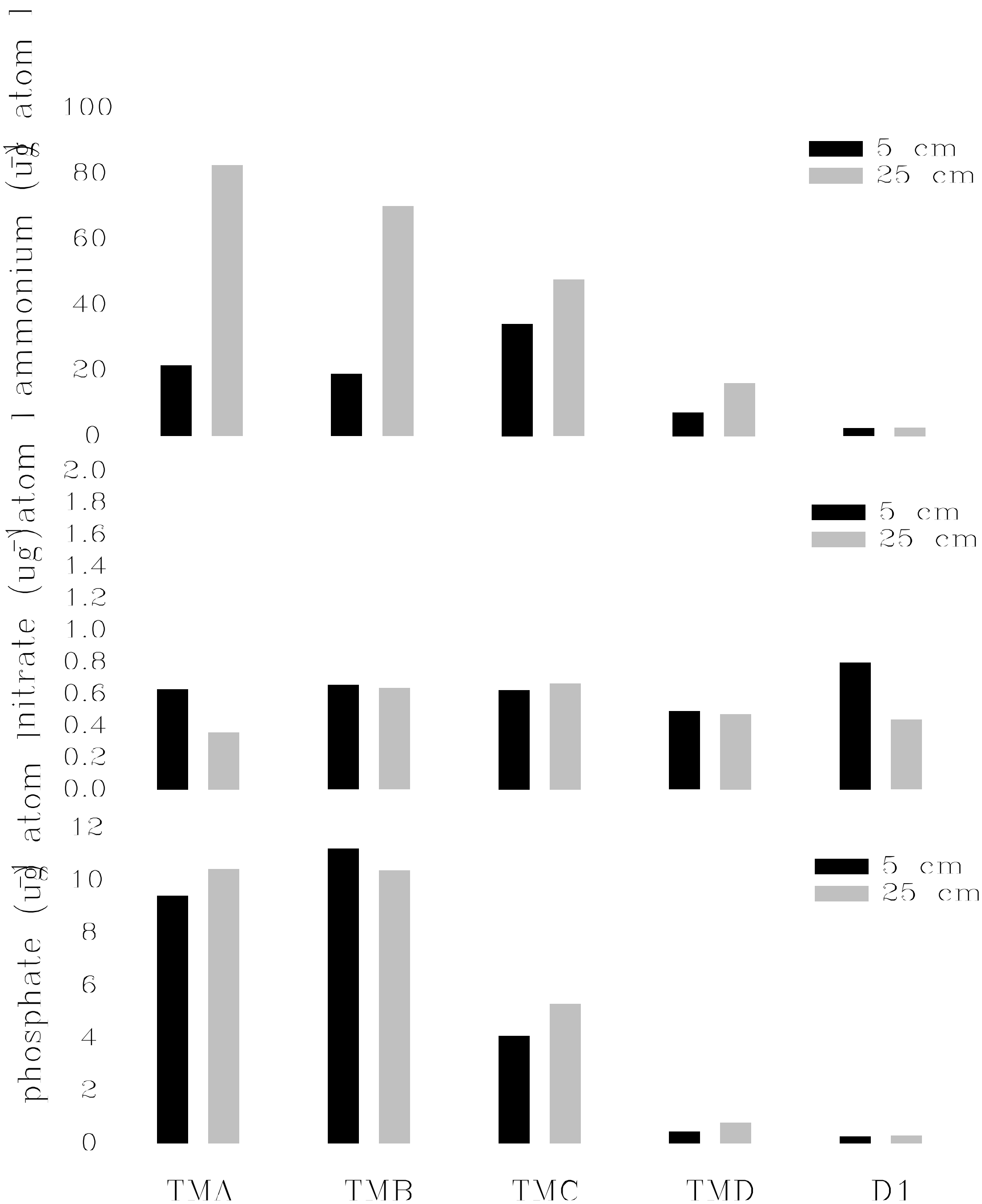

Figure 12. Porewater ammonium, nitrate, and phosphorous concentrations in :g atom l^{-1} at two depthsfor the four project sites and one donor site.

DISCUSSION and CONCLUSION

Comparison of Vegetative Cover and Biomass

Based on vegetation composition, the four project sites support their classification as *Eleocharis baldwinii*-dominated thin-mat marsh (fresh spikerush in Visser et al. 1999). Although, the two estimates of primary production—vegetative cover and biomass—gave conflicting results, species composition and dominant species were similar using both methods. These differences might be due to the fact that the plots harvested for biomass were much smaller and located in a different area of the site than those used to estimate cover. Although no significant differences in total biomass were detected among the sites, total cover did significantly differ. This is probably due to the larger sample size used to determine total cover.

Suspended Matter

Although we found no statistically significant differences among the suspended loads of the four project sites, the sites represent a large range of potential sediment input into the marsh. As expected, the site closest to the Atchafalaya River (TMD) had the highest suspended load of the four sites (32.5 to 112 mg/l). Previous work has estimated the suspended load in the vicinity of this site at 59 to 200 mg/l (see Sasser et al. 1995a). The lowest suspended sediment load was found at TMA (6 to 50 mg/l). These data show that the project sites represent the large variation in sediment availability that can be found throughout the northwestern Terrebonne marshes.

Conclusions

Vegetation	The four project sites can be classified as *Eleocharis baldwinii*-dominated thin-mat marsh.
Hydrology	The four project sites showed water and marsh mat movements consistent with floating thin-mat marsh.
Substrate	The four project sites have substrates consistent with floating thin-mat marsh.
Suspended Matter	The four project sites represent the desired range of sediment availability.

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