State of Louisiana

Coastal Protection and Restoration Authority of Louisiana

2017 Operations, Maintenance, and Monitoring Report

for

Coastwide Vegetative Planting Project (LA-0039)

State Project Number LA-0039
Priority Project List 20

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Operations, Maintenance, and Monitoring Report

Coastwide Vegetative Planting Project (LA-0039)

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Preface

The Coastwide Vegetative Planting Project (LA-0039) is funded through the Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) on the 20th Priority Project List and was authorized by Section 303(a) of Title III Public Law 101-646, enacted on November 29, 1990, as amended. The United States Department of Agriculture's National Resources Conservation Service (NRCS) serves as the federal sponsor of LA-0039, in partnership with the Coastal Protection and Restoration Authority (CPRA) as the state sponsor. This 2017 Operations, Maintenance, and Monitoring (OM&M) Report for LA-0039 addresses eleven LA-0039 plantings that have been completed as of December 2016. The 2017 report is the 1st report in a series of reports. Reports and other information for this project are accessible through CPRA's Coastal Information Management System (CIMS) website at *http://cims.coastal.louisiana.gov*.

I. Introduction

The LA-0039 project provides an annual mechanism for nominating, screening, and selecting restoration planting sites, as well as for formulating site-specific designs. The project includes herbaceous and woody plantings that are implemented coastwide to create/protect emergent vegetation and maintain landscape features in coastal areas. The LA-0039 project is intended to facilitate a consistent and responsive planting effort in coastal Louisiana that is flexible enough to routinely plant on a large scale and be able to rapidly respond to specific areas of need following storms or other damaging events. Following installation, the planting sites are monitored to assess survivorship and the overall condition of the plantings and planting site. Lessons learned from the monitoring help to inform subsequent site selection and planning. Unique to LA-0039 within the context of CWPPRA projects, new sites are added annually; therefore, several project components occur simultaneously (site selection, planning, construction, and monitoring).

II. Site Selection, Planning, and Design Review (Phase II - O&M)

Each year, the LA-0039 project team, consisting of NRCS and CPRA personnel, and a CWPPRA advisory panel select planting sites. Around 15 sites are nominated each year; the project team and advisory panel screen and score nominated sites using five criteria with weighted values: Probability of Success (30 points), Landrights/Logistical Access (25 Points), Urgency (20 Points), Landscape Value (15 Points), and Relation to Existing CWPPRA Projects (10 Points). Around six of the nominated sites are selected for further evaluation each year. After field visits, the project team preliminarily selects sites for the project year and develops planting concepts for the advisory panel to review. Three to six of the nominees are chosen as planting sites each year.

Following final site selection, NRCS starts permitting and land rights processes, conducts necessary surveys, and develops planting designs which are reviewed by the project team. The plans are then distributed to the LA-39 project team and CWPPRA advisory panel for review and final approval. When approved, NRCS develops final plans, specifications, and cost estimates for contract bid packages; timing is dependent on targeted season of planting. The contracts are then advertised to IDIQ contactors and awarded for construction.

Planting sites are intended to be selected for the first 10 years of the project life. Over the first six years of the project, 24 planting sites were selected and 18 sites were planted. The typical time from site selection to planting is one and half to two year within LA-39 which is much shorter than the time from project selection to construction for a typical CWPPRA project. Following planting, sites are distributed among the CPRA regional offices for monitoring (Table II-1; Fig. II-1). The following chapters detail 10 sites planted through 2015.

Table II-1. Coastwide Planting Project (LA-0039) selected planting sites.

Project Year	Site Name	Parish	Regional Office	Status	Planting Date	Plants
1	South Lake DeCade	Terrebonne	TRO	Planted	Fall 2012	33,330
2011	Cameron Creole	Cameron	LRO	Planted	Spring 2013	49,340
	Marsh Island	Iberia	LRO	Planted	Spring 2013	9,116
2	West Little Lake	Lafourche	TRO	Planted	Fall 2014	10,570
2012	DeCade Area	Terrebonne	TRO	Planted	Fall 2016	10,674
	The Prairie	St. John	NORO	Planted	Spring 2014	13,565
3	The Jaws	St. Mary	LRO	Planted	Fall 2014	10,650
2013	Little Vermilion Bay	Vermilion	LRO	Planted	Fall 2014	25,900
	Willow Lake	Cameron	LRO	Planted	Fall 2014	17,961
	Mud Lake	Cameron	LRO	Planning	TBD	
4	Green Island Bayou	Vermilion	LRO	Planted	Fall 2015	31,840
2014	Point Aux Chenes	Terrebonne	TRO	Planted	Fall 2015	3,874
	Rockefeller Unit 4	Cameron	LRO	Planted	Spring 2015	11,350
	Northwest Little Lake	Lafourche	TRO	Planning	TBD	
5	South Bayou DeCade	Terrebonne	TRO	Terminated	Spring 2017	1,700
2015	East Grand Terre	Plaquemines	TRO	Planted	Spring 2017	67,145
	Rockefeller Terraces	Cameron	LRO	Planted	Spring 2016	57,900
6	Sabine Unit 1 Overflow	Cameron	LRO	Planted	Fall 2017	30,260
2016	The Jaws #2	St. Mary	LRO	Planted	Fall 2017	4,425
	Belle Isle Lake	Vermilion	LRO	Awarded	Spring 2018	9,850
	Gentilly Unit	Orleans	NORO	Planted	Spring 2017	26,700
	West Little Lake #2	Lafourche	TRO	Planted	Spring 2017	15,360
	Willow Lake #2	Cameron	LRO	Awarded	Spring 2018	9,450
	Decade Vicinity	Terrebonne	TRO	Awarded	Spring 2018	16,590
					TOTAL	472,423

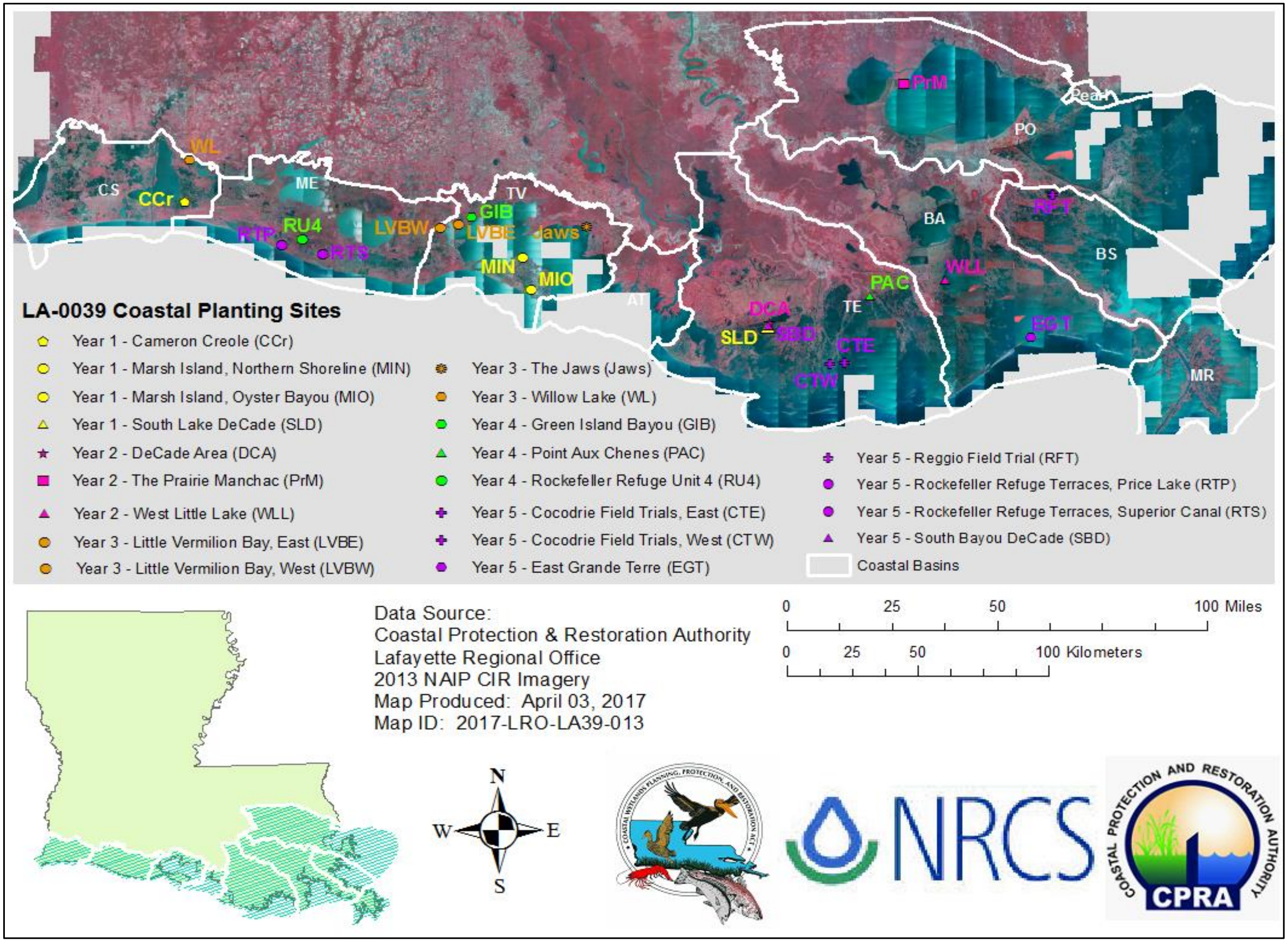


Figure II-1. LA-0039 Coastwide Vegetative Planting Project has established sites across coastal Louisiana from 2012-2017.

III. <u>Year 1 – South Lake DeCade</u>

Prepared by Margaret Luent and Tommy McGinnis – CPRA Lafayette Regional Office
Data collected by CPRA Thibodaux Regional Office

A. Site Description

South Lake DeCade, a Year 1 planting site, is in Terrebonne Parish southwest of Lake DeCade just south of Bayou DeCade (Fig. III-1) in the Terrebonne basin (Fig. II-1). Based on marsh categorization since 1949, the marsh along Bayou DeCade switched from brackish (1949-1988) to intermediate (1988-2013). The planting site, which experienced steady land loss since 1932, has a recent (1985-2010) land change rate of -0.85% per year which is a high loss rate (Couvillion et al. 2011; CPRA 2017). The planting site is within the CWPPRA project boundaries of TE-44 North Lake Mechant Landbridge Restoration, which protects the area from gulf tidal conditions to the south, and TE-34 Penchant Natural Resources Basin Plan Increment 1, which delivers freshwater and sediments from the north (CPRA 2017). The site is divided into three (3) planting areas (Fig. III-1). The final construction inspection of the South Lake DeCade planting was on October 29, 2012.

Area 1 consists of interior area plantings in a fragmented marsh intended to reconnect and stabilize patches of existing marsh. The interior of Area 1 was planted with plugs of *Spartina alterniflora* Vermilion (smooth cordgrass) in rows of plants spaced five ft apart with plants on five ft alternating centers with five ft spacing between rows. Perimeter segments were planted with a single row of trade-gallon sized smooth cordgrass planted on 10 ft centers. A small area within open water was planted with trade-gallon sized smooth cordgrass in north to south oriented rows spaced five ft apart with plants on five ft alternating centers.

Area 2 is oriented parallel to the shoreline south of Bayou DeCade and intended to establish vegetative cover in open water to disrupt wind fetch which may protect existing shoreline. Area 2 consists of two double rows of trade-gallon sized *Schoenoplectus californicus* (California bulrush) positioned approximately 60 ft and 120 ft from the shoreline. The double rows have 20' spacing between the rows, with plants on five ft alternating centers.

Area 3 is denoted as auxiliary and was planted with extra trade-gallon sized *Schoenoplectus californicus* (California bulrush). The Area 3 plantings were designed to reinforce the shoreline along the tidal channel. Rows were spaced five ft apart with plants on five ft alternating centers.

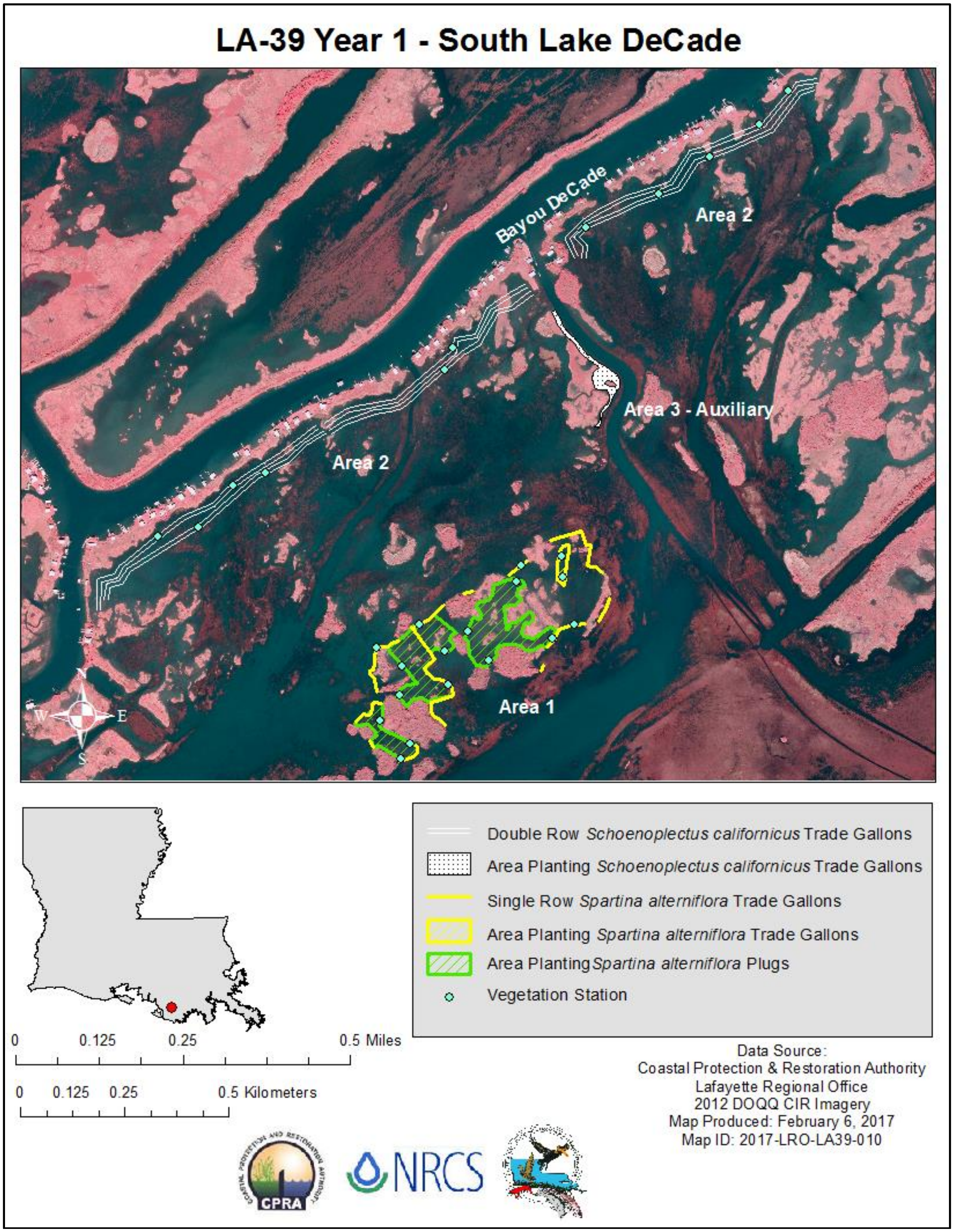


Figure III-1. LA-39 Year 1 Site – South Lake DeCade site map shows plantings areas and types. The vegetative monitoring stations are also displayed.

B. Monitoring Activity

1. Monitoring Goals

The Year 1 South Lake DeCade plantings were designed to reinforce submerged and broken marsh platforms (interior area and perimeter plantings), to protect existing marsh, and to vegetate open water (double row plantings).

The goals of the South Lake DeCade plantings are:

- Area 1 broken marsh plantings of *Spartina alterniflora* Vermilion plugs will survive and expand between patches of existing marsh.
- Area 1 broken marsh perimeter plantings of trade-gallon sized *Spartina alterniflora* Vermilion will survive and expand to reinforce the submerged and broken marsh platform.
- Area 2 double row plantings will survive and expand to establish vegetation in open areas and break wind fetch.
- Area 3 plantings will survive and revegetate a degrading marsh platform.

2. Monitoring Elements

The monitoring elements include procedures to assess planting survival and effects on the planting site for the two main types of project plantings, interior area coverage and shoreline protection. Vegetation stations are intended to monitor planting survival and vegetative cover representative of the variety of planting strategies over time (Table III-1). Hydrologic data from nearby CRMS sites are used to explain hydrologic influences such as flooding and salinity.

Table III-1. Sampling schedule for LA-39 Year 1 site, South Lake DeCade

Sampling Type	T_1 2012	T_2 2013	T_3 2015	T_4 2017	T_5 2022
Planting Survival	Nov	Oct	Oct	Fall	Fall
Percent Cover	Nov	Oct	Oct	Fall	Fall

<u>**Vegetation Assessment**</u>

To assess the plantings and their effect on the planting areas, 29 vegetation stations were established to monitor planting survival and emergent vegetation cover. Data collection for planting survival and vegetative cover was conducted one week, one year, and three years after plant installation and will continue five and ten years after plant installation. Percent survival was calculated from 10 plants at each vegetation station; plants were characterized as live (any green vegetation) or dead/absent. Vegetative cover data includes cover of emergent vegetation (%), cover of species present (%), vegetative stand height (ft), and height of dominant species (ft) within a 4 m^2 plot (Folse et al. 2014). Flooding depth, surface water salinity, and temperature were collected at all sampling stations during each sampling event. Conditions occurring outside of the stations and segments including additional species were also noted along with photo documentation.

Area 1 (Fragmented Marsh Planting) has 18 vegetation stations to monitor planting survival and vegetative cover. Nine stations are within the plug-sized smooth cordgrass plantings. The trade-gallon sized smooth cordgrass planting have seven stations along the perimeter segments and two stations are within the open-water area planting.

Area 2 (Double Row California Bulrush Plantings) has 11 stations divided between the two double rows of California bulrush; five stations are in the double row 60 ft from the shoreline, and six stations are in double row 120 ft from the shoreline.

Area 3 (Auxiliary California Bulrush Plantings) does not have any vegetation stations. Progression of the plantings will be qualitatively described with Google Earth imagery.

<u>Planting Failure/Success Causation</u>

Hydrologic data from CRMS0398, located 1.5 miles north of the planting site, will be used to describe area water-level trends and salinity. The water level data will be compared to planting elevations (ft, NAVD88, Geoid 12A) to describe flood conditions. Photographic documentation will also be used to describe processes of planting success and failure.

3. Monitoring Results and Discussion

a. Vegetation Assessment

The ocular estimates of the planting areas captured the general performance of the plantings (Table III-2). Healthy stands of intermediate submerged aquatic vegetation (*Ceratophyllum demersum, Myriophyllum spicatum, and Vallisneria americana*) were present during planting and throughout the monitoring period in all areas. Most of the smooth cordgrass plantings, plug and trade gallon sized, in Area 1 were gone by one year after planting (Fig. III-2 A and C) and were completely absent by three years after planting (Fig. III-2 B and D). Naturally occurring *Phragmites australis* (Roseau cane) has expanded from the existing marsh patches (Fig. III-2 C) and onto floating vegetation mats (Fig. III-2 D). Area 2 double row plantings of California bulrush had survived and expanded by the first year after planting with the exception of plantings near the opening of Bayou DeCade (Table III-2) and continued to do so through early 2015 (Fig. III-3). By three years after planting (October 2015), much of the California bulrush was destroyed by floating mats of giant Salvinia and water hyacinth (Fig. III-4). Auxiliary Area 3 plantings of California bulrush had survived and expanded with minor losses through early 2015 (Fig. III-5).

Table III-2. Overall % Survival of LA-39 Year 1 South Lake DeCade plantings were ocularly estimated over time while conducting monitoring field trips.

		% Overall Survival		
Area	Planting Type	T_1 Nov 2012	T_2 Oct 2013	T_3 Oct 2015
Area 1	Fragmented Marsh Openings	100	<5	0
	Perimeter Segments	100	<5	0
	Open Water	100	0	0
Area 2	Double Row – 60 ft from marsh	100	70	20
	Double Row – 120 ft from marsh	100	70	20
Area 3	Channel Reinforcement	100	90	ND*

* ND = Not Documented

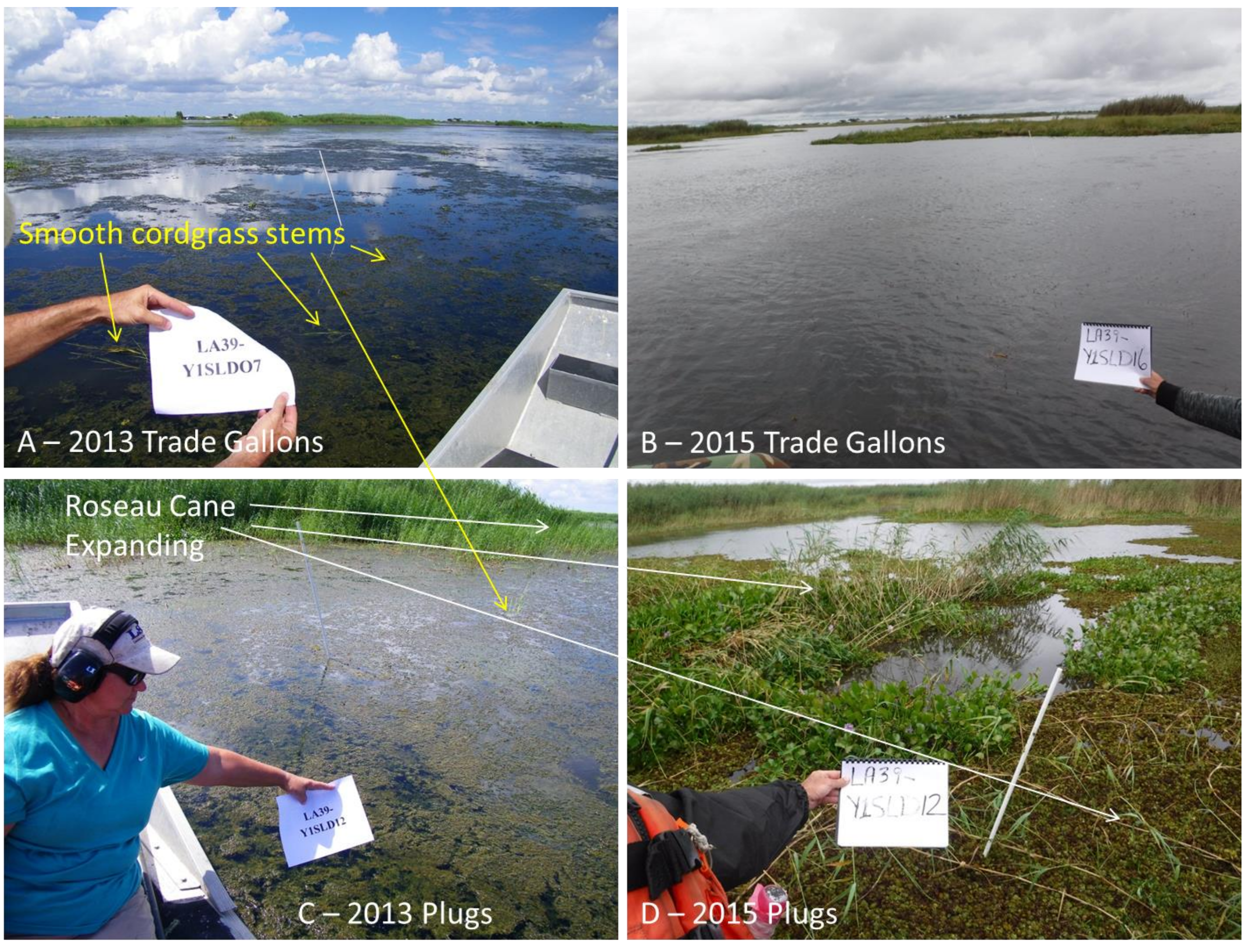


Figure III-2. Pictures of LA-39 Year 1 South Lake DeCade Area 1 *Spartina alterniflora* Vermilion (smooth cordgrass) plantings were taken during October 2013 and 2015 monitoring trips. Top row of photos are depicting the trade-gallon sized plant plantings from 2013 (A) and 2015 (B). The bottom row of photos depicts the plug sized plantings from 2013 (C) and 2015 (D). Note algae on submerged aquatic vegetation in A and C. Also note advancement of Roseau cane from marsh edge in C (2013) and onto floating vegetation in D (2015).

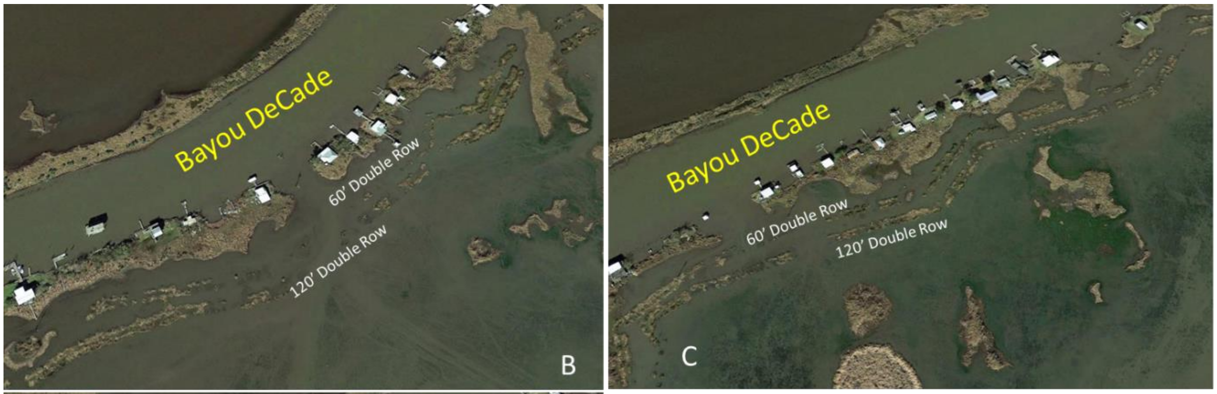


Figure III-3. Aerial imagery dated January 24, 2015 of LA-39 Year 1 South Lake DeCade Area 2 - Google Earth images showing Double Row Plantings of *Shoenoplectus californicus*. Frames A-C are oriented from southwest to northeast along Bayou DeCade. The two sets of double row plantings had good survival and expansion, overall. Note losses of plantings in close proximity to openings with Bayou DeCade (B and C).

Figure III-4. Expansive mats of floating vegetation impacted the Area 2 by pushing over and covering Califonia bullwhips (A). Sparse and damaged plants, if any, typically remain when the mats dissipate (B). Pictures were taken during the Oct 2015 monitoring.

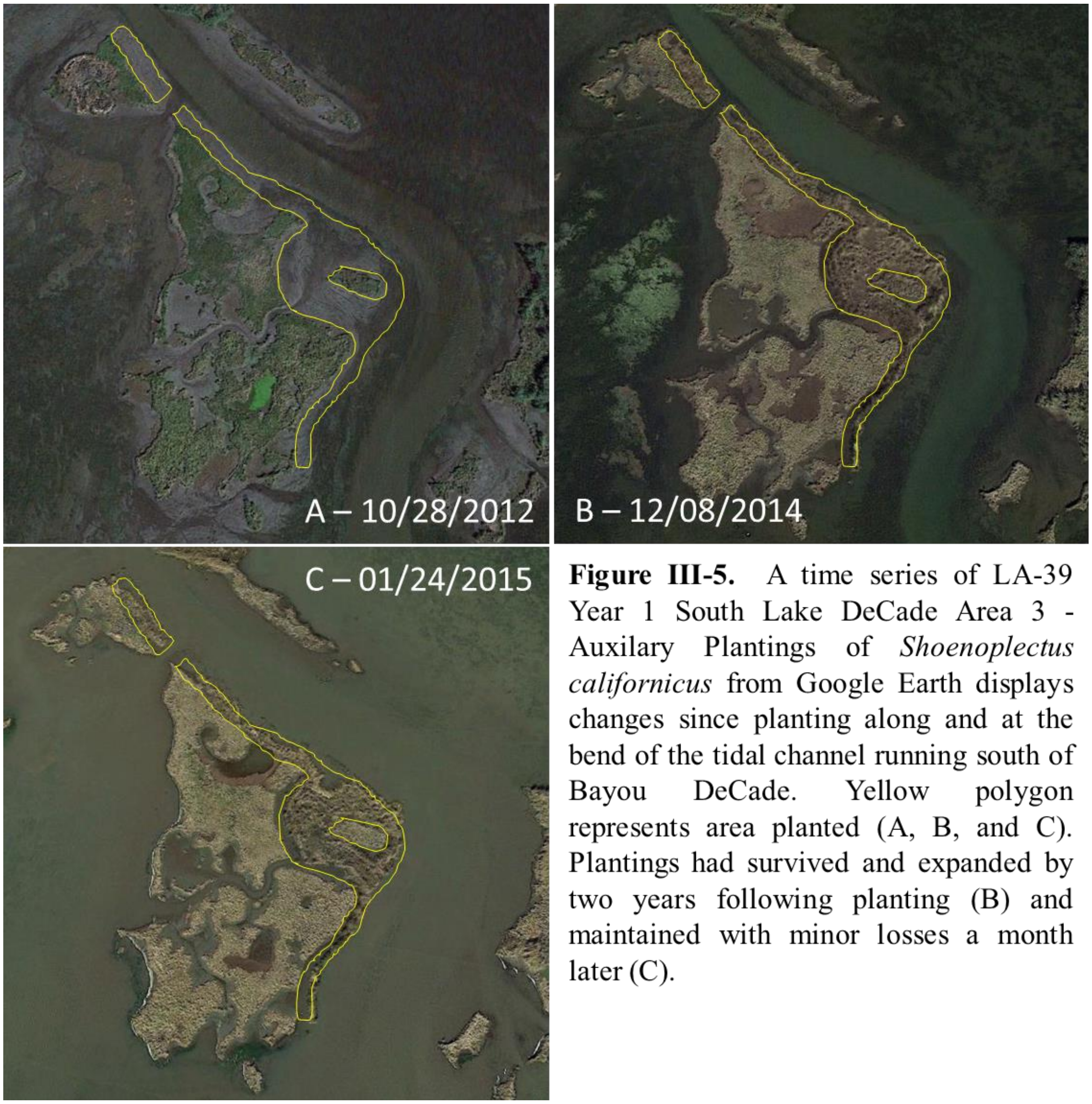


Figure III-5. A time series of LA-39 Year 1 South Lake DeCade Area 3 - Auxilary Plantings of *Shoenoplectus californicus* from Google Earth displays changes since planting along and at the bend of the tidal channel running south of Bayou DeCade. Yellow polygon represents area planted (A, B, and C). Plantings had survived and expanded by two years following planting (B) and maintained with minor losses a month later (C).

Vegetation station data collected over three years captured the station scale performance of the plantings. Percent survival was 0% at all Area 1 vegetation stations by one year after planting, and vegetation stations were not established in the Area 3 Auxiliary; therefore, station level analyses were only conducted for the Area 2 double rows of California bulrush, and stations from the 60 ft and 120 ft marsh double rows were combined because of performance similarities. Percent survival decreased about 30% by one year after planting and continued to decrease by another 50% by three years after planting (Table III-2) because of rafting by floating vegetation (Fig. III-4). Percent cover of emergent vegetation at least doubled a year after planting (Fig. III-6A) as surviving plants expanded despite some loss caused by floating vegetation (Fig III-7). By three years after planting, emergent vegetative cover at stations showed no additional expansion driven by impacts from floating vegetation. Stem height of remaining plantings at least doubled by a year after planting and had decreased by about 1.5 ft three years after planting (Fig. III-6B).

Stem heights ranged from three to nine ft depending on impacts from floating vegetation mats ranging from high to low, respectively (Fig. III-4).

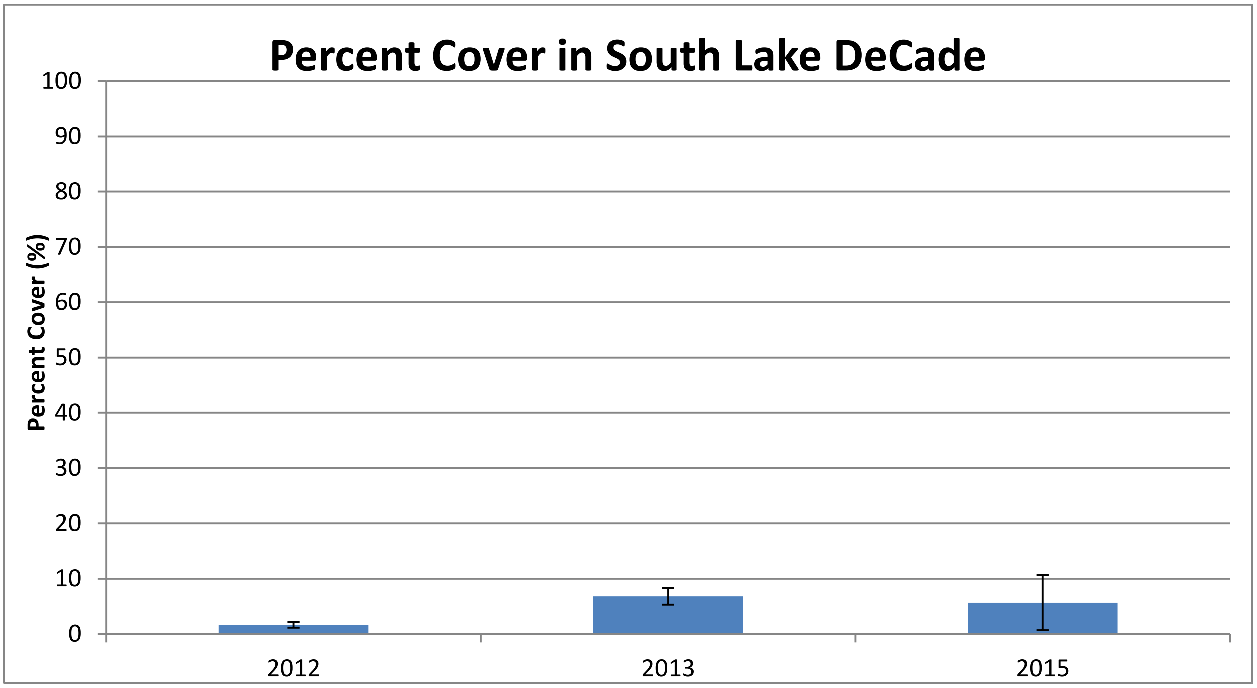


Figure III-6A. Percent cover was collected from vegetation stations in Area 2 Double Row plantings of *Shoenoplectus californicus* in the LA-39 Year 2 South Lake DeCade site.

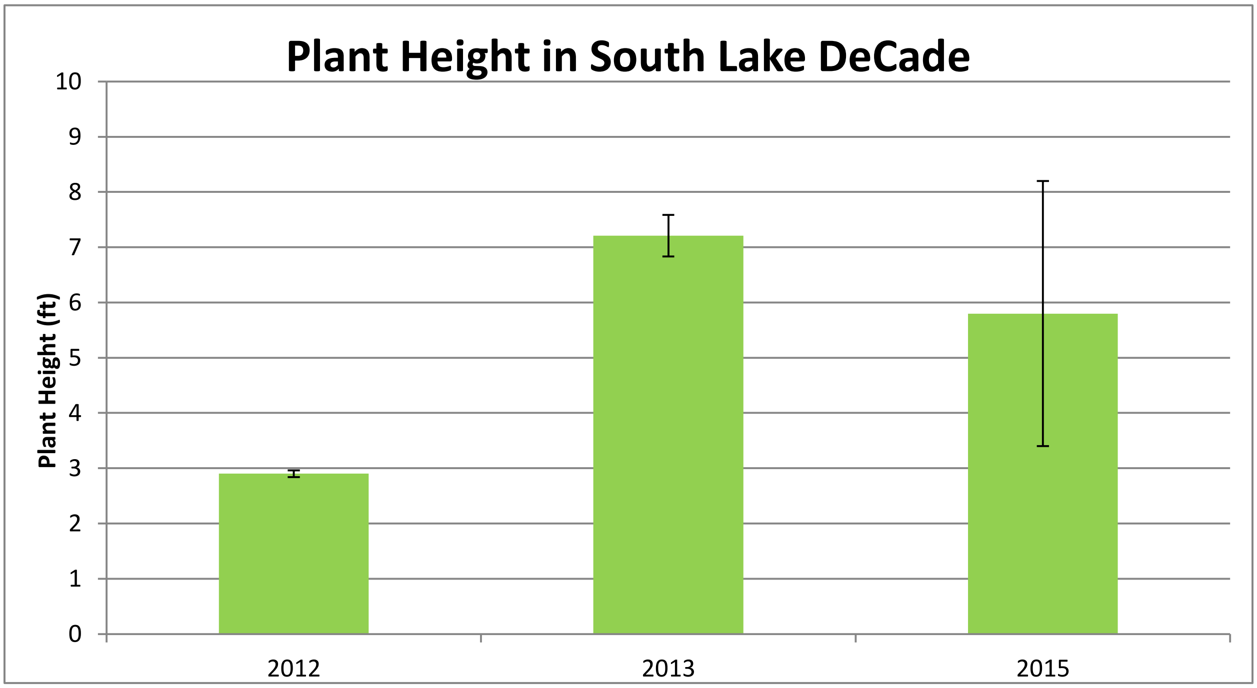


Figure III-6B. Plant height was collected from vegetation stations in Area 2 Double Row plantings of *Shoenoplectus californicus* in the LA-39 Year 2 South Lake DeCade site.

Figure III-7. Pictures of LA-39 Year 1 South Lake DeCade Area 2 - Double Row *Shoenoplectus californicus* (California bulrush) plantings were taken during 1 (A) and 3 (B) years after planting. Losses from the rafting of floating aquatic vegetation began prior to the 2013 sampling (A) and expanded by the 2015 sampling (B). The dead stems in B are from seasonal senescence's.

b. Planting Failure Causation

Water depths were typically greater than the optimum range of 1 - 18 inches for smooth cordgrass 'Vermilion' strain establishment (Fine and Thomassie. 2000); and, the plants were constantly flooded (Fig. III-8) which causes anaerobic soil conditions that can be toxic to plant roots. Isolated plants, as planted along rows with five feet spacing between plants, are especially vulnerable to anaerobic soil conditions. Submerged and floating aquatic vegetation (SAV and FAV) rafting over the plants is another significant contributor to planting failure (Fig. III-2). Water salinity averaged around 2 ppt which is within the tolerance range of smooth cordgrass 'Vermilion' strain (8–30 ppt) and should not have been a stress factor (Fine and Thomassie. 2000). The California bulrush plantings were not stressed by the water levels or salinity. Sometime between January 2015 (Fig. III-3) and field sampling in October 2015 established stands of California bulrush were smothered out by large mats of floating invasive species, giant Salvinia and water hyacinth (Fig. III-4).

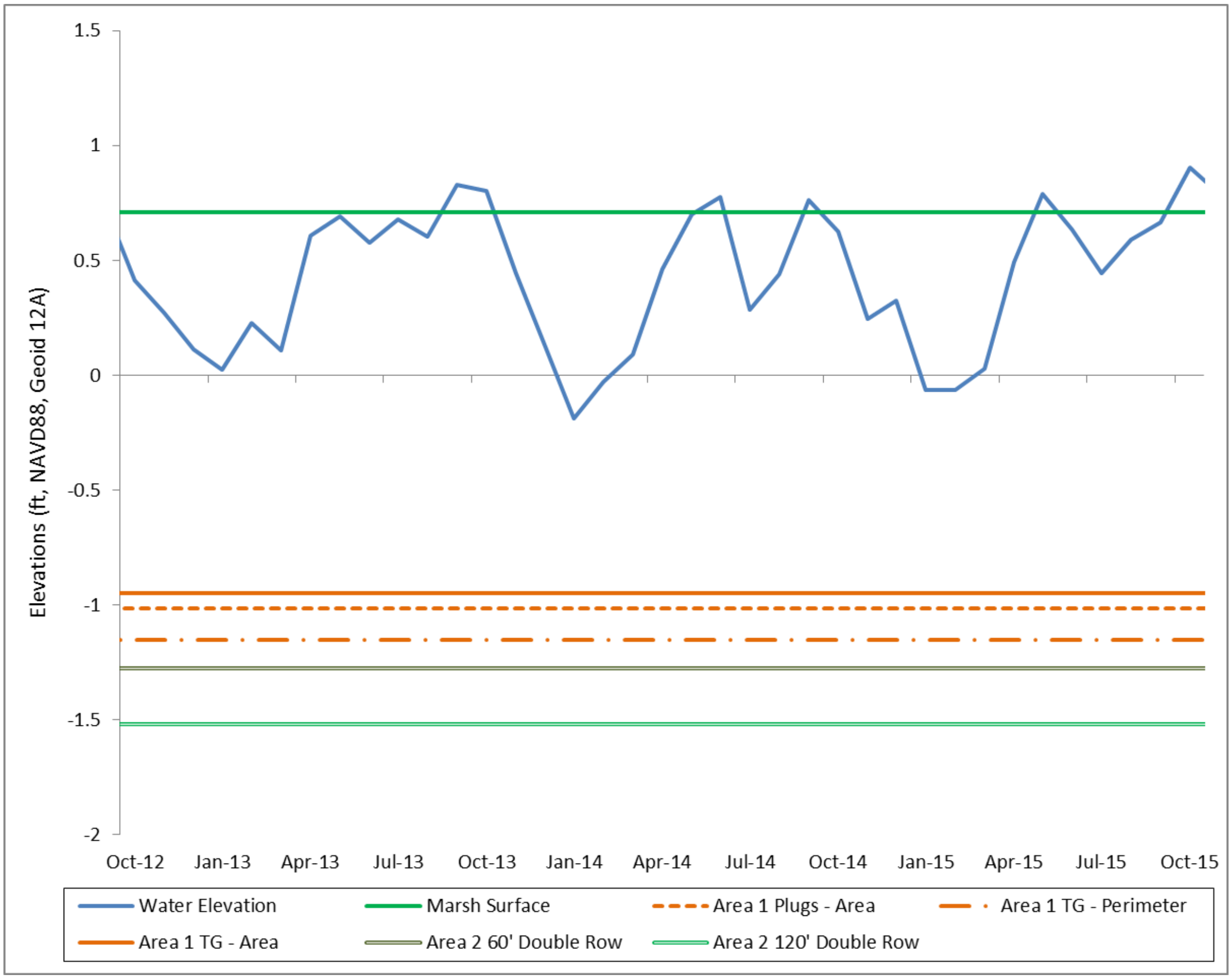


Figure III-8. Monthly averages of water-level elevations from CRMS0398-H01 are plotted relative to average plant elevations measured throughout the South Lake DeCade plantings. The Area 1 plantings were different sized (smaller plugs and larger trade gallons = TG) *Spartina alterniflora* Vermilion (smooth cordgrass), and the Area 2 plantings were TG sized *Schoenoplectus califonicus* (California bulrush). Note increased inundation during the growing seasons and the elevation of the adjacent marsh surface relative to water and planting elevations.

C. Conclusions

The Year 1 South Lake DeCade plantings had very limited success. The smooth cordgrass plantings sharply declined within the first year after planting and were completely gone by three years after planting. California bulrush plantings had successfully established and expanded over the first 2+ years; however, most of the plantings were physically destroyed and smothered by floating vegetation mats by the three year sampling in October 2015. However the more tidal plantings in Area 3 have continued to thrive and expand.

1. Project Effectiveness

As per the project goals:

- Area 1 broken marsh plantings of *Spartina alterniflora* Vermilion (smooth cordgrass) plugs did not survive and expand between patches of existing marsh.
- Area 1 broken marsh perimeter plantings of trade-gallon sized smooth cordgrass did not survive and expand to reinforce the submerged and broken marsh platform.
- Area 2 double row plantings of *Schoenoplectus californicus* (California bulrush) survived and expanded to vegetate open areas; however, they were severely impacted by rafts of floating vegetation.
- Area 3 plantings of California bulrush survived and expanded to revegetate a degrading marsh platform along a tidal channel.

2. Recommended Improvements

Plant mature stalks of *Phragmites australis* which is expanding in the area where smooth cordgrass was attempted.

3. Lessons Learned

The Year 1 South Lake DeCade planted smooth cordgrass and California bulrush on chronically flooded, former marsh platforms, and California bulrush performed much better. Planting of smooth coedgrass in such areas should be avoided. Planting smooth cordgrass could be useful to compliment other restoration/ conservation measures that increase elevations such as marsh creation, sediment nourishment, or terracing.

Large, nearly three year old, stands of California bulrush were pushed over and smothered by floating vegetation composed mainly of giant Salvinia and water hyacinth. The occurrence of large mats of floating vegetation in recent years are attributable to recent mild winter temperatures and a decrease in nuisance floating vegetation control by the Louisiana Department of Wildlife and Fisheries along with moderate to heavy rainfall. Planning for additional resources to be implemented for floating invasive species control may need to be considered.

IV. Year 1 – Cameron Creole

Prepared by Tommy McGinnis – CPRA Lafayette Regional Office

A. Site Description

Cameron Creole, a Year 1 planting site, is in Cameron Parish within the USFWS Cameron Prairie National Wildlife Refuge just west of the South Prong of Grand Bayou. The refuge is hydrologically managed. The marsh in the refuge was severely damaged during Hurricanes Rita in 2005 and Ike in 2008 and has since degraded. The site is divided into four (4) areas planted with trade-gallon sized *Spartina alterniflora* Vermilion (smooth cordgrass) in a variety of planting strategies intended to stabilize existing marsh and re-establish vegetation in shallow open water areas (Fig. IV-1). The final construction inspection of the Cameron Creole planting was on June 13, 2013.

The **Northwest Area (NWA)** consists of marsh platform (~23 acres of broken marsh and mudflats) and bankline plantings (~3500 lf) along Lambert Bayou. The marsh platform plantings were planted in parallel rows 15 ft apart with plants on alternating five ft centers; the rows are on a submerging marsh platform and are roughly perpendicular to Lambert Bayou. The bankline plantings along Lambert Bayou consist of double rows spaced three ft apart with plants planted on alternating five ft centers.

The **Central Area (CA)** has five interior plantings in shallow open water and five perimeter plantings. The interior plantings consist of parallel rows 15 ft apart with plants on alternating five ft centers covering ~ 12 acres of open water. The perimeter plantings are a single row with plants planted on three ft centers around existing marsh platforms and cover ~8050 linear feet of perimeter.

The **Northeast Area (NEA)** has two techniques of interior plantings differing by row grouping and orientation to the South Prong of Grand Bayou. Triple rows are within open water and run perpendicular to South Prong; they consist of 31 sets of three rows five ft apart with plants on alternating five ft centers. The area planting that parallels the South Prong is adjacent to existing marsh in six rows planted five ft apart with plants on alternating five ft centers.

The **Southeast Area (SEA)** is an area planting parallel to the South Prong and adjacent to existing marsh just south of the NEA. SEA covers ~10 acres with parallel rows planted five ft apart with plants on alternating five ft centers.

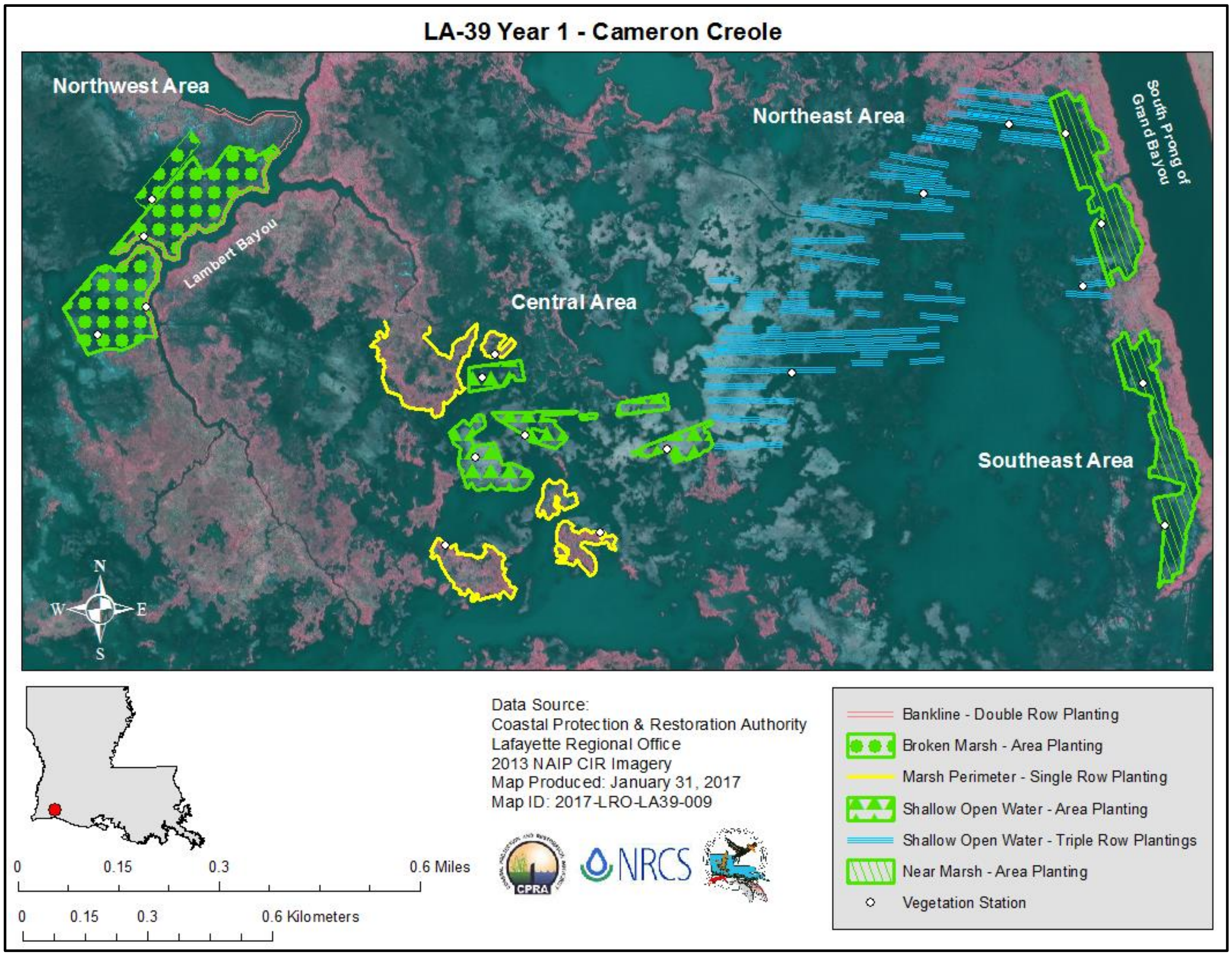


Figure IV-1. LA-39 Year 1 Site – Cameron Creole site map shows plantings areas and types, the vegetative monitoring stations are also displayed.

B. Monitoring Activity

1. Monitoring Goals

The Year 1 Cameron Creole plantings were designed to stabilize existing marsh vegetation (bankline and perimeter plantings) and establish vegetation on large expansive mudflats and submerged marsh platforms (broken marsh interior plantings, interior, triple row, and area plantings).

The goals of the Cameron Creole plantings are:

- NWA interior plantings will survive and expand on the broken and submerging marsh platform.
- NWA bankline plantings will survive and expand to stabilize the Lambert Bayou bank.
- CA perimeter plantings will survive and expand to stabilize stands of existing marsh vegetation.

- CA interior plantings will survive and expand to form and reconnect existing stands of marsh vegetation on mudflats and submerged marsh platforms.
- NEA triple-row interior plantings will survive and expand to form bands of marsh vegetation on mudflats and submerged marsh platforms.
- NEA and SEA area plantings will survive and expand to widen vegetation along Grand Bayou onto submerged marsh platforms.
- Determine if triple row (NEA) or interior (CA) plantings are more effective at establishing marsh vegetation on mudflats and submerged marsh platforms.

2. Monitoring Elements

The monitoring elements include procedures to assess planting survival and effects on the planting area for the two main types of project plantings, existing marsh stabilization and interior area coverage. Vegetation stations are intended to monitor planting survival and vegetative cover representative of the variety of planting strategies over time (Table IV-1). Hydrologic data from nearby CRMS sites are used to explain hydrologic influences such as flooding and salinity.

Table IV-1. Sampling scheduled for LA-39 Year 1 site, Cameron Creole.

Sampling Type	T_0 2013	T_1 2013	T_2 2014	T_3 2016	T_4 2018	T_5 2023
Planting Survival	June 13	June 25	June 24	June 23	June	Spring
Percent Cover		June 25	June 24	June 23	June	Spring

<u>Vegetation Assessment</u>

To assess planting status, an ocular estimate of % survival and plant condition was conducted at the station level for each area and planting type while visually inspecting the entire site during sampling visits. Planting survival and % vegetative cover data was collected at the vegetation station level; 19 stations were established to represent the areas and planting types. Percent survival was calculated from a set number of plants at each vegetation station; plants were characterized as live or dead/absent. PVC poles were placed on both ends of the plants monitored for survival. Vegetative condition was assessed by measuring % cover of species present, vegetative stand height, and height of dominant species at 4 m^2 vegetation plots at the vegetation stations (Folse et al. 2014). Flooding depth, surface water salinity and temperature, and porewater salinity and temperature were also collected at all sampling stations during each sampling event. Conditions occurring outside of the stations and segments including additional species, marsh interspersion, and site-specific points of interest were noted along with photographic documentation.

<u>NWA – Broken Marsh Platform:</u> Two vegetation stations were established with a PVC pole marking the SW corner along planting rows which are generally oriented west to east. The percent vegetative cover plot is a 2 × 2 m (4 m^2) plot incorporating the row, and 10 survival plants extend east along the planting row from the PVC pole.

NWA – Bankline: Two vegetation stations are oriented along the bankline double row with a PVC pole marking the beginning of the station. The percent cover plot is 4 m long × 1 m wide (4 m^2) incorporating both rows and the 10 survival plants are divided evenly between the two rows (5 plants per row).

CA - Mudflat/Shallow Openwater Grid: Four vegetation stations were established in planting grids with a PVC pole marking the SW corner along a planting row. Percent vegetative cover is determined in a 2 × 2 m (4 m^2) plot, and 10 survival plants extend east from the PVC pole divided evenly between two rows (five plants per row).

CA – Existing Marsh Perimeter: Three vegetation stations are oriented along the bankline row extending clockwise around the patch of existing marsh with a PVC pole marking the beginning of the station. The percent cover plot is 4 m long × 1 m wide (4 m^2) encompassing the single row and 10 survival plants extend in a clockwise direction.

NEA – Mudflat/Shallow Openwater Triple Row: Four vegetation stations were established among the triple row plantings marked with a PVC pole in the southwest corner along the southern most row. The percent vegetative cover is determined in a 2 × 2 m (4 m^2) plot along the southern row of plants. Fifteen survival plants are divided evenly among the three rows (five plants per row) and extend east from the PVC pole.

NEA/SEA – Mudflat/Shallow Openwater, Near-Marsh Grid: Four vegetation stations, two within the NEA and two within the SEA, were established along the north to south oriented rows with a PVC pole marking the NW corner. The percent vegetative cover is determined in 2 × 2 m (4 m^2) plot, and 10 survival plants extend in a row from the PVC pole.

Planting Failure/Success Causation

If significant loss of plants occurs, suspected causes (soil conditions, hydrologic conditions, planting removal) will be investigated. Hydrologic data from CRMS0645-H01, located just northeast of the planting site in the South Prong of Grand Bayou, will be used to describe area water-level trends and salinity. The water level data will be compared to planting elevations (ft, NAVD88, Geoid 12A) to describe flood conditions.

3. Monitoring Results and Discussion

a. Vegetation Assessment

The ocular estimates of overall planting areas captured the overall performance of the plantings. The maximum planting depth was lowered from -0.25 ft NAVD88 to -0.5 ft NAVD88 during installation because of limited planting areas higher than -0.25 ft NAVD88. Boundaries and number of plantings in the NWA broken marsh platform and CA mudflat/open water grids were modified during planting because of algae rafting on submerged aquatic vegetation (SAV, mainly *Ruppia maritima*) was immersing new plantings. A few weeks after planting, the plants looked healthy aside from some herbivory and rafting from algae and SAV. Survival a year following planting had decrease by > 90 % in all areas, and surviving plants were not expanding. Three years after planting, surviving plants were only found in patches of the NWA among previously existing plants at higher elevations, a 400 ft stretch at the northern end of NWA bankline (30% survival in that stretch), and some individual plants in the northern section of the NEA open water near marsh grid that have not expanded. (Table IV-2). The previously existing marsh in the Cameron Creole site is mainly composed of *Spartina patens* and *S. alterniflora*. Marsh vegetation has degraded in the NWA since construction, especially along the bankline of Lambert Bayou which is barely discernible. The existing marsh in the other areas has looked healthy but is eroding along the edges over the three years since planting. *Ruppia maritima* was abundant throughout the site since planting.

Table IV-2. Overall % Survival of LA-39 Year 1 Cameron Creole plantings was ocularly estimated over time while conducting the final inspection and monitoring field trips.

		% Overall Survival			
Area	Planting Type	T_0 Jun 13, 2013	T_1 Jun 25, 2013	T_2 Jun 24, 2014	T_3 Jun 23, 2016
Northwest	Marsh Platform	100	82.5	5	1.75
	Bankline	100	92.5	5	2.5
Central	Mudflat/Open Water Grids	100	90	0.5	0
	Marsh Perimeter	100	98	6.67	0
Northeast	Open Water Triple Rows	100	88.75	0	0
	Open Water Near Marsh Grid	100	90	0.5	<1
Southeast	Open Water Near Marsh Grid	100	90	1	0

Plantings were assumed to have 100 percent survival, occupy a percentage of a 4 m^2 vegetation station based on number of plants in the cover plot, and to have 30 inch stem heights upon planting in June 2013 as per planting specifications. Vegetation station data collected over three years captured the performance of the plantings. Station level percent survival was similar to overall percent survival from the ocular estimates. Percent vegetative cover a couple of weeks following the final planting inspection was similar to assumed coverage during planting for most planting combinations. Percent vegetation cover was, or was nearing, 0 percent for all combinations by 1 year following planting except for the CA perimeter plantings which also included previously existing marsh vegetation. By three years following planting, stations along the CA perimeter were 0% as the existing marsh had eroded back 3-6 feet from the original planting alignment (Fig. IV-2A and B). Note the changes in the area pictures from June 2013 and later (Figs. IV3-9).

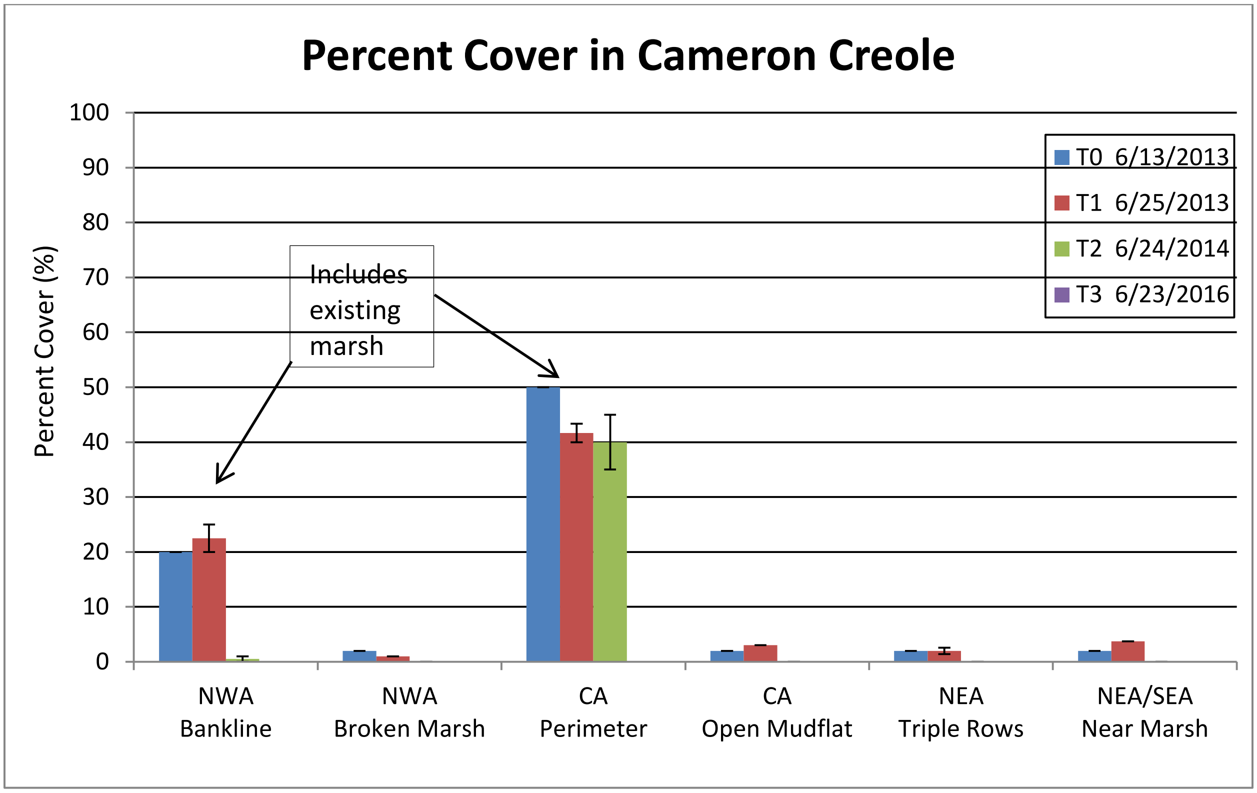


Figure IV-2A. Station scale percent cover was collected from different area and planting type groups within LA-39 Year 1 Cameron Creole over three years.

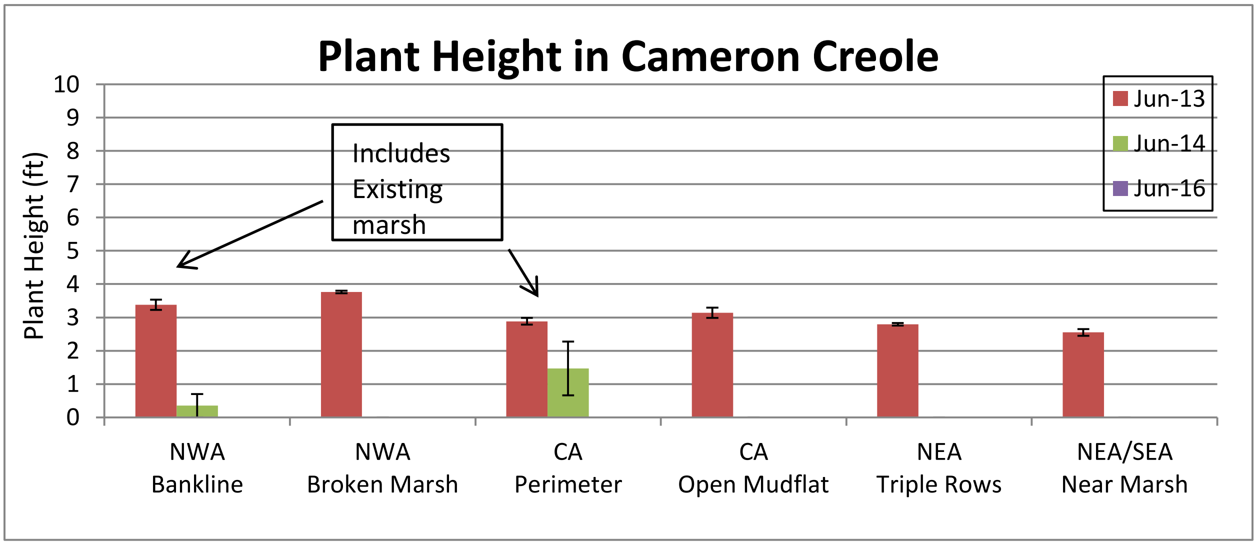


Figure IV-2B. Station scale plant height was collected from different area and planting type groups within LA-39 Year 1 Cameron Creole over three years.

Figure IV- 3. A double row of *Spartina alterniflora* Vermilion was planted to stabilize the Lambert Bayou shoreline in the Northwest Area of the LA-39 Year 1 Cameron Creole site in June 2013 (A). Most of the plantings were absent a year later in June 2014 (B).

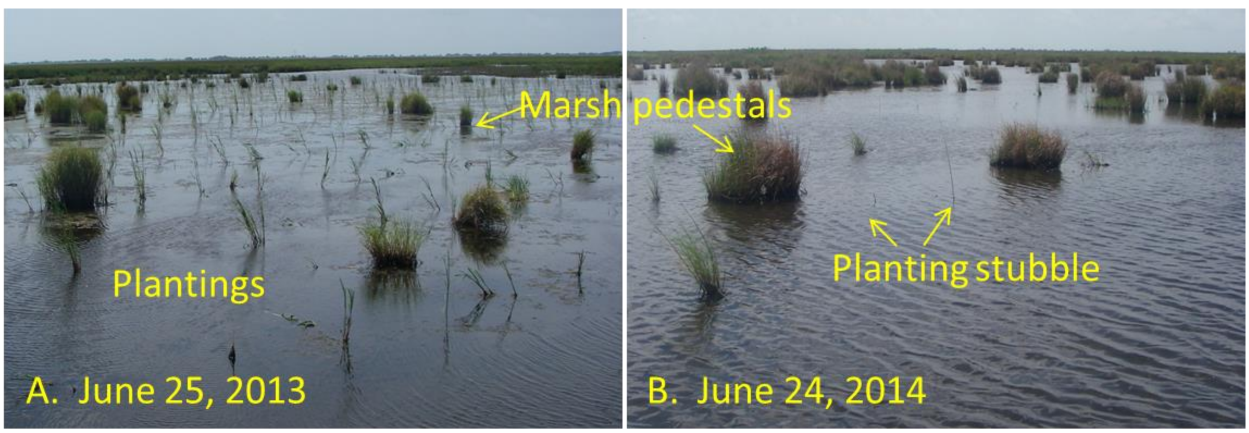


Figure IV- 4. *Spartina alterniflora* Vermilion was planted on a broken marsh platform in the Northwest Area of the LA-39 Year 1 Cameron Creole site in June 2013 (A). Most of the plantings were absent a year later in June 2014 (B).

Fig 1V- 5. *Spartina alterniflora* 'Vermilion' strain was planted around patches of existing marsh in the Central Area of the LA-39 Year 1 Cameron Creole site in June 2013 (A). Most of the plantings were absent a year later in June 2014 (B). The marsh edge eroded 3-9 ft by June 2016 (C); the poles represent the original planting position.

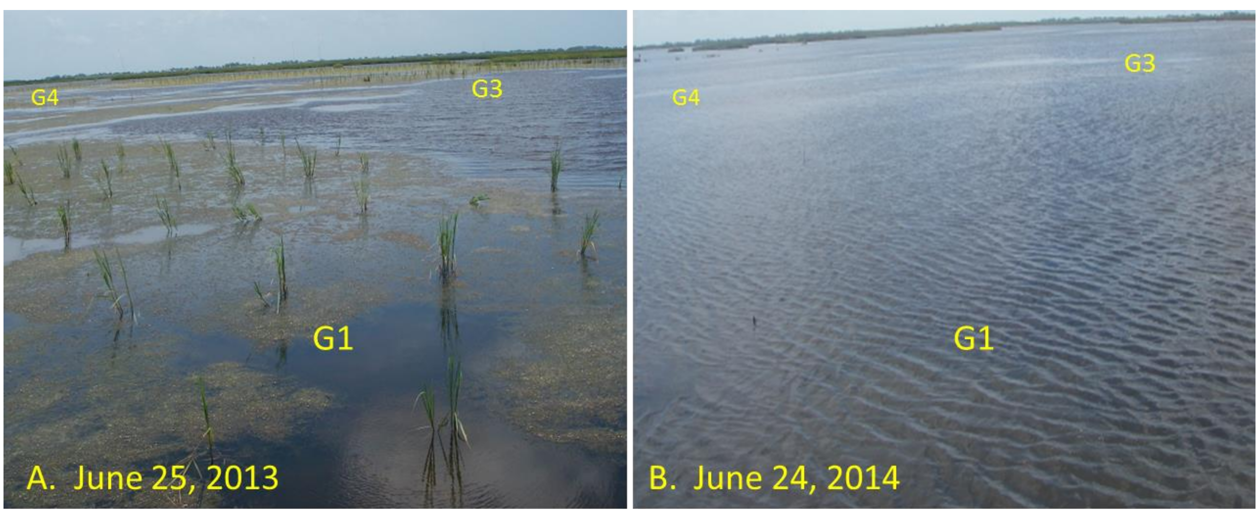


Figure IV- 6. *Spartina alterniflora* Vermilion was planted in shallow open water/former mudflats between patches of marsh in the Central Area of the LA-39 Year 1 Cameron Creole site in June 2013 (A). Note algae rafts on SAV in A. All of the plantings were absent a year later in June 2014 (B); SAV was still present although algae were reduced. G# represents different planting grids.

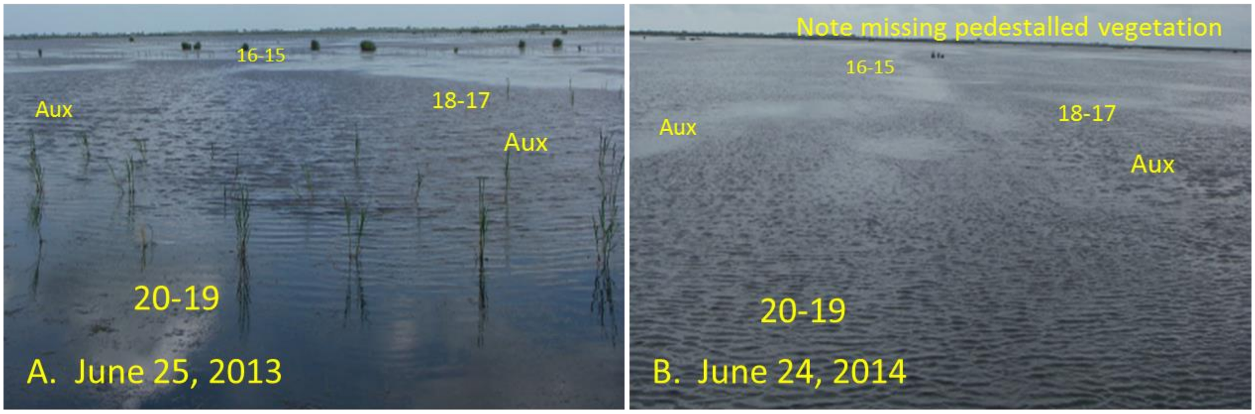


Figure IV- 7. Triple rows of *Spartina alterniflora* Vermilion was planted in shallow open water/former mudflats in the Northeast Area of the LA-39 Year 1 Cameron Creole site in June 2013 (A). Note some algae rafts on SAV in A. All of the plantings and most pedestals of marsh vegetation were absent a year later in June 2014 (B); SAV was still present although algae were reduced. Paired numbers and "Aux" represent sets of triple rows.

Figure IV- 8. Rows of *Spartina alterniflora* Vermilion were planted in shallow open water/former mudflats near marsh in parallel to the South Prong of Grand Bayou in the Northeast Area (A). Most of the plantings were absent and most pedestals of marsh vegetation were collapsing a year later in June 2014 (B). Note 6'4" Bernard Wood (CPRA) for scale (A). SAV was present in both years.

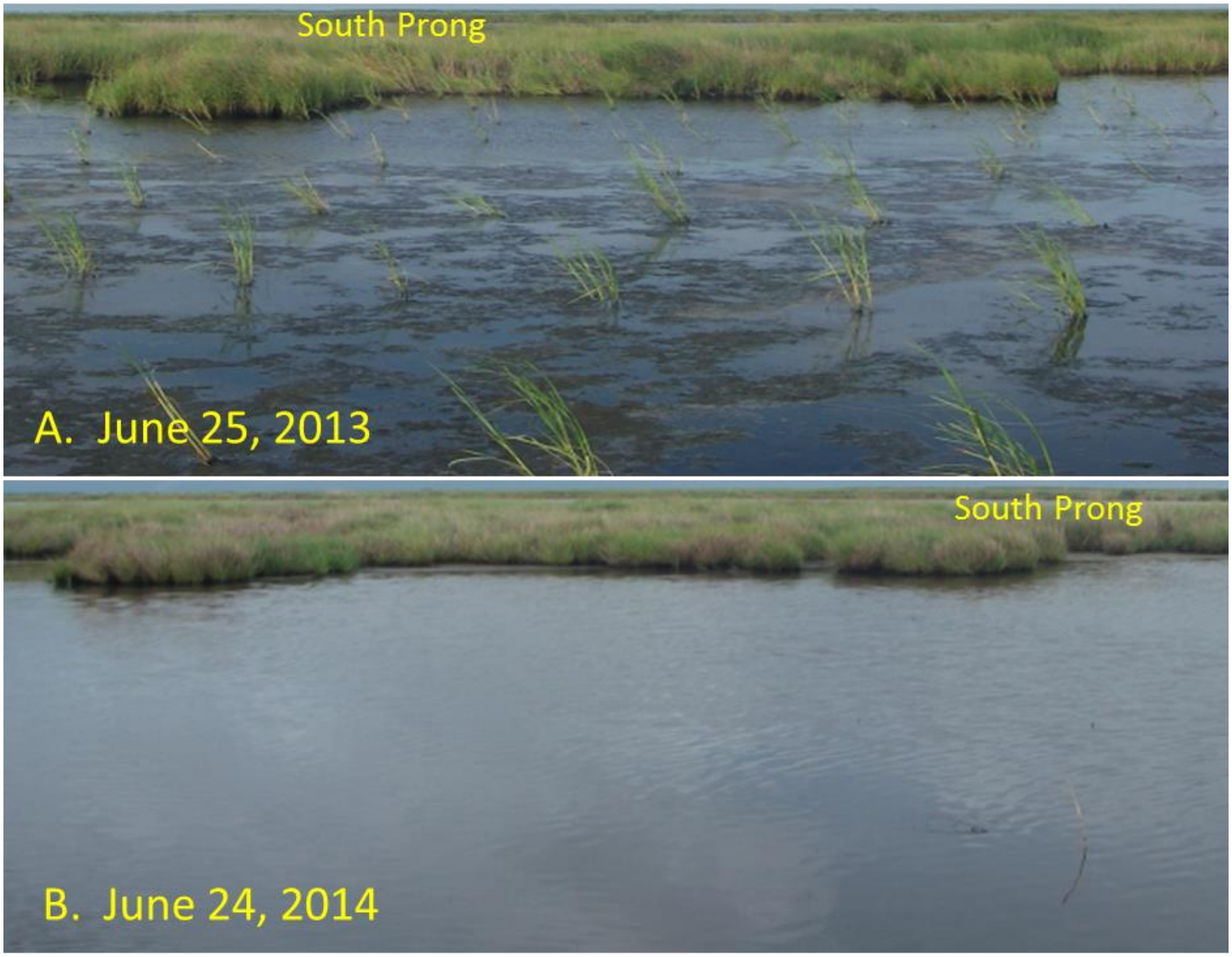


Figure IV- 9. Rows of *Spartina alterniflora* Vermilion were planted in shallow open water/former mudflats near marsh in parallel to the South Prong of Grand Bayou in the Northeast Area (A). Note some algae rafts on SAV in A. Most of the plantings were absent a year later in June 2014 (B); SAV was still present although algae were reduced.

b. Planting Failure/Success Causation

Failure of the Cameron Creole plantings was caused by chronic flooding of mostly stagnant water (Fig. IV-10). Chronic flooding causes anaerobic soil conditions that can be toxic to plant roots. Isolated plants, planted along rows with five ft spacing between plants, are especially vulnerable to anaerobic soil conditions. Of the existing marsh, higher elevation vegetation within larger patches was healthy throughout the monitoring period whereas isolated pedestals of vegetation and plantings diminished (Fig. IV-11). Rafting by algae and SAV physically damaging the plants is another contributor to planting failure; however, algal rafting was not as widespread throughout the site as the planting failure. Water salinity averaged 7.9 ± 5.2 ppt within a range of 0.4 – 22.5 ppt which is within the tolerance range of smooth cordgrass (Vermilion) and should not have been a stress factor (Fine and Thomassie 2000).

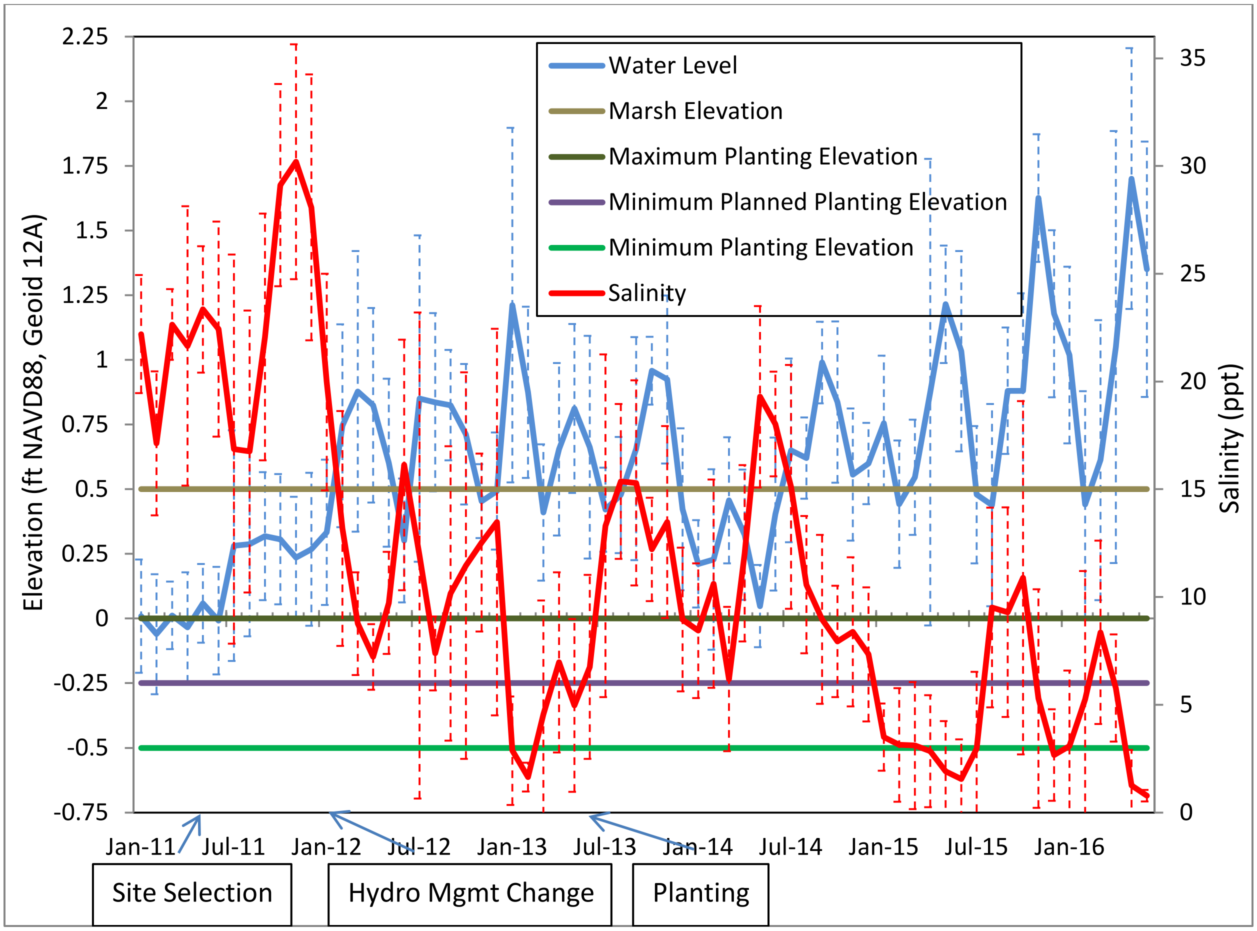


Figure IV-10. Monthly averages of water-level elevations and salinity from CRMS0645-H01 are plotted relative to average plant elevations for the Cameron Creole plantings. The Maximum Planting elevations were typical for the plantings within and around the broken marsh (Northwest Area and Central Area Perimeters) while the Minimum Planting elevations were typical for all other planting areas. Major events were noted along the x-axis.

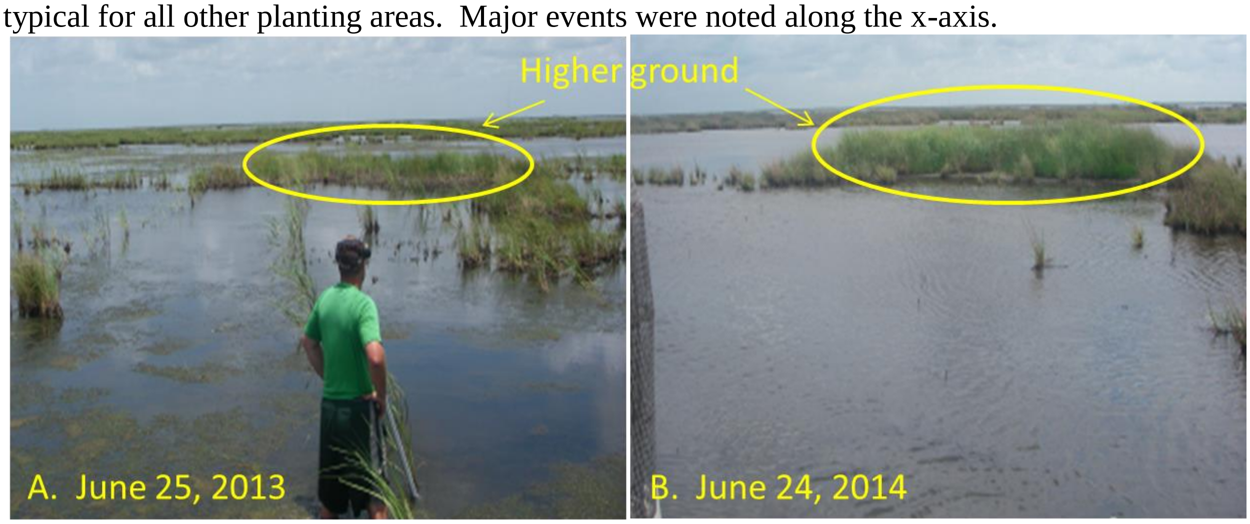


Figure IV-11. Higher elevation vegetation in larger patches fared better than lower elevation vegetation such as the individual plantings and pre-existing pedestalled vegetation.

Climatic and watershed management conditions changed from site selection in May 2011 to the time of planting and monitoring (June 2013-2016), water levels were lower and salinities were higher in 2011 than in 2012-2016 (Fig. IV-10). In 2011, the Cameron Creole area was in a drought that lasted into early 2012 and did not return through 2016 (NOAA 2011-2016). Coincidentally, the Cameron Creole watershed resumed hydrologic management to maintain lower salinity on January 1, 2012 which also increased water levels. Areas that were mudflats with sprouting smooth cordgrass during initial site selection in May 2011 (Fig. IV-12) converted to open water supporting vigorous submerged aquatic vegetation by the time of planting in June 2013 (Figs. IV4-8). Minimum planting elevations were lowered from -0.25 ft NAVD 88 to -0.5 ft NAVD 88, which was still within the reported tolerance of Vermilion smooth cordgrass (Fine and Thomassie. 2000), to accommodate the lowering of elevation at the site.

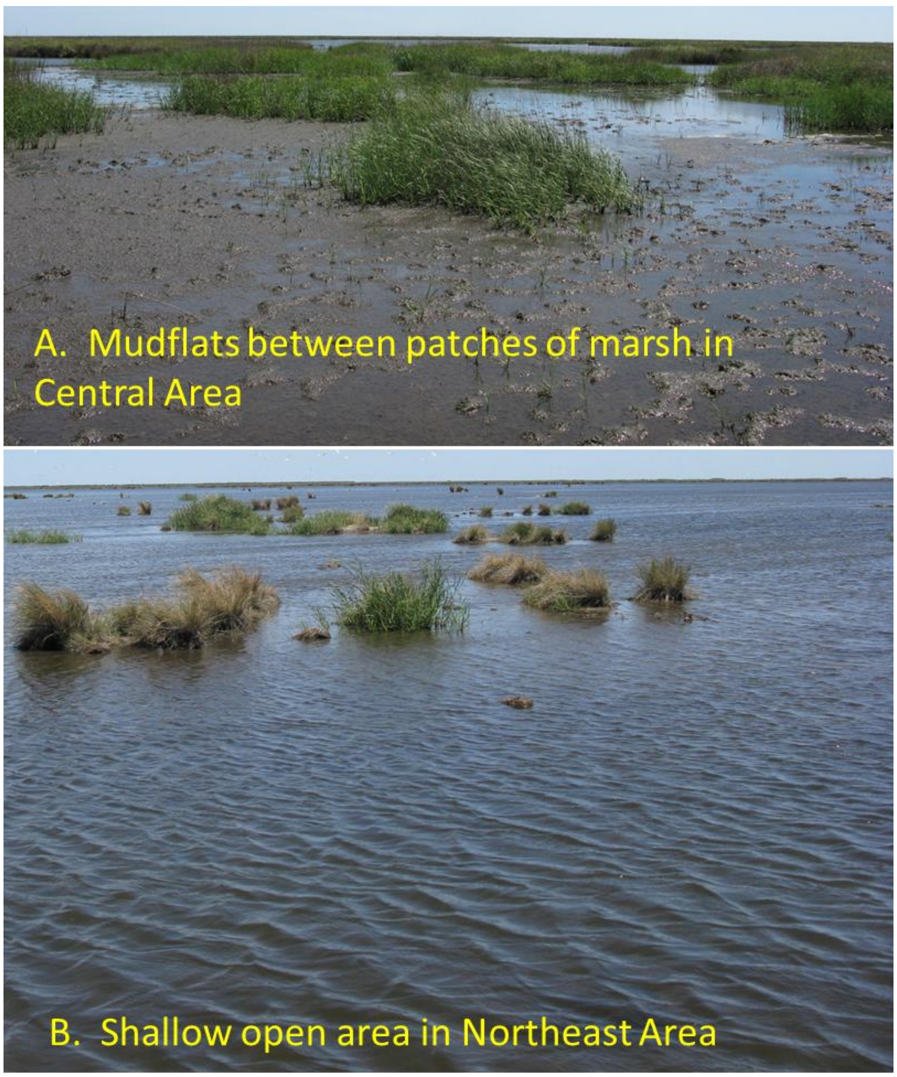


Figure IV-12. The LA-39 Year 1 Cameron Creole site was initially visited on May 4, 2011; water levels were ~0.16 ft NAVD88 which was about 0.5 ft below average marsh elevation at that time. (A) Note sprouting *Spartina alterniflora* on mudflats. (B) Water was 2-4 inches deep throughout open areas, and no SAV was established.

C. Conclusions

The Year 1 Cameron Creole plantings were not successful. Marshes within the Cameron Creole watershed has degraded since Hurricanes Rita and Ike, and the planting site has been chronically flooded since 2012. While this has allowed for a dramatic increase in the SAV population it correspondingly flooded the newly planted area with water further lowering the soils redox potential (Eh).

1. Project Effectiveness

As per the project goals:

- NWA interior plantings did not survive and expand on the broken and submerging marsh platform.
- NWA bankline plantings did not survive and expand to stabilize the Lambert Bayou bank.
- CA perimeter plantings did not survive and expand to stabilize stands of existing marsh vegetation.
- CA interior plantings did not survive and expand to form and reconnect existing stands of marsh vegetation on mudflats from submerged marsh platforms.
- NEA triple-row interior plantings did not survive and expand to form bands of marsh vegetation on mudflats from submerged marsh platforms.
- NEA and SEA area plantings did not survive and expand to widen vegetation along Grand Bayou onto submerged marsh platforms.
- Neither triple row (NEA) nor interior (CA) plantings were effective at establishing marsh vegetation on mudflats from submerged marsh platforms.

2. Recommended Improvements

Avoid planting smooth cordgrass in chronically flooded areas with little water movement.

3. Lessons Learned

The Year 1 Cameron Creole planting attempted to establish smooth cordgrass in degraded coastal marsh conditions, permanently flooded shallow open ponds/open water areas with unconsolidated organic soils, for which vegetative plantings as a stand-alone technique may not provide a solution. Planting in such areas could be used to compliment other restoration/conservation measures to increase elevations such as marsh creation, sediment nourishment, or terracing.

Planting conditions worsened considerably over the two years from the site selection trip in May 2011 to planting in June 2013 as the area switched from promising mudflats with sprouting vegetation to chronically flooded water bottoms with firmly established SAV. After conducting elevation surveys, original plans were altered to select the more conducive areas remaining. Planners could have further reduced the planting effort to test sections.

V. Year 1 – Marsh Island

Prepared by Tommy McGinnis – CPRA Lafayette Regional Office

A. Site Description

Marsh Island, a Year 1 planting site, is in Iberia Parish between Vermilion Bay and the Gulf of Mexico; it is a wildlife and game refuge managed by the Louisiana Department of Wildlife and Fisheries. The Marsh Island plantings are comprised of two planting areas, the northern shoreline of Marsh Island (Northern Shore Plantings, NSP) and interior marsh blown out by previous hurricanes along West Branch Oyster Bayou in the southeastern part of the island (Oyster Bayou Plantings, OBP). The Year 1 Marsh Island plantings were designed as trials because wave conditions along the northern shoreline are harsh for plant survival and a previous attempt to plant the Oyster Bayou areas had failed.

North Shore Plantings (NSP)

The NSP are short segments located along a 6.5 mile stretch of shoreline centrally located along the northern shoreline of Marsh Island (Fig. V-1a). The northern shoreline receives direct waves from Vermilion Bay which resulted in a mean erosion rate of 14 ft/yr from the 2004 to 2012 ranging from 0-81 ft/y depending on location (Byrnes et al. In Press). The NSP consists of three strategies: open shoreline protection, shoreline enhancement behind foreshore-rock dikes, and pond area coverage near the shoreline:

The **open shoreline** plantings are short segments in 6 reaches of the northern shoreline (Fig. V-1a). Trade-gallon sized *Spartina alterniflora* Vermilion (smooth cordgrass) was planted in a row of plants on 5 ft centers as close as possible to the existing marsh no deeper than 0.0 ft NAVD88, and every other plant was anchored with a metal reinforcement rod. The Bayou Platte East reach had a wider submerged platform resulting in room for an additional row staggered 5 feet from the near-shore row resulting in 2.5 ft centers between rows. In total, 1,389 plants were planted on 6,335 linear feet (1.2 miles) of shoreline which was 18 % of the available shoreline.

The **protected shoreline** plantings behind the foreshore rock dikes are located along opposing banks of the mouth of Bird Island Bayou (Fig. V-1a). Double rows of trade-gallon sized *Schoenoplectus californicus* (California bulrush) were planted 20 ft apart with plants spaced on alternating 5 ft centers. The center line of the double rows were positioned parallel to and 10-40 feet from the existing shoreline no deeper than -1.0 ft NAVD88, and alternating plants within each row were anchored. 5,830 linear feet of double rows consisting of 1,166 plants covered 2,915 linear feet of shoreline.

The **pond area** plantings are located south of the Bayou Michael East segments in a small pond vulnerable to the influence and flooding of Vermilion Bay (Fig. V-1a). Smooth cordgrass trade gallons were planted in parallel rows with plants on 7 ft alternating centers 10 ft apart no deeper than -0.25 ft NAVD88. The rows were oriented west to east.

Oyster Bayou Plantings (OBP)

The OBP are located in open water, hurricane blowout areas north and south of West Branch Oyster Bayou which runs southeast from Oyster Lake (Fig. V-1b). The plantings consist of 13, single test rows with plants on 5 ft centers; the rows consist of different species and/or plant sizes. Planting elevation limits were -0.5 ft NAVD88 for smooth cordgrass trade gallons, -0.25 ft NAVD88 for smooth cordgrass plugs, and no limit established for *Juncus roemerianus* (black needlerush). Rows 1-10 are oriented west to east across the blown out areas, and rows 11-13 are oriented perpendicular to hydrologic connections with Oyster Bayou.

***Spartina alterniflora* Vermilion (smooth cordgrass) trade-gallons** were planted in a deeper section of row 2 (segment 2B). 196 plants covered 980 linear feet.

***Spartina alterniflora* Vermilion (smooth cordgrass) trade-gallons and vegetative plugs** were planted in alternating fashion in 11 rows. 1725 plants covered 9695 linear feet.

Smooth cordgrass trade-gallons, smooth cordgrass vegetative plugs, and *Juncus roemerianus* (black needlerush) trade gallons were planted in alternating fashion in two rows. 524 plants covered 3100 linear feet.

An **auxiliary planting** with extra smooth cordgrass trade gallons (141 plants), smooth cordgrass plugs (140 plants), and black needlerush trade gallons (33) was planted in the northern blown out section.

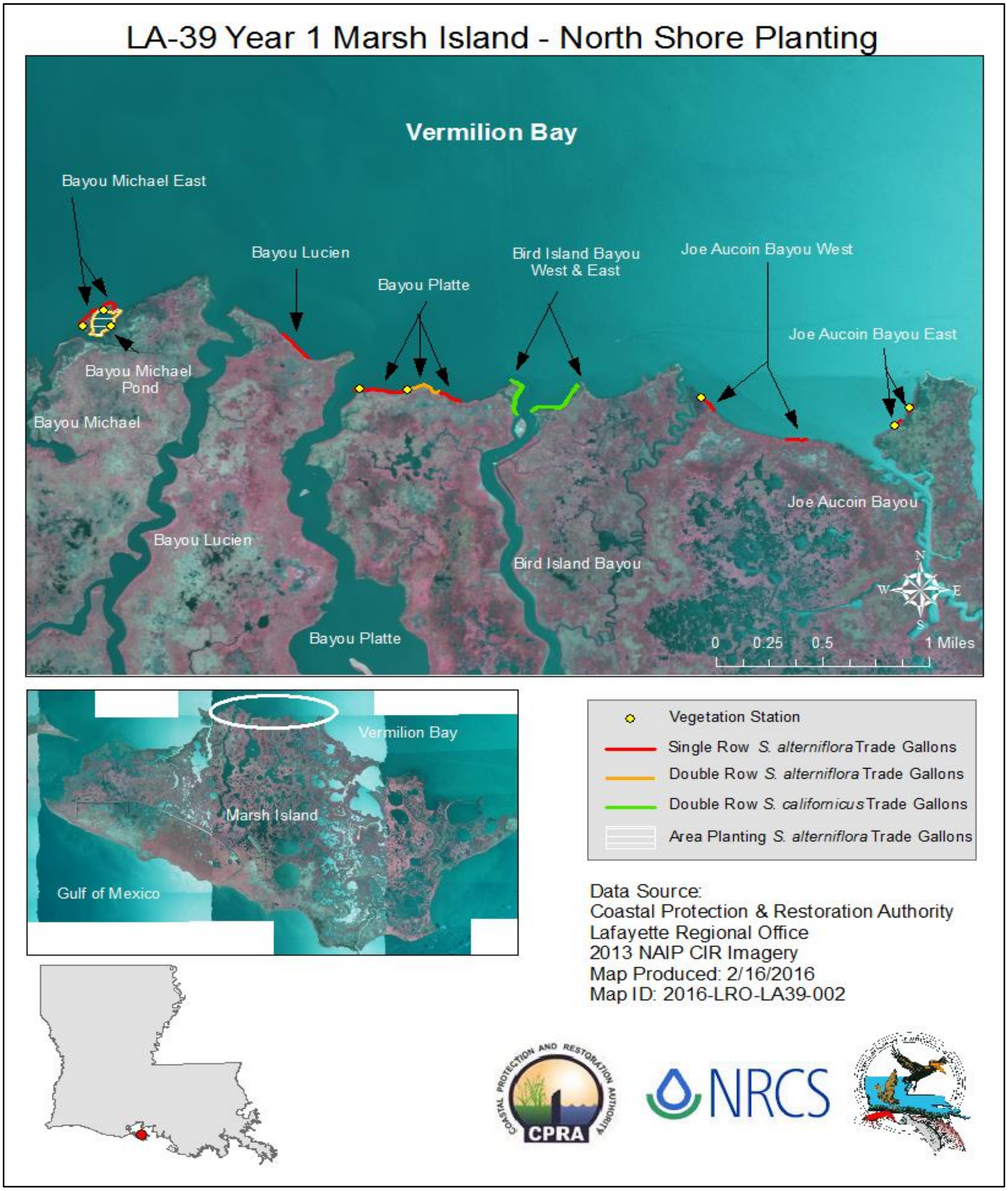


Figure V-1a. LA-39 Year 1 Site – Marsh Island North Shore plantings site map showing location of plantings and vegetative monitoring stations. Metal anchors were used to secure every other plant in all reaches except Bayou Michael Pond.

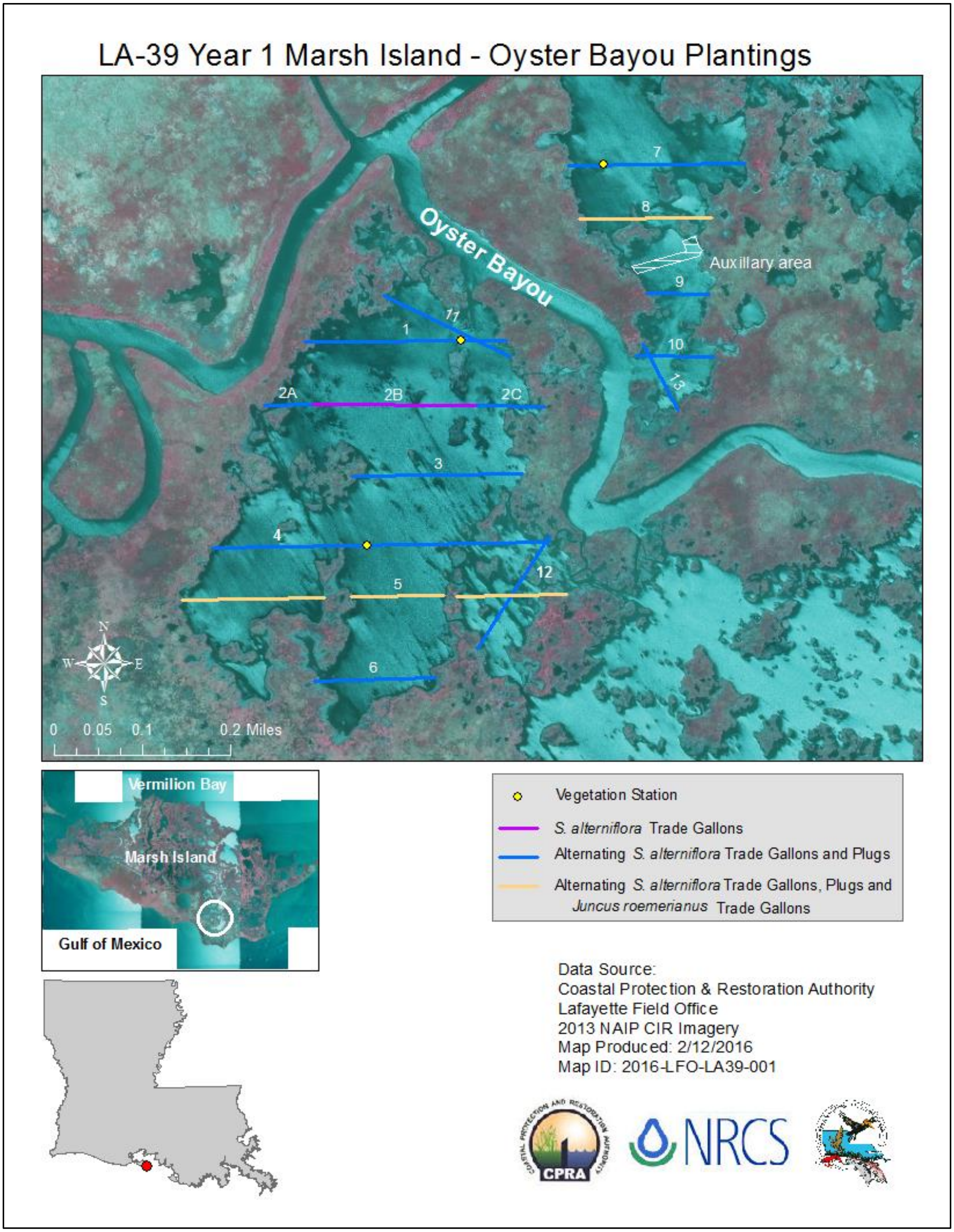


Figure V-1b. LA-39 Year 1 Site – Marsh Island Oyster Bayou Plantings site map showing location of plantings and vegetative monitoring stations.

B. Monitoring Activity

1. Monitoring Goals

The Year 1 Marsh Island plantings were designed as trials because conditions along the northern shoreline are harsh for plant survival and a previous attempt to plant the Oyster Bayou areas failed.

The goals of the Marsh Island plantings are to determine if:

- Plantings along the northern, open shoreline along a large bay are feasible.
- Anchoring plants help to secure plantings in open shoreline conditions.
- Plantings behind a foreshore dike at a lower elevation along a large bay are feasible.
- Plantings in lower elevation areas of former marsh blown out by storms are feasible.
- Plant size or species affects planting survival in lower elevation areas of former marsh blown out by storms.

2. Monitoring Elements

The monitoring elements include procedures to assess planting survival and effects on the planting area for the two main types of project plantings, shoreline protection and interior area coverage. Vegetation stations were intended to monitor planting survival and vegetative cover representative of the variety of planting strategies within the NSP (open/protected shorelines, single/double row plantings, anchored/nonanchored plants) and OBP (plant species, plant sizes, and depths) areas over time. However, locations with surviving plants were targeted for sampling stations because planting survival was extremely low (<5% in the NSP and 0% in OSP) at the initial monitoring (T_1) trip on June 3, 2013, seven weeks following the planting inspection (T_0). Because of the trial nature and anticipated harsh conditions of the Marsh Island plantings, the monitoring schedule was compressed to allow for higher frequency sampling of planting survival within the first two years (Table V-1). Sampling was suspended after the second monitoring trip (T_2) on December 18, 2013 because planting survival was 0% with the exception of 1 surviving plant in the Bayou Michael Pond.

Table V-1. Sampling scheduled for LA-39 Year 1 site, Marsh Island. Sampling was discontinued because survival was 0% in Dec 2013.

Sampling Type	T_0 2013	T_1 2013	T_2 2013	T_3 2014	T_4 2014	T_5 2015	T_6 2018
Planting Survival	April	June	Dec	Spring	Fall	Spring	Spring
Percent Cover		June	Dec	Spring	Fall	Spring	Spring
Mapping		June					Spring

Vegetation Assessment

To assess planting status an ocular estimate of % survival and plant condition was conducted for each reach, segment, and/or row. Planting survival and % vegetative cover data was also collected at the vegetation station level; stations were established among remaining live plants. Percent survival was calculated from a set number of plants at each vegetation station; plants were characterized as live or dead/absent. PVC poles were placed on both ends of the plants monitored for survival. Vegetative condition was assessed by measuring % cover of species present, vegetative stand height, and height of dominant species at 4 m^2 vegetation plots at the vegetation stations (Folse et al. 2014). Flooding depth, surface water salinity and temperature, and porewater salinity and temperature was also collected at all sampling stations during each sampling event. Conditions occurring outside of the stations and segments including additional species, marsh interspersion, and site-specific points of interest were noted along with photographic documentation.

NSP - Open Shoreline: Six stations were established among the shoreline reaches, targeting live plantings. Percent survival of 10 plants per station and % cover data were recorded at each station. At each station, 5 anchored and 5 unanchored plants were monitored for presence (live or dead)/absence in order to compare the effectiveness of anchoring plants in a high wave-energy environment. Monitoring was suspended after Dec 2013 field trip as survival reached 0%.

NSP - Protected Shoreline: Initially, four stations were to be divided among the California bulrush plantings along the two banks at the mouth of Bird Island Bayou. At each station, 5 anchored and 5 unanchored plants were to be monitored to compare the effectiveness of anchoring plants in a low wave-energy environment. The intent of planting double rows spaced 20’ apart is that the rows would eventually grow together to strengthen wind-fetch disruption; therefore, the space between the rows was planned to be measured at each station. However, no plantings survived behind the rock dike; therefore, no sampling stations were established. The area was re-evaluated during the Dec 2013 field trip, and no plantings were found.

NSP - Pond Coverage: Low planting survival was observed during the June 2013 monitoring; therefore, two stations targeting the two areas along the shallow bank with live planting were established. Sampling was suspended following the Dec 2013 field trip although one plant remained.

OBP – Hurricane Blowout Areas: Initially, ten percent survival and cover stations were to be dispersed among combinations of species, planting sizes, and planting elevations throughout the two areas to assess differential survival and cover among the combinations. The four stations among the different-sized smooth cordgrass plantings and black needle rush plantings (rows 5 and 8) were to consist of 15 plants per station rather than 10 for monitoring survival to account for 3 planting types. Although some dead stems were present, no live stems in were found in either area during the June 2013 monitoring; therefore, one station was established in each area. The OBP was re-evaluated during the Dec 2013 fieldtrip; no stems, live or dead, were found. Three soil cores were collected (two in the southern area and one in the northern area) to observe soil physical conditions.

Planting Failure/Success Causation

Hydrologic data from CRMS0520-H01 for the NSP and CRMS0499-H01 for the OBP will be used to describe area water-level trends and salinity. The water level data will be tied to water depths collected within the planting areas to convert water depth (ft) to planting elevations (ft, NAVD88 Geoid 12A) and calculate flood parameters (levels, duration, and frequency).

3. Monitoring Results and Discussion

a. Vegetation Assessment

The ocular estimates of overall planting areas captured the large scale poor performance of the plantings, as the cautious approach to planting in known harsh environments was validated. Survival two months following planting was sparse in the NSP and non-existent in the OBP. The low survival in the NSP was variable among segments during the June 2013 sampling. Survival was 0% across all areas by the December 2013 sampling, eight months after planting in April 2013 (Table V-2).

Table V-2. Overall % Survival of LA-39 Year 1 Marsh Island plantings over time. Open Shoreline and Pond Area plantings in Northern Shoreline plantings (NSP) were *Spartina alterniflora* Vermilion (smooth cordgrass) trade gallons, and the Protected Shoreline was *Schoenoplectus californicus* (California bulrush) trade gallons. The Oyster Bayou plantings were trade gallon sized and plugs of Vermilion smooth cordgrass and trade gallon sized *Juncus roemerianus* (black needlerush).

		% Overall Survival		
Plantings	Types	T_0 Apr 2013	T_1 Jun 2013	T_2 Dec 2013
NSP	Open Shoreline	100	15	0
	Bayou Michael East	100	1	0
	Bayou Platte West	100	10	0
	Bayou Platte East - Single	100	5	0
	Bayou Platte East - Double	100	10	0
	Joe Aucoin Bayou West	100	30	0
	Joe Aucoin Bayou East	100	15	0
	Protected Shoreline	100	0	0
	Pond Area	100	1	~0 (1 stem)
OBP	Smooth Cordgrass Trade Gallons	100	0	0
	Smooth Cordgrass Plugs	100	0	0
	Black Needlerush Trade Gallons	100	0	0

In areas with surviving plants during the first sampling in June 2013, the North Shore open shoreline and pond area, surviving plantings were targeted for vegetation station locations to quantify changes in plant survival, percent cover, and stem heights over time (Figs. V-2A and

B). Plantings were assumed to have 100 percent initial survival, occupy ~5% of a 4 m2 vegetation station, and to average 27 inch stem heights upon planting in April 2013 as per planting specifications. Percent survival sharply declined by the first sampling in June 2013 and continued to decline towards 0% by the December 2013 sampling. Vegetative cover initially shrank to ~ 1 percent by two months after planting and also continued to decline towards 0% at eight months after planting. Surviving plants did not grow after planting as stem heights decreased by 77% along the open shoreline and 55% in the pond area. Surviving plants were impacted by herbivory and wave damage (Fig. V-3). By the December 2013 sampling, the northern shoreline had eroded 10-20 feet (Fig V-4), and there was only a single surviving stem, located in the pond area (Fig. V-5).

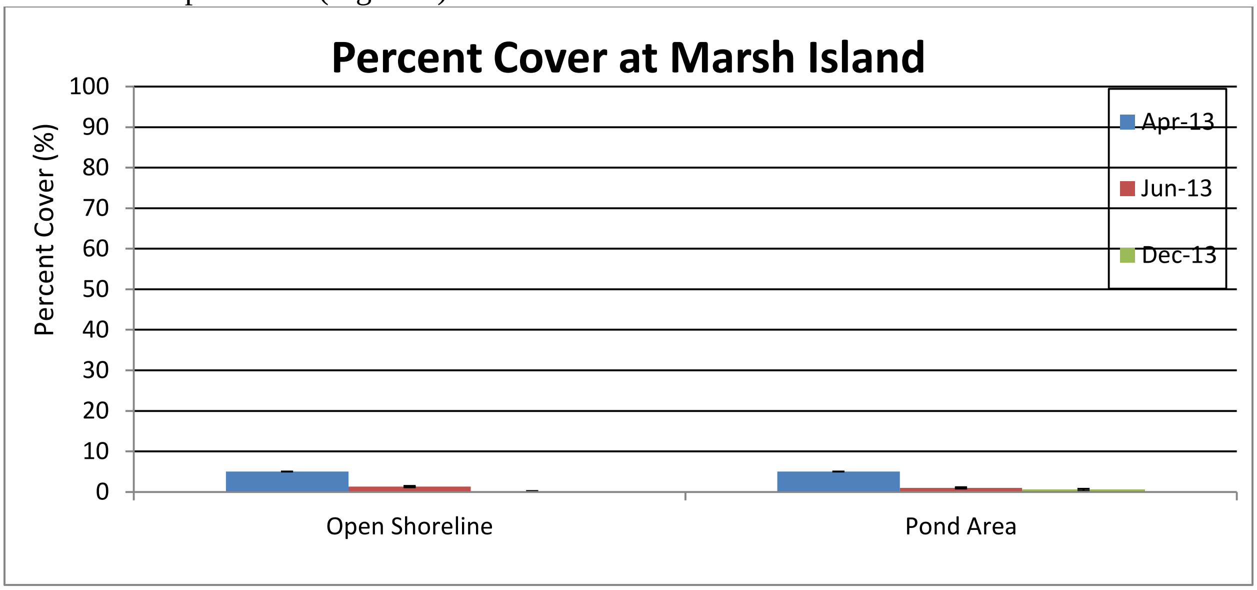


Figure V-2A. Percent cover collected from April – December 2013 at Marsh Island Northern Shoreline Plantings.

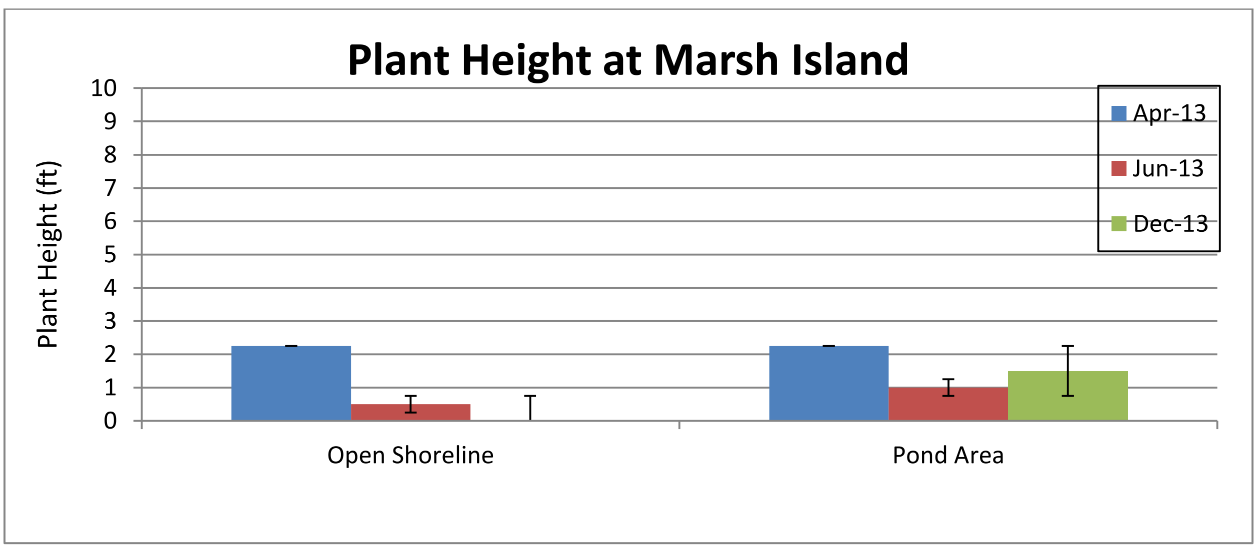


Figure V-2B. Plant stem heights collected from April – December 2013 at Marsh Island Northern Shoreline Plantings.

Figure V-3. The Northern Shoreline on 06/03/2013 during typical water levels. Note the taller, interior marsh vegetation in the background, the reduced vegetation height in the nearshore marsh platform impacted by herbivory (note taller vegetation in the crab cage), and the unvegetated shoreline eroded by surf conditions with a surviving plant to the bottom right side.

Figure V-4. The Northern Shoreline had low water levels on 12/18/2013. Empty anchors along the brown line indicate the planting alignment. The shoreline eroded back about 15-20 ft in the 8 months since the plantings installation.

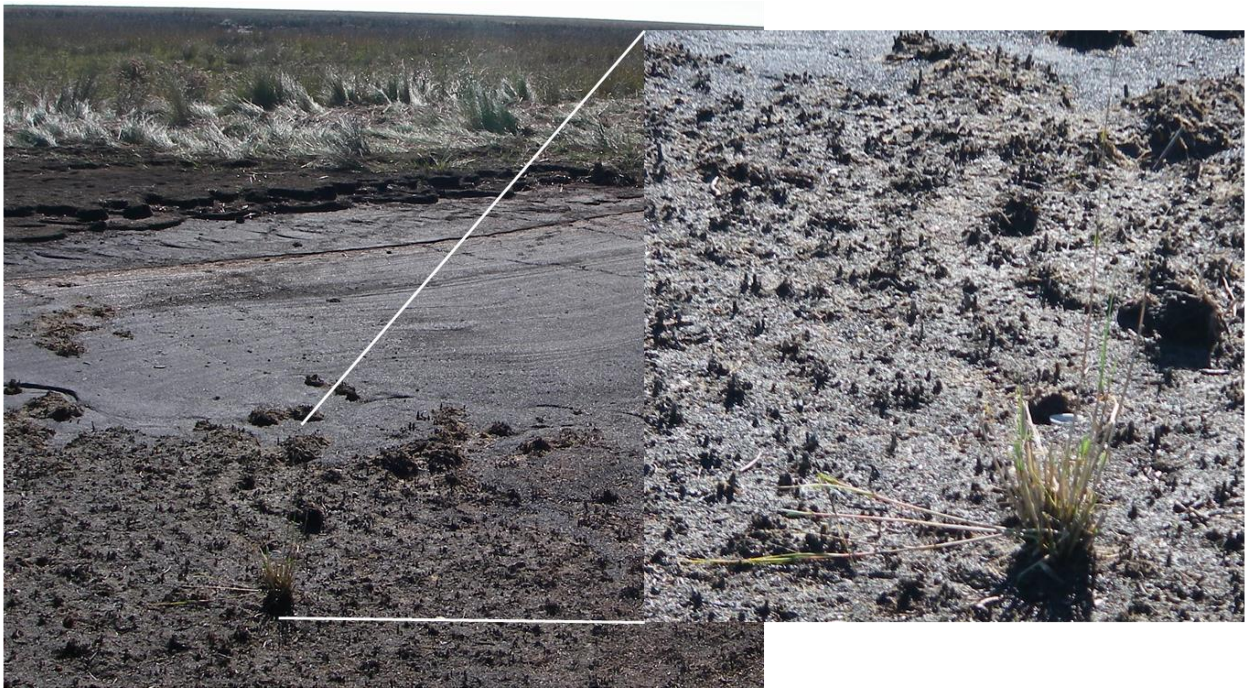


Figure V-5. The loan surviving plant was in Bayou Michael Pond area planting along the northern shoreline of Marsh Island; it was photographed on 12/18/2013 during very low water levels.

Anchoring plants with metal rods did not help to secure plantings in the high wave-energy environment of the open shoreline. The percentage of plants found (live or dead) did not significantly differ between plants with or without anchors during the June or December 2013 sample dates (Figs. V-6 and 7). The percentage of plant present significantly decreased from June to December 2013.

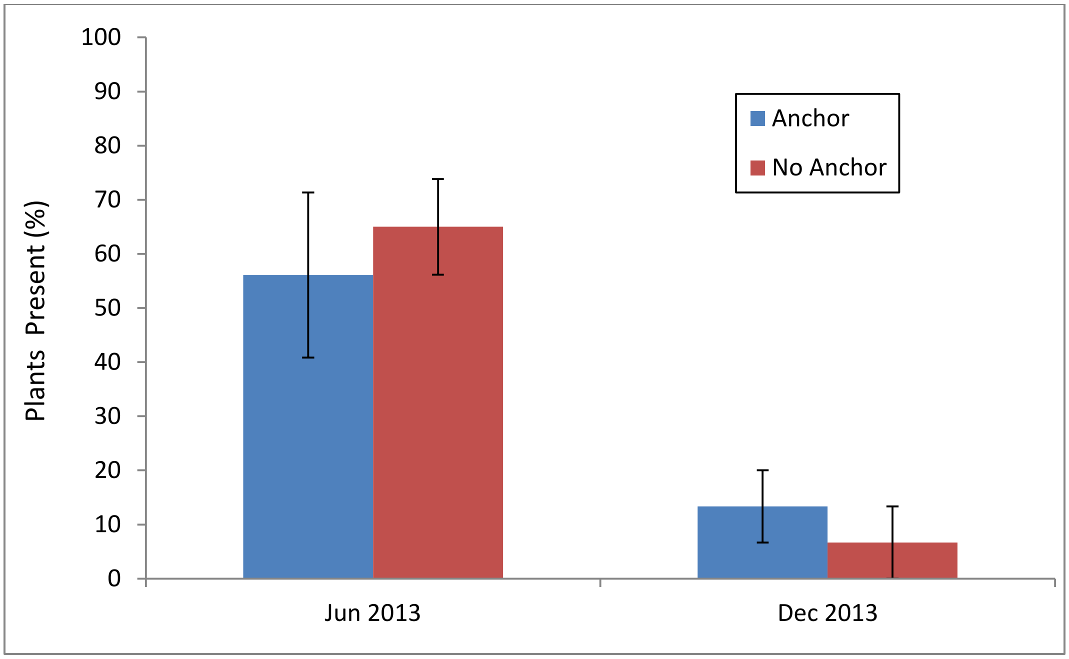


Figure V-6. The presence (live or dead) of plants was recorded at vegetation stations along the Northern Shoreline plantings two and eight months after installation in April 2013. Half of the plants were secured with anchors.

Figure V-7. Two surviving plants along a typical Northern Shoreline planting alignment were photographed on 06/03/2013 during typical water levels and calm wave conditions. Surviving plants were impacted by wave action. Note the anchored plant on the left and the non-anchored plant on the right. Two plants, one non-anchored and one anchored (anchor is missing), are absent between the surviving plants based on the planting specifications.

b. Planting Failure Causation

The low survival of Open Shoreline plantings was caused by constant wave energy and, secondarily, herbivory. A large storm passage following the planting effort and regular high water levels relative to planting depth resulted in poor survival in the Bayou Michael Pond area (Fig. V-8). Water salinity averaged 4.7 ± 3.1 ppt with a range of 0.3-11.3 ppt; this was not a contributing factor for the failure of smooth cordgrass which is a salt tolerant plant.

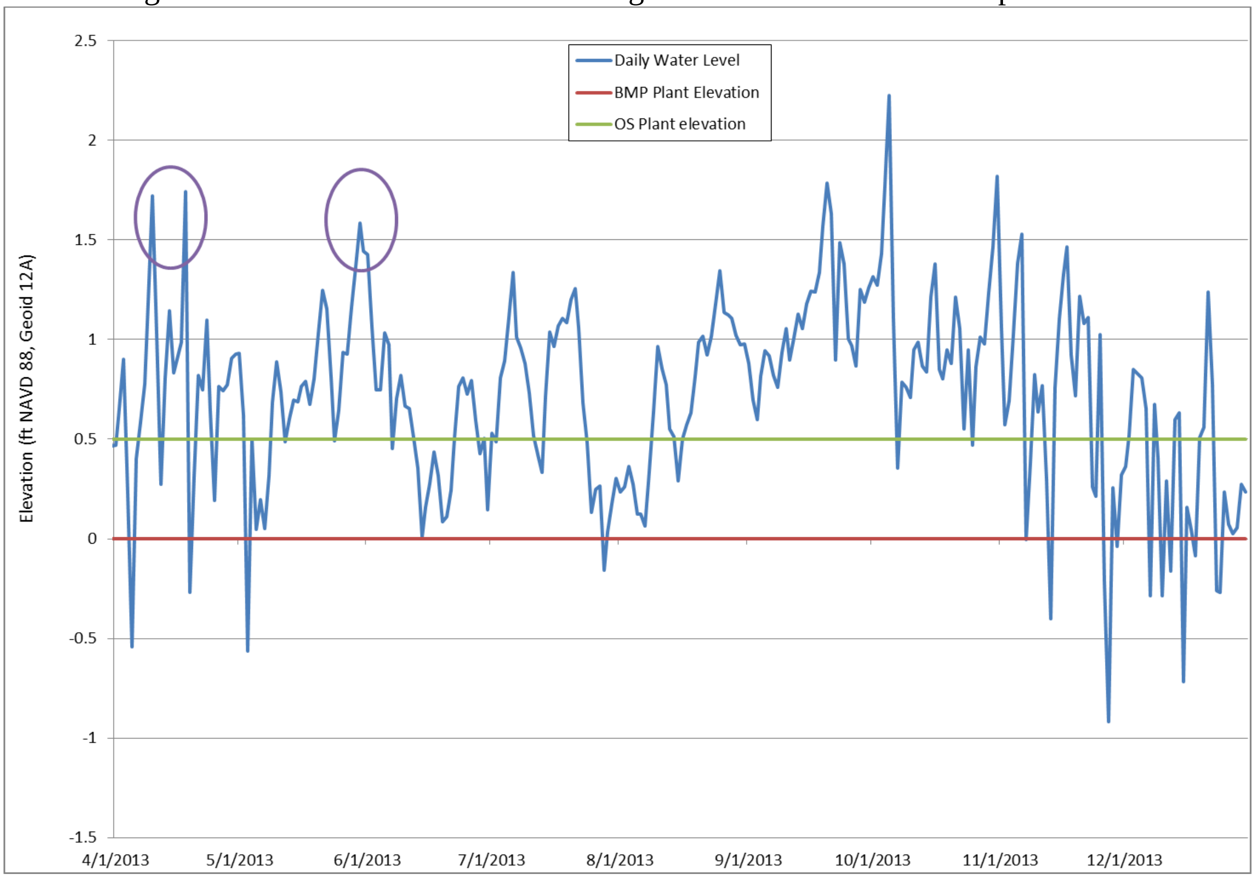


Figure V-8. Water level elevations were plotted relative to plant elevations for the Bayou Michael Pond (BMP) and Open Shoreline (OS) plantings from time of planting to the end of 2013. Note the high water levels resulting from storm passage just after planting and prior to the June 2013 field trip (purple ovals).

The Protected Shoreline plantings along the mouth of Bird Island Bayou were uprooted and removed soon after planting following a large storm system passage accompanied by high water levels within 2 weeks after the plants were installed. Marsh Island Wildlife Refuge employees observed the bulrush plantings being washed away from behind the foreshore rock dike into Bird Island Bayou. Water overtopped the foreshore dike and a strong current formed between the shoreline and dike as the high water levels receded (Fig V-9). Water salinity may have stressed the lower salt tolerant California bulrush plantings if they had survived as salinity was often > 8 ppt from August through December.

Figure V-9. California bulrush was planted in two double rows behind the foreshore rock dike protecting the shoreline along the mouth of Bird Island Bayou. Pictures were taken from both sides of rocks on the southern end of the west bank. **A** - note the watermark on the higher rocks during typical water levels; this indicates that the dike is overtopped during high water events. **B** - note the small opening between the dike and shoreline where water exists as water levels recede into Bird Island Bayou; also note the Louisiana Department of Wildlife and Fisheries Refuge camp.

Failure of the Oyster Bayou plantings was caused by flooding that persisted as a result of low planting elevations located in the hurricane blowout ponds (Fig. V-1b). The plantings were chronically inundated by water with flood depths averaging 1.35 ft for the first two months after plant (Fig. V-10). Flooding would have been a constant struggle as flooding averaged 1.35 ft throughout the growing season (Figs. V-10 and 11). Chronic flooding causes anaerobic soil conditions that can be toxic to plant roots. Isolated plants, planted along the single rows with five ft spacing between plants, are especially vulnerable to anaerobic soil conditions. Water salinity averaged 4.9 ± 2.1 ppt within a range of 0.9 - 9.3 ppt and was not a stress factor as it was within the tolerance of smooth cordgrass and black needlerush.

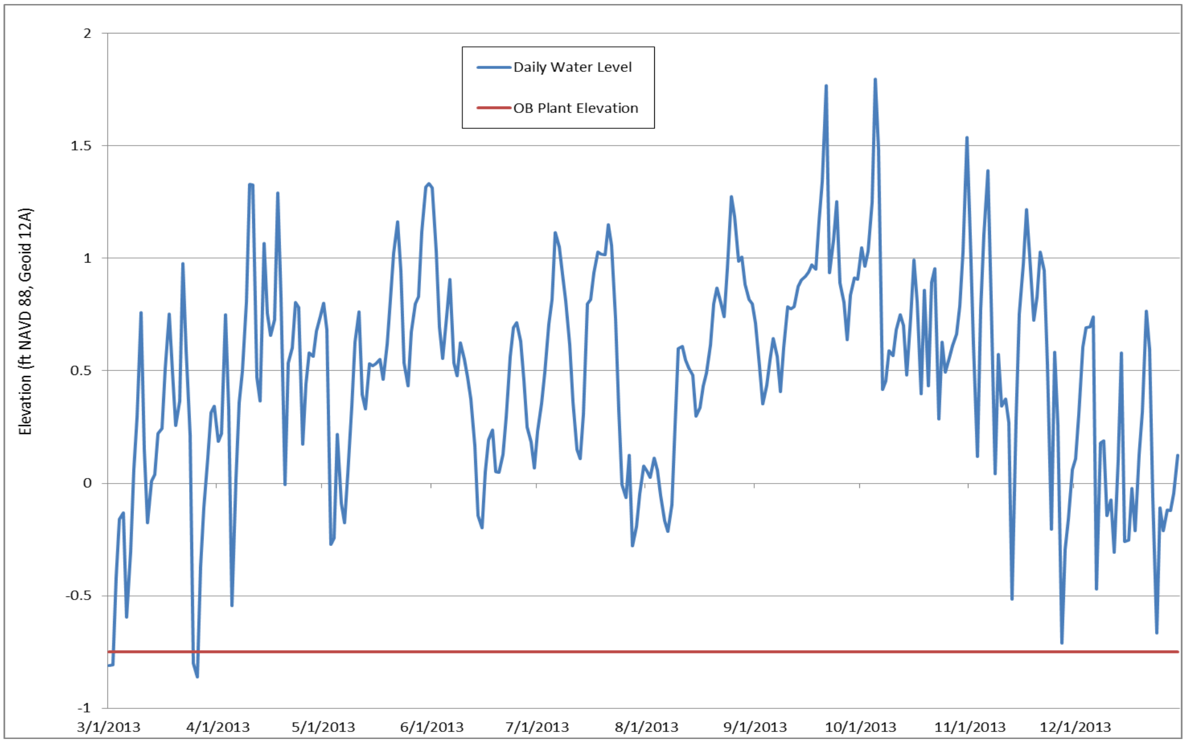


Figure V-10. Water level elevations were plotted relative to average plant elevations for the Oyster Bayou (OB) plantings from planting to the end of 2013.

Figure V-11. The Oyster Bayou planting area was photographed on 12/18/2013 during very low water level; however, the area was still inundated with a couple inches of water. Note the potential remnant of a planting in the circle.

C. Conclusions

Marsh Island Year 1 planting was largely experimental because of the harsh conditions along the shore of a large water body such as Vermilion Bay and expanding marsh pond conditions along Oyster Bayou. Shoreline plantings were limited to less than 7% of the northern shoreline of Marsh Island, and interior pond plantings along Oyster Bayou were limited to 13 transects in two ponds. Project sponsors should continue to be cautious and use limited plant numbers to determine if sufficient plant survival is attainable in such conditions before planning more expanded plantings. A large storm system just after plant installation is a potential confounding factor; if the plants had time to become more firmly rooted then performance may have differed, especially for the bulrush planted along the protected mouth of Bird Island Bayou.

1. Project Effectiveness

As per the project goals:

- Plantings along the northern, open shoreline along a large bay were unsuccessful. Survivorship of plantings was initially low 7 weeks (<5 – 30 % survival) after planting and decreased to 0% by 34 weeks after planting.
- Anchoring plants did not help to secure plantings in open shoreline conditions. There was no difference in plants present between the plants originally anchored and not anchored.
- Plantings along the mouth of a bayou protected by a foreshore dike along a large bay were unsuccessful. No plantings (live or dead) were found during field trips 7 and 34 weeks after planting.
- Plantings in open water areas of former marsh blown out by storms were unsuccessful. No live plantings were found during field trips 7 and 34 weeks after planting.
- There was no difference in planting survival between smooth cordgrass and black needle rush nor between different sizes of smooth cordgrass. All plantings in the Oyster Bayou areas were dead or absent 7 and 34 weeks after planting.
-

2. Recommended Improvements

Regardless of the period selected for plant installation, it is recommended that project sponsors incorporate flexibility in planting dates to provide some opportunity to avoid planting during excessive high water events.

3. Lessons Learned

The Marsh Island Year 1 planting illustrates two types of degraded coastal marsh conditions for which vegetative plantings, as a stand-alone technique, may not provide a solution:

1) Eroding shorelines of large, high energy water bodies.
2) Permanently flooded, shallow open-water areas with unconsolidated organic soils.
3) Planting in such areas could be used to compliment other restoration/conservation measures.

VI. <u>Year 2 - The Prairie</u>

Prepared by Danielle Richardi – CPRA New Orleans Regional Office

A. Site and Planting Description

The Prairie refers to a shallow pond that comprises approximately 500 acres in St. John the Baptist Parish along the northwest rim of Lake Pontchartrain (Fig. VI-1). The planted project area encompasses slightly greater than 16 acres of The Prairie, which is located within the Manchac Wildlife Management Area (WVA) and is managed by the Louisiana Department of Wildlife and Fisheries (LDWF).

Several restoration projects have targeted shoreline protection of the eroding, narrow strip of land that separates The Prairie and the surrounding fresh/intermediate marsh from Lake Pontchartrain. Turtle Cove Shoreline Protection (PO-0010) is a state-funded project that was completed in 1994. The project consisted of a 1,642 ft rock-filled gabion breakwater constructed in Lake Pontchartrain, approximately 300 ft from the shoreline along the far northeastern reach of the Prairie. Monitoring was only conducted for three years post-construction, but results indicated that the project was successful in reducing wave energy along the shoreline and in trapping sediment behind the gabion (O'Neil and Snedden, 1999).

The following year, the U.S. Army Corps of Engineers (USACE) constructed the Manchac Wildlife Management Area (MWMA) mitigation project, which consisted of segmented rock breakwaters with marsh creation between the breakwaters and the shoreline (USACE, 2014). This project did not produce the anticipated results, prompting a revised construction plan that filled in the gaps between the breakwaters and added dredged sediment to the marsh creation area. This Modified MWMA Mitigation Project was completed in September 2013, but additional changes were still deemed necessary by the USACE to reach the goals of the project. The current project, Lake Pontchartrain and Vicinity Mitigation MWMA Marsh Creation (state project number PO-0146) dredged sediment from the lake to raise the marsh platform to an approximate as-built elevation of + 2.5 ft NAVD 88 (Geoid 03) and constructed and repaired earthen dikes and rock dikes. The project was completed the summer of 2016 and should provide much-needed shoreline protection for the narrow stretch of land between the lake and the Prairie.

<u>The Prairie Project Features</u>

Plantings were conducted in four areas following three planting designs: area planting, double row planting and single row shoreline enhancement planting (Fig. VI-1). A total of 13,168 trade gallon *Schoenoplectus californicus* (California bulrush) and 567 trade gallon *Spartina alterniflora* Vermilion (smooth cordgrass) were planted in The Prairie between March 11−15, 2014. *Schoenoplectus californicus* was used for the interior plantings, while *S. alterniflora* was used for the edge shoreline plantings. Maximum planting depth was specified as no lower than -0.75 ft NAVD88 (GEOID12A) for *S. californicus*, and no lower than - 0.25 ft NAVD88 (GEOID12A) for *S. alterniflora*.

Area 1

1A: *Schoenoplectus californicus* was planted in parallel rows 5 feet apart, with plants on 5-foot alternating centers. The planting row alignment was parallel to the shoreline and followed an area planting design.

1B: *Schoenoplectus californicus* was planted in four double rows perpendicular to the shoreline. The two rows within each double row were planted approximately 20 feet apart. Plants within each row were planted on 5-foot alternating centers.

1C: *Spartina alterniflora* Vermilion was planted on 5-foot centers in one row following the alignment of the existing marsh edge as a shoreline enhancement.

Area 2

2A: *Schoenoplectus californicus* was planted in parallel rows 5 feet apart, with plants on 5-foot alternating centers. The planting row alignment was parallel to the shoreline and followed an area planting design.

2B: *Spartina alterniflora* Vermilion was planted on five-foot centers in one row following the alignment of the existing marsh edge as a shoreline enhancement.

Area 3:

3A: *Schoenoplectus californicus* was planted in 10 double rows that were arranged in a delta-splay formation. The two rows within each double row were planted approximately 20 feet apart. Plants within each row were planted on 5-foot alternating centers.

Auxiliary Planting Area:

An area within The Prairie adjacent to the southwestern boundary of Area 3 was designated for the placement of surplus plants. *Schoenoplectus californicus* was planted in parallel rows 5 feet apart with plants on 5-foot alternating centers, following an area planting design.

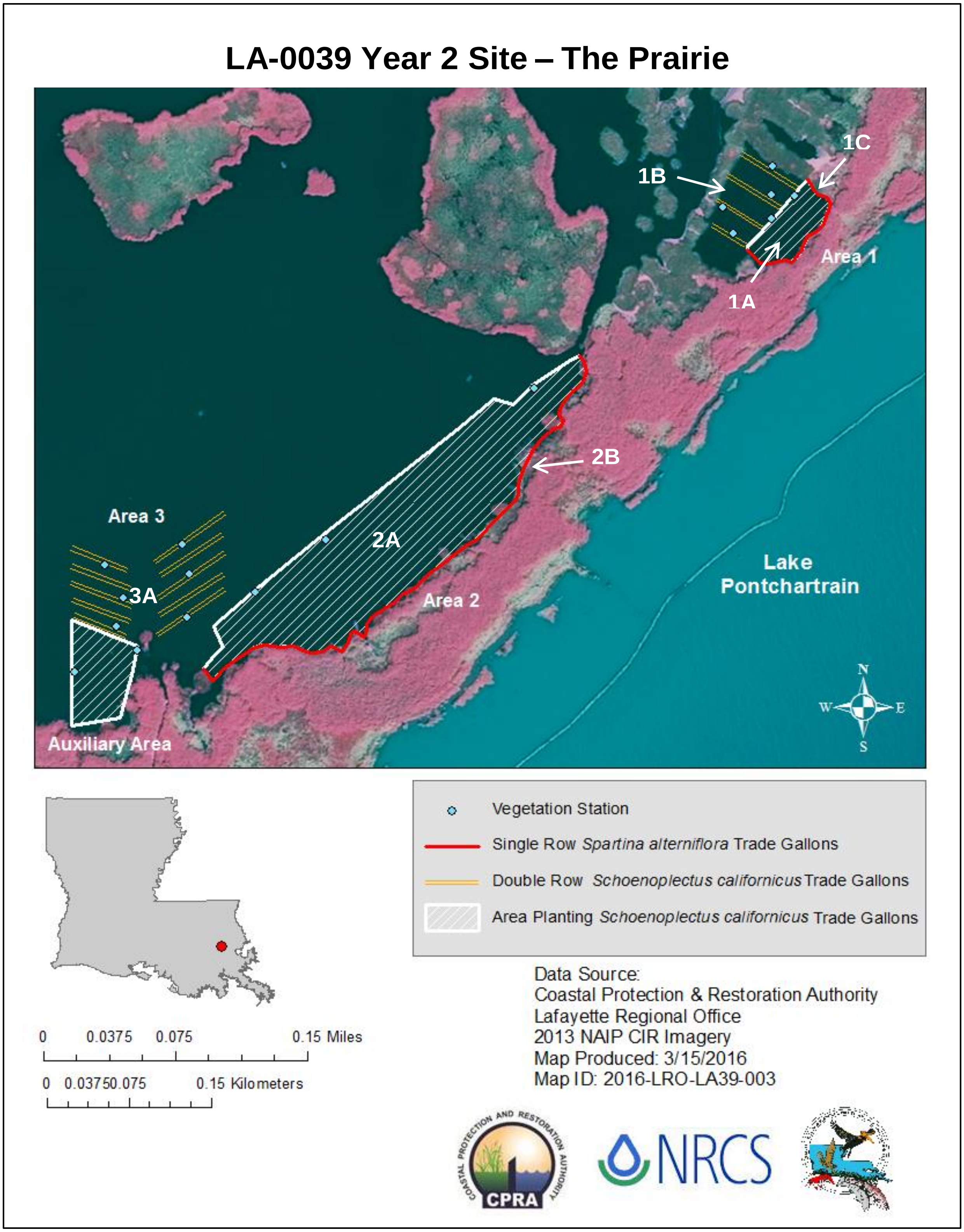


Figure VI-1. Map of LA-0039 Year 2 Site – The Prairie, showing the location of planting areas and vegetation monitoring stations.

B. Monitoring Activity

1. Monitoring Goals and Objectives

The goal of interior area plantings is to establish emergent vegetation in areas devoid of vegetation and/or in areas with damaged or degraded vegetation. The goal of shoreline plantings is primarily to reduce shoreline erosion. The CWPPRA Environmental Work Group predicts shoreline loss reduction and land loss rate reduction of at least 50% for plantings assuming successful colonization and expansion of planted vegetation (NRCS 2010).

The objectives for the Prairie planting are as follows:

- Area plantings of *S. californicus* in open water areas will survive and expand.
- Area plantings of *S. californicus* will widen the land bridge in Areas 1 and 2.
- Double row plantings of *S. californicus* in open water areas will survive and expand.
- Shoreline plantings of *S. alterniflora* will survive and expand in Areas 1 and 2.

2. Monitoring Elements

A basic level of monitoring will be required to assess each planting effort, determine if additional planting is needed, and evaluate and track project benefits over time. If distinct areas of planting failures are observed in the field, the failures will be investigated for causation and results will be used to guide future plantings. All statistical analyses were performed using ANOVA in Proc GLM, $\alpha = 0.05$, followed by a Tukey's post-hoc test (SAS Institute Inc., Cary, NC, version 9.4).

Table VI-1 shows the current monitoring schedule for LA-0039 Year 2 Site − The Prairie. The baseline planting survival was the date of the planting inspection, March 17, 2014 (T_0). The initial vegetation survey was conducted May 20, 2014 (T_1), and the year 1 survey was conducted June 2, 2015 (T_2). Originally, an assessment of vegetative growth was not scheduled for the 2015 and 2017 surveys, but due to the demonstrated ability to collect all data within one day, vegetative growth was monitored in 2015 and is also planned for 2017. The final monitoring event in 2024 will only be conducted if deemed appropriate based on the results of the 2019 survey and if funding is available.

Table VI-1. Monitoring schedule for LA-0039 Year 2 Site – The Prairie.

Sampling Type	T_0 2014	T_1 2014	T_2 2015	T_3 2017	T_5 2019	T_6 2024
Planting Survival	March	May	June	Spring	Spring	Spring
Percent Cover	March	May	June	Spring	Spring	Spring

Vegetation Assessment

Seventeen vegetation stations were established to assess planting survival and vegetative growth (Fig. VI-1). Due to the 5-foot spacing of the *S. californicus* rows in the area plantings (1A, 2A and Auxiliary), the interior of the planted areas was not accessible without damaging plants. Therefore, monitoring stations were established along the perimeter of these planting areas. The *S. alterniflora* shoreline plantings (1C and 2B) were even less accessible between the area plantings and the existing shoreline. A general assessment of survival of the shoreline plantings was conducted from the boat when possible and was supplemented with Goggle Earth aerial photography.

The assessment of planting survival is based on monitoring 10 plants at each station; plants are characterized as live or dead/absent. The survival monitoring plants, 10 plants along a single row or 5 plants along two neighboring parallel rows, are marked with PVC poles at the start and at the end. The survival monitoring plants extend beyond the 4 m^2 quadrant that is used for vegetative growth monitoring, but it is considered part of the same monitoring station. Vegetative growth is determined by measuring total percent vegetative cover, species composition, percent cover of each species, dominant species height, and vegetative layer height at 4 m^2 stations following CRMS methodology (Folse et al. 2014). An ocular assessment of the overall survival and condition of adjacent area and double row plantings were also noted. In addition to planting survival and vegetative growth, the distance between each row of the double rows is measured to determine if *S. californicus* is expanding and closing the gap between the double rows.

Hydrology

Surface and porewater salinity (ppt), specific conductivity (*u*S/cm), and temperature (°C) are measured at each vegetation station during each survey. Porewater is collected from a depth of 20 cm beneath the sediment surface. The depth of water at each station is also measured during sampling. Salinity and water level data recorded hourly from CRMS0030, located approximately 4 miles north-northeast of the site, were utilized to document salinity variation and approximate the flooding depth and duration for the planted vegetation. Porewater data are collected at CRMS0030 when the site is visited for servicing and during the annual vegetation surveys. Porewater salinity data from CRMS0030 were used to approximate conditions in the Prairie.

3. Monitoring Results and Discussion

a. Vegetation

Planting survival of *Schoenoplectus californicus* was 100% at each of the 17 vegetation stations for the 2014 initial vegetation survey. By the 2015 survey, *S. californicus* had vegetated prolifically along and between the planted rows and individual plants were indistinguishable within the stations. Survival at all stations is assumed to be 100% or nearly 100% (Figures VI-2–5). This level of survival was representative of all of the area and double row plantings.

Figure VI-2. Double row planting area 3A, photographed during the 2014 vegetation survey.

Figure VI-3. Double row planting area 3A, photographed during the 2015 vegetation survey.

Figure VI-4. Area planting 2A, photographed during the 2014 vegetation survey.

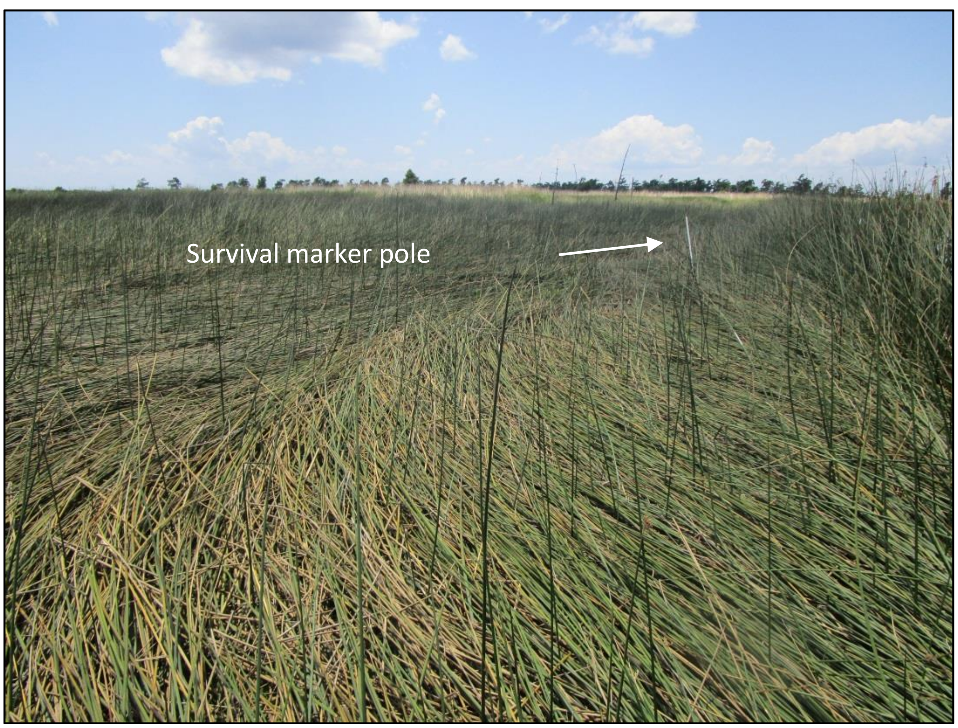


Figure VI-5. Area planting 2A, photographed during the 2015 vegetation survey. The SW marker pole for the survival plantings for station P08 is visible in the photograph. Note the laid over *S. californicus* stems.

The positive growth response of *S. californicus* between the 2014 and 2015 surveys indicates that this species is well-suited for the environmental conditions that exist in the shallower areas of The Prairie. Mean total percent cover at the stations increased from 5.9% ± 0.4 SE in 2014 to 78.2% ± 4.8% SE in 2015. For the 2014 survey, 100% of the cover was attributed to *S. californicus*, with no other species colonizing the stations within the short 2.5 months between the planting and the survey. In 2015, the species composition was again comprised nearly entirely of *S. californicus* (77.9% mean cover) with *Alternanthera philoxeroides* (alligatorweed) being the only other rooted species recorded at the stations (0.8% mean cover). Among the five planting areas, mean total percent cover between surveys increased the greatest in the Auxiliary planting area (7.5% in 2014 to 97.5% in 2015) and increased the least in the 1A planting area (6% in 2014 to 50% in 2015) (Fig. VI-6).

Mean total percent cover between sites was significantly different in 2015, with planting area 1A having less cover than the Auxiliary planting area ($p = 0.0154$, $F = 4.78$). There was a general trend of increasing cover for planting areas from the east to the west (Fig. VI-6). There are several possible explanations for the lower cover in area 1, including a greater presence of *Salvinia molesta* (kariba weed) and a lower planting elevation, both of which are discussed later. In addition to these potential contributing factors, planting area 1 is in a more enclosed location than the other planting areas (Fig. VI-1). As a result, the plants could be experiencing less hydrologic exchange and possibly inferior water quality as compared to the other planting areas. Cover between the double row and area planting designs did not significantly differ.

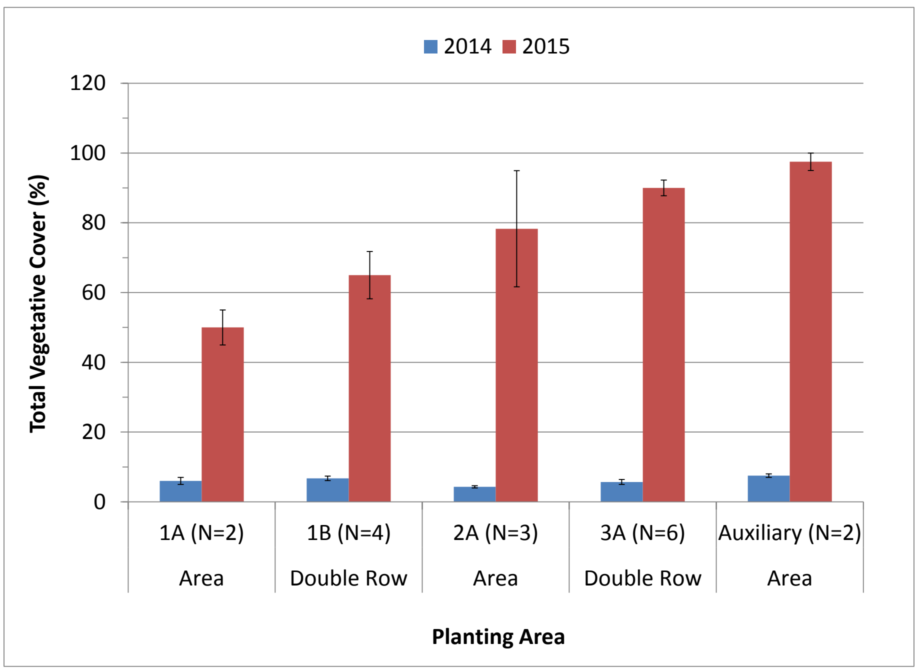


Figure VI-6. Mean total cover (± SE) of vegetation at stations in each planting area as measured during the 2014 and 2015 vegetation surveys. Area and Double Row refer to the type of planting. N refers to the number of stations surveyed.

The mean height of *S. californicus* also increased at all stations between years, from 5.1 ft ± 0.1 SE in 2014 to 8.4 ft ± 0.2 SE in 2015 (Fig. VI-7). The increase in height between years averaged

3.3 ft and ranged from a low of 2.4 ft for area 1B to a high of 3.8 ft for area 3A. Stem height among planting areas or planting designs in 2015 did not differ significantly. The height of *S. californicus* at each station was measured by vertically elongating five randomly-selected stems within the 4 m^2 quadrant (Fig. VI-8). A separate height measurement, the height of the herbaceous layer, is estimated as the plants lie without elongation of any stems. The layer height was considerably lower than the species height due to significant flattening of vegetation at many of the stations (Fig. VI-8). In 2014, the herbaceous layer height was 5.0 ft ± 0.1 SE and in 2015 it was 4.5 ft ± 0.3 SE. A definitive reason for the stems bending over has not been identified; however, it may be the result of high wind. Despite being laid over, most of the stems were alive.

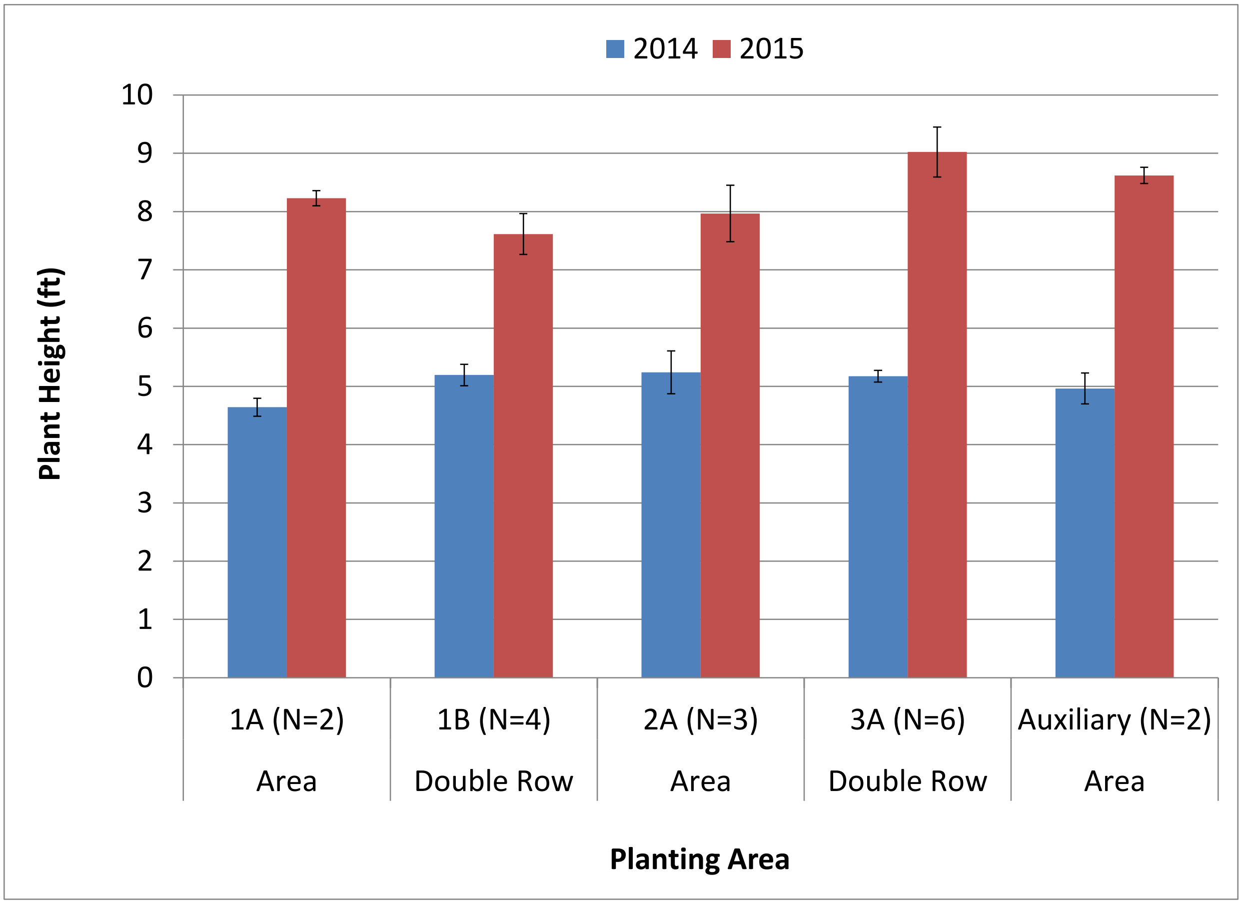


Figure VI-7. Mean height of *S. californicus* (± SE) at stations in each planting area as measured during the 2014 and 2015 vegetation surveys. *Area* and *Double Row* refer to the type of planting. *N* refers to the number of stations surveyed.

Figure VI-8. Ten-foot tall *S. californicus* photographed during the 2015 vegetation survey in double row planting area 3A.

Double rows were planted with approximately 20 feet between each row in two areas (1B and 3A). The double rows are intended to converge as the plants proliferate. *Schoenoplectus californicus* spreads primarily through rhizomes and under appropriate conditions can expand its coverage 8–10 feet within one growing season (Materne and Fine 2000). This rate of expansion would result in each double row merging into one row within one to two growing seasons. In planting area 1B, the mean distance between rows declined from 20 ft in 2014, to 4 ft in 2015 (N=4 for both years). In planting area 3A, the mean distance between rows declined from 19 ft in 2014 (N = 3) to 5 ft in 2015 (N = 4). At this rate of expansion, the double rows are expected to unite into a single row by the 2017 survey (Figs. VI- 9−12).

One row of *Spartina alterniflora* Vermilion (1C and 2B) was planted along the shoreline, directly behind planting areas 1A and 2A (Fig. VI-1). While a quantitative assessment of the species was not possible without destroying other plants, it was visible from the boat and was noted as being alive in both planting areas in 2014. By 2015, the dense growth and increased height of *S. californicus* in the 1A and 2A planting areas prohibited any on-the-ground detection of the species; however, aerial imagery has provided some additional information. The 1C planting of *S. alterniflora* is visible in Goggle earth aerial imagery taken October 31, 2014, but it is no longer discernible in the latest Google earth imagery taken April 4, 2016 (Fig. VI-9). A section of the *S. alterniflora* 2B planting also appears visible in the 2014 Google earth imagery, but it too is no longer discernible in 2016 (Fig. VI-10). The ideal salinity and water depth for the *S. alterniflora* 'Vermilion' cultivar are 8−30 ppt and 1−18 inches, respectively (Fine and Thomassie 2000). While the water depth is within the range exhibited in The Prairie, the salinity is not; mean daily salinity in the area was approximately 1 ppt in 2014 and 2015 (see Hydrology section). *Spartina alterniflora* Vermilion can grow in freshwater environments without competitors; however, its growth has been shown to be greatly hindered when it is planted in association with freshwater-adapted species (Crain et al. 2004).

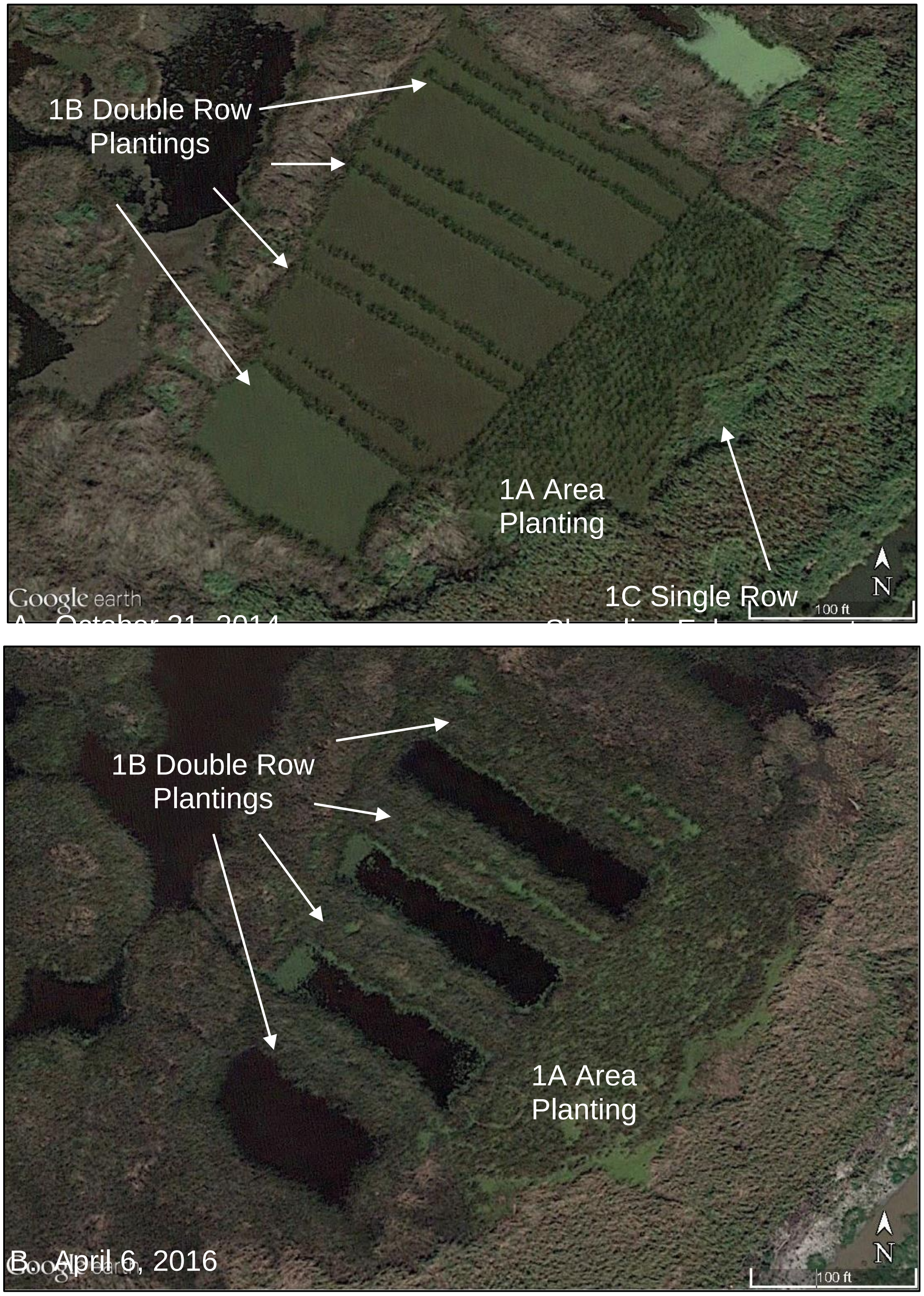


Figure VI-9. Google earth imagery taken October 31, 2014 (A) and April 6, 2016 (B), of planting area 1. The 1B double rows of *S. californicus* have largely grown together. The 1C single row planting of *S. alterniflora* appears visible 2014 (A) but not 2016 (B).

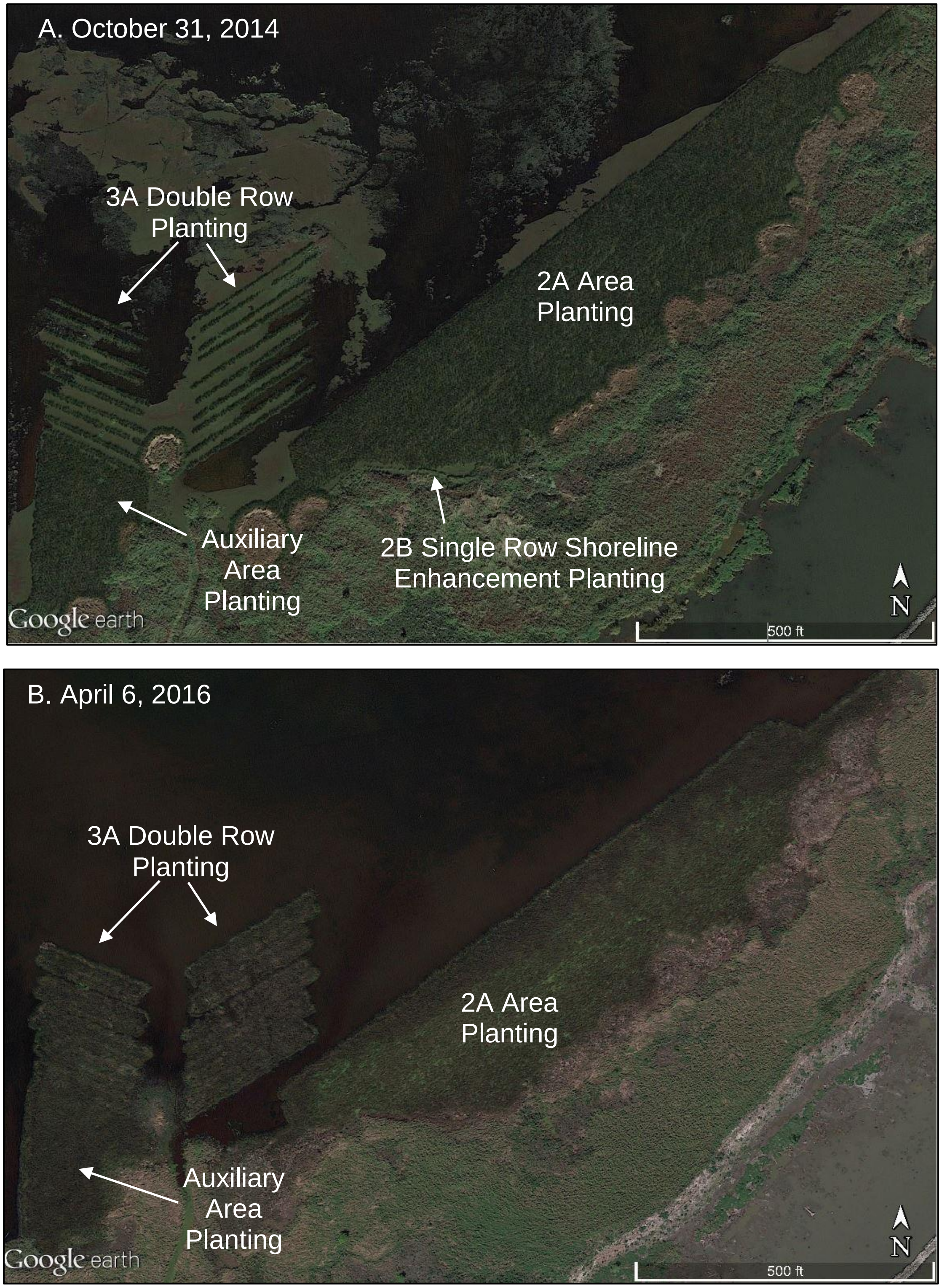


Figure VI-10. Google earth imagery taken October 31, 2014 (A) and April 6, 2016 (B) of planting areas 2, 3, and the Auxiliary planting area. The 2B single row of *S. alterniflora* appears visible in 2014 (A) but not 2016 (B). The 3A double rows of *S. californicus* appear to have grown together (B).

Figure VI-11. New *S. californicus* stems are visible growing between a double row during the 2015 vegetation survey in area 1B. *Salvinia molesta* covers the surface of the water.

Figure VI-12. Approximately 5 ft remained between the double row of *S. californicus* during the 2015 vegetation survey in area 3A. *Salvinia minima* covers the surface of the water.

In addition to the expansion and growth of *S. californicus*, there has also been an increase in submerged and floating aquatic vegetation. While present in 2014 at several stations, submerged aquatic vegetation was more dense and diverse during the 2015 survey in areas that were not covered by *Salvinia molesta* (kariba weed) or *Salvinia minima* (water spangles) (Fig. VI-12). *Ceratophyllum demersum* (coon’s tail), *Najas guadalupensis* (southern waternymph), and *Potamogeton pusillus* (small pondweed) were all prevalent in or bordering the 2A, 3A and Auxiliary planting areas. Submerged aquatic vegetation was also dense in the shallow open water expanse of The Prairie. The expansion of the invasive aquatic plant *Salvinia molesta* is of concern in Louisiana and along much of the coastal United States. This species was not noted in planting areas during the 2014 survey; however, it blanketed much of the water’s surface between the double rows in 2015. Salvinia weevils (*Cyrtobagous salviniae*) were released in The Prairie in May and August of 2015 and again in May 2016 as part of an ongoing effort by the Louisiana State University AgCenter and LDWF to combat the invasive species. The weevil has not established a locally-reproducing population and to date has not effectively controlled *S. molesta* in The Prairie. It was observed during the 2015 survey that the *S. molesta* mat was providing a floating substrate for the establishment of other species, including *Amaranthus australis* (southern amaranth), *Habenaria repens* (waterspider bog orchid) and *Symphyotrichum* sp. (aster). *Salvinia molesta* was particularly dense in planting area 1, and may partially account for the lower vegetative cover for *S. californicus* in the area. The species is certainly reducing light penetration through the water and may be having a smothering effect on emerging vegetation.

b. Hydrology

Mean salinity recorded at the 17 vegetation stations during the May 20, 2014, survey was 1.18 ppt ± 0.01 SE. This salinity corresponded closely with the mean hourly salinity of 1.01 ppt ± 0.02 SE recorded during the same time frame at CRMS0030. Mean salinity recorded during the June 2, 2015, survey was 0.48 ppt ± 0.02 SE, which again corresponded closely with the mean hourly salinity of 0.55 ± 0.00 SE recorded at CRMS0030 during the same time (Fig. VI-13). Porewater salinity at the vegetation stations also from 20 cm beneath the sediment surface. In 2014, porewater salinity was only measured from one station due to the water extractor clogging with sediment. The porewater salinity was 3.3 ppt at the one successfully sampled station. In 2015, porewater salinity was sampled from 10 stations for a mean salinity of 0.9 ppt ± 0.1 SE.

For 2014 and 2015, mean daily salinity at CRMS0030 was 1.09 ppt ± 0.02 SE (Fig. VI-13). *Schoenoplectus californicus* grows best in salinities between 0 – 6 ppt and can tolerate brief spikes of higher salinity (Materne and Fine 2000). Even with the pulse of higher salinity that occurred the latter half of October 2015 (Fig. VI-13), mean daily salinity remained well within the tolerance levels for this species. The salinity pulse resulted from a period of sustained easterly winds that pushed more saline waters from Lake Pontchartrain into the marsh. Mean porewater salinity measured at CRMS0030 between 2014 and 2015 was 1.53 ppt ± 0.17 SE, higher than the surface water salinity, but still within a favorable range for *S. californicus.* The reported porewater salinity values are an average of porewater salinity collected at 10 cm and 30 cm depth, as is standard collection procedure at CRMS sites (Fig. VI-13).

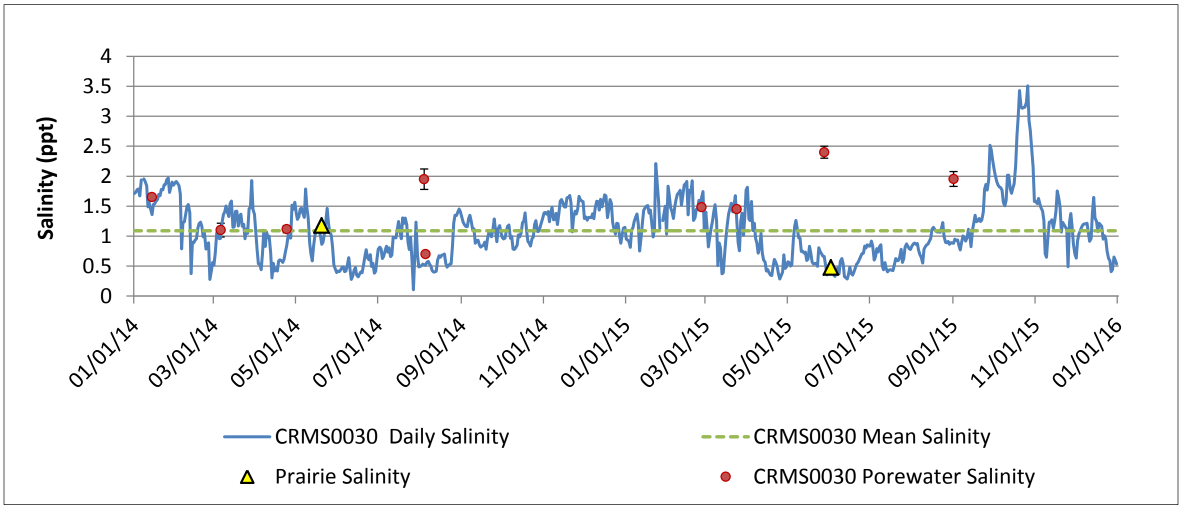


Figure VI-13. Mean salinity at vegetation stations in The Prairie during the 2014 and 2015 surveys graphed in relation to mean daily and mean overall salinity measured at CRMS0030 01/01/2014 – 12/31/2015. Porewater salinity (± SE) measured at CRMS0030 is also displayed.

For 2014 and 2015, mean daily water elevation (NAVD88, GEOID 12A) at CRMS0030 was +0.47 ft and ranged from a high of +3.44 ft to a low of -0.93 ft (Fig. VI-14). The same easterly winds that resulted in an increase of salinity at CRMS0030 also likely contributed to the increase in water elevation that occurred October 25–27, 2015. However, the 6.68 inches of rain that fell on October 25 (Louisiana Regional Airport in Gonzales, LA) may have also contributed to the increase in water level.

The plant elevation was estimated by subtracting the water depth measured at each vegetation station during the survey, from the water elevation recorded at the corresponding time at CRMS0030. The estimated planting area elevation was calculated by averaging the elevation of all plants within a planting area. Mean estimated planting area elevation ranged from a high of -0.4 ft in the Auxiliary planting area, to a low of - 0.9 ft in areas 1A and 1B (Table VI-2). Using these elevations and the water elevation at CRMS0030, the depth and duration of flooding for 2014 and 2015 were calculated for the planting areas. The mean depth of flooding in the planting areas was + 1.2 ft, and ranged from a high of + 1.4 ft in Area 2A, to a low of + 0.9 ft in the Auxiliary area. On average, the plants were flooded 98.1% of the time, with flooding ranging from a high of 99.7% in area 2A and a low of 94.0% in the Auxiliary area. The optimum water depth for establishment of *S. californicus* is reported as between 1 to 2 feet (Materne and Fine 2000). The estimated mean depth of inundation for the plants is within this range for all planting areas except the Auxiliary area, which had the greatest cover in 2015 and shows no negative impact from slightly less frequent and shallower flooding. Planting area 1 had the greatest depth and duration of flooding, and also had lower vegetative cover than the other planting areas. It seems unlikely that the greater flooding resulted in reduced growth, but it is a noted difference between planting areas.

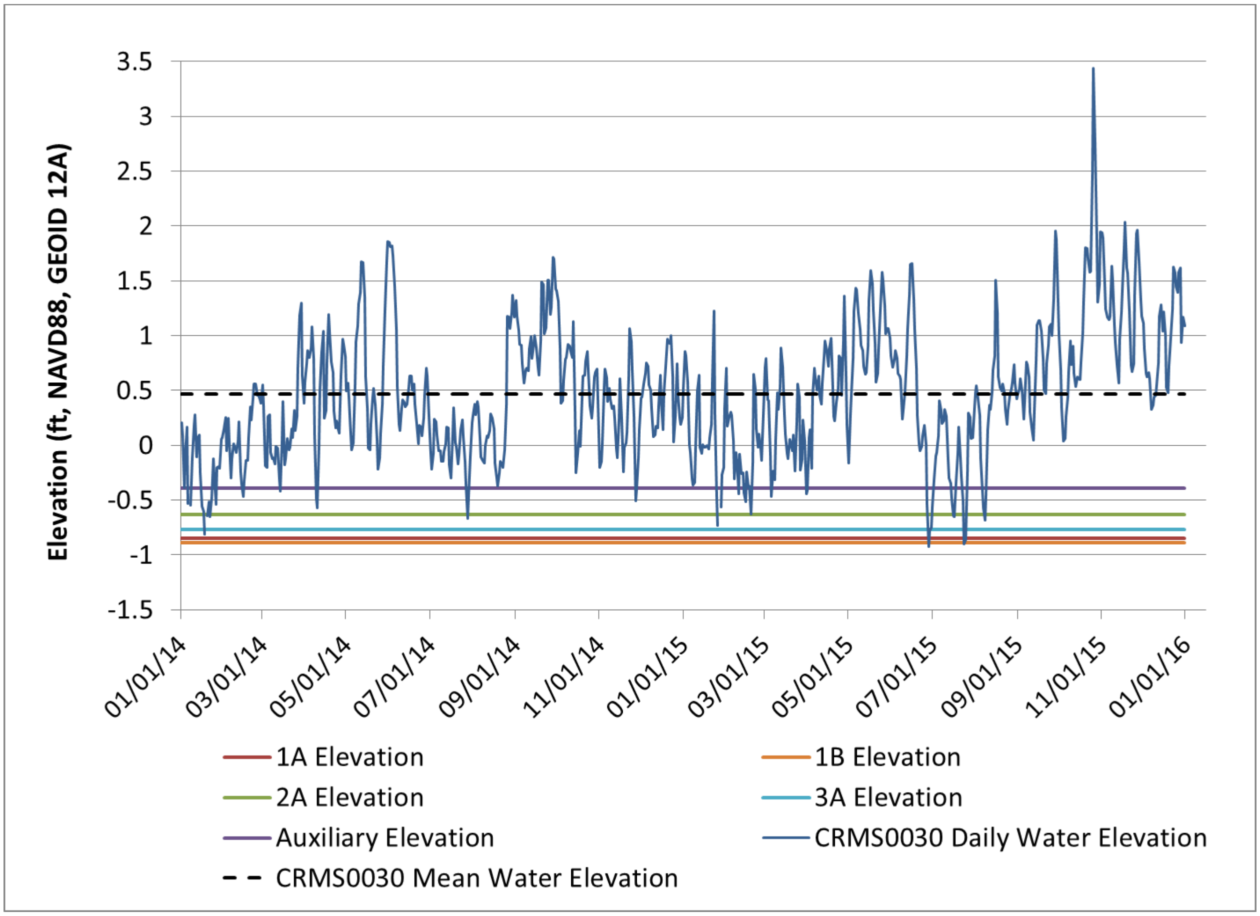


Figure VI-14. Mean daily and mean overall water elevation at CRMS0030, graphed with the estimated elevation of each planting area in The Prairie.

Table VI-2. Depth and duration of flooding for each planting area within The Prairie 01/01/2014–12/31/2015. The calculations include the 2.5 months in 2014 prior to the planting (ft NAVD88 GEOID 12A).

		Depth of flooding (ft)			Time Flooded (%)
The Prairie Planting Area	**Planting Area Elevation (ft)**	**Mean**	**High**	**Low**	
1A	-0.9	1.3	4.3	-0.1	99.6
1B	-0.9	1.4	4.3	0.0	99.7
2A	-0.6	1.1	4.1	-0.3	98.1
3A	-0.8	1.2	4.2	-0.2	99.3
Auxiliary	-0.4	0.9	3.8	-0.5	94.0
	Mean	1.2	4.1	-0.2	98.1

C. Conclusions

1. Project Effectiveness

Based on observations and data collected during the 2014 and 2015 vegetation surveys of LA-0039 Year 2 − The Prairie, the planting of *Schoenoplectus californicus* has been successful.

- For the 2014 and 2015 vegetation surveys, the area plantings of *S. californicus* in areas 1B, 2A and the Auxiliary area survived and expanded. Survival was 100% in 2014 and as best as could be assessed, was also 100% in 2015. The original plants could not be identified in 2015 due to the continuous growth and expansion of the species along rows. Vegetative cover increased in all planting areas from 2014 to 2015.

- The expansion of *S. californicus* coverage in the 1B and 2A area plantings has served to widen the land bridge between Lake Pontchartrain and The Prairie.

- For the 2014 and 2015 vegetation surveys, the double row plantings of *S. californicus* in areas 1B and 3A survived and expanded. Survival was 100% in 2014 and as best as could be assessed, was also 100% in 2015. The original plants were indistinguishable in 2015 due to the vigorous growth and expansion of the species along rows. Vegetative cover increased in both planting areas from 2014 to 2015 and the distance between double rows decreased as a result of the growth of new stems.

- The 1C and 2B single row shoreline plantings of *S. alterniflora* appear to have survived initially, but an on-the-ground assessment was difficult, even in 2014, due to the location of the plantings. The plants appear visible in the October 2014 Google earth imagery; however, the species is no longer evident in the Google earth April 2016 imagery. This species may not have survived, or is not distinguishable because of other species expansion.

- There was no detectable difference between the success of the area and double row plantings in 2015, as based on the percent cover of vegetation and the species height at the stations. Both planting strategies have performed well.

- Mean percent cover between sites was significantly different in 2015, with planting area 1A having significantly less cover than the Auxiliary planting area. Possible explanations for the lower cover in area 1 include a greater presence of *Salvinia molesta* (kariba weed), a lower planting elevation, and reduced hydrologic exchange as compared to the other planting areas.

2. Recommended Improvements

Salvinia molesta was blanketing the surface of the water between the 1B double row plantings and was also covering the surface of the water in sections of the other double row and area plantings. The LDWF is attempting to control the species with the introduction of the Salvinia weevil, but the current assessment of this strategy indicates that the weevils are not establishing a viable reproducing population in The Prairie. It is recommended that invasive species control is considered where the spread of *S. molesta* or other invasive species is likely.

Shoreline enhancement plantings may be unnecessary in conjunction with adjacent area plantings if environmental conditions are similar in the planting areas and an expansion of the area planting is expected to occur.

Spartina alterniflora Vermilion does not appear to have thrived under the same conditions as *S. californicus*. The low salinity in the Prairie may have hindered its successful establishment. This species may perform better under higher salinity conditions and in association with species that will not have a greater competitive advantage.

3. Lessons Learned

Schoenoplectus californicus is a rapidly growing species that does well in shallow, continuously-flooded fresh to intermediate marsh habitats such as The Prairie. Based on survival and growth data collected to present, this species is recommended for future plantings in similar environments.

The planting of *Spartina alterniflora* Vermilion may not be advisable for fresh/intermediate marsh plantings, although conditions other than salinity could have affected the species success in the Prairie. Assessment of *S. alterniflora* has been difficult due to the location of the shoreline enhancement plantings; therefore, it is possible that some plants are still alive.

Future monitoring will determine the effects, if any, of the laid down *S. californicus* and will indicate whether this is a repeating occurrence in the project area.

VII. Year 2 – West Little Lake

Prepared by Bernard Wood, Tommy McGinnis, Margaret Luent – CPRA Lafayette Regional Office and Elaine Lear - Thibodaux Regional Office

Data collected by the CPRA Thibodaux Regional Office

A. Site Description

West Little Lake, a Year 2 planting site, is in Lafourche Parish on a peninsula of marsh that projects out from the west bank of Little Lake, with Bay L'Ours to the south (Fig. VII-1). The surrounding marsh is intermediate vegetation.

The West Little Lake site is divided into six (6) areas and has three (3) planting strategies (shoreline plantings, double rows, and area plantings in smaller ponds) (Fig. VII-1). A combination of *Schoenoplectus californicus* (California bulrush) (9,670 plants) and *Spartina alterniflora* Vermilion (smooth cordgrass) (900 plants) trade-gallon sized plants were planted.

Shoreline plantings are smooth cordgrass and California bulrush rows located along the Little Lake (north) side of the peninsula (Site 1). Smooth cordgrass was planted as close as possible to the existing marsh edge on 5 ft centers no lower than +0.25 ft NAVD88; California bulrush was planted 1 ft – 3 ft from the existing marsh edge on 5 ft alternating centers from the smooth cordgrass no lower than -0.75 ft NAVD88.

Hedge row plantings of California bulrush were installed in hedges of 5 rows parallel to the shoreline. Rows within a hedge were spaced 5 ft apart with plants on 5 ft alternating centers for a total hedge width of 20 ft no deeper than -0.75 ft NAVD88. Hedges are located in **coves** along the peninsula open to Little Lake (Site 2 and 3) and in a large pond (Site 4).

Double row plantings are 8 double rows of California bulrush in a larger pond almost bisecting the peninsula (Site 4). Within each double row, rows are spaced 5 ft apart with plants on 5 ft alternating centers no deeper than -1.0 ft NAVD88.

Pond area plantings all California bulrush planted in smaller ponds in parallel rows 5 ft apart with plants on 5 ft alternating centers over the entire pond no deeper than -1.0 ft NAVD88 (Sites 5 and 6). A similar auxiliary area was planted in the south end of Site 4.

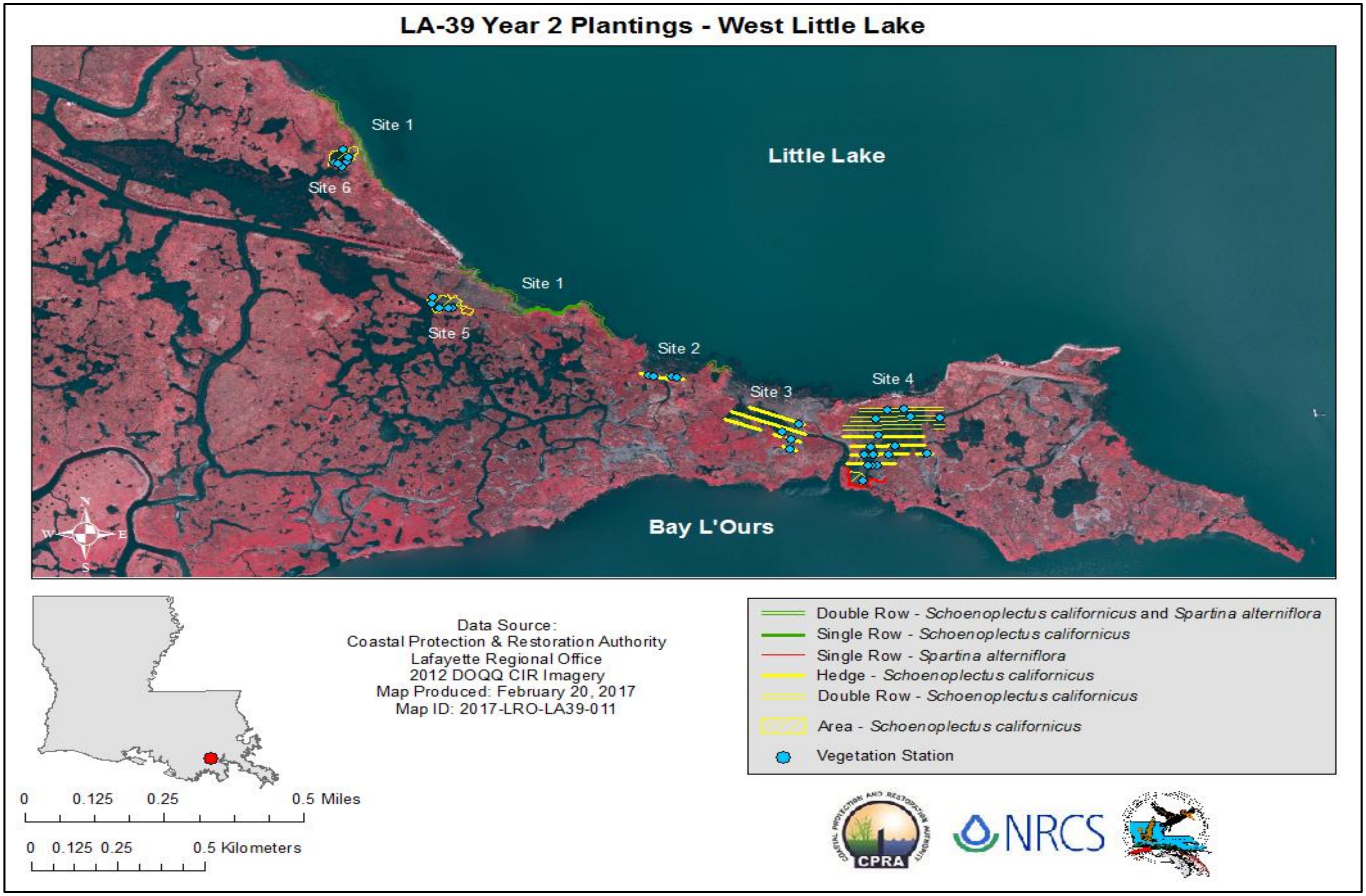


Figure VII-1. LA-39 Year 2 Site – West Little Lake site map shows plantings areas, planting types, and vegetative monitoring stations.

B. Monitoring Activity

1. Monitoring Goals

The goals of the West Little Lake plantings are:

- Shoreline plantings of smooth cordgrass and California bulrush will survive and expand to reinforce shorelines.
- Cove hedge row plantings of California bulrush will survive and expand within the coves along Little Lake shoreline.
- Double row plantings of California bulrush will survive and expand within the pond.
- Area plantings of California bulrush will survive and expand within the small ponds.

2. Monitoring Elements

The monitoring elements include procedures to assess planting survival and effects on the planting area for the project plantings. Vegetation stations are intended to monitor planting survival and vegetative cover representative of the variety of planting strategies over time (Table VII-1). Hydrologic data from nearby CRMS sites are used to explain hydrologic influences such as flooding. The final planting inspection of October 15, 2014 is considered the beginning of the monitoring period.

Table VII-1. Sampling scheduled for LA-39 Year 2 site, West Little Lake.

Sampling Type	T_0 2014	T_1 2014	T_2 2015	T_3 2017	T_4 2019	T_5 2014
Planting Survival	Oct 15	Nov 10	Oct 26	Fall	Fall	Fall
Percent Cover		Nov 10	Oct 26	Fall	Fall	Fall

Vegetation Assessment

To assess planting status an ocular estimate of % survival and plant condition was conducted for each area and planting type while visually inspecting the site during sampling visits. Planting survival and vegetative growth data was also collected at the vegetation station level; 35 stations were established to represent the areas and planting types. Percent survival was calculated from 10 plants at each vegetation station; plants were characterized as live (any green vegetation) or dead/absent. The 10 plants were divided evenly among two rows of plantings (5 plants per row). Vegetative cover data includes percent (%) vegetative cover of emergent vegetation, % cover of species present, vegetative stand height, and height of dominant species within a $4m^2$ plot (Folse et al. 2014). Conditions occurring outside of the vegetation stations including additional emergent species, floating and submerged vegetation, marsh interspersion, and site-specific points of interest were noted along with photographic documentation.

Shoreline Plantings have no vegetation stations. Shoreline plantings were destroyed or covered by wrack before the first monitoring visit (approximately 6 weeks after planting).

Cove Hedge Row Plantings have eight (8) vegetation stations (Site 4).

Pond Hedge Row Plantings have 10 vegetation stations (Site 2 and 3).

Pond Double Row Plantings have six (6) vegetation stations (Site 4).

Pond Area Plantings have 12 vegetation stations (Site 5 and 6). The stations are located along the perimeters of the plantings so that plants are not damaged via access. Therefore, the results may be biased by conditions along the perimeter.

Hydrology

Surface and porewater salinity (ppt), specific conductivity (*u*S/cm), and temperature (°C) are measured at each vegetation station during each survey. Porewater is collected from a depth of 20 cm beneath the sediment surface. The depth of water at each station is also measured during sampling. Salinity and water level data recorded hourly from CRMS4218, located approximately 3 miles northeast of the site, were utilized to document salinity variation and approximate the elevation for the planted vegetation in NAVD 88 GEOID 12A.

3. Monitoring Results and Discussion

a. Vegetation Assessment

The ocular estimates of the planting area captured the overall performance of the plantings. All planting sites at this project area have reacted similarly over time, with the exception of the shoreline plantings. The shoreline plantings were destroyed or covered with wrack by the first monitoring visit in November 2014 resulting in a total loss; no vegetation stations were established. The remaining planting regimes (area plantings, cove hedges, pond hedges and double row) declined in percent survival (Table VII-2); however, surviving plants increased in both percent vegetative cover and stem heights (Fig. VII-2 and VII-3). Most of the decrease in survival was due to disturbance by floating aquatic vegetation (water hyacinth and/or giant Salvinia).

Table VII-2. Overall % Survival of LA-39 Year 2 West Little Lake plantings were ocularly estimated over time while conducting the final inspection and monitoring field trips.

		% Overall Survival		
Location	Planting Type	T_0 Oct 2014	T_1 Nov 2014	T_2 Oct 2015
Shoreline	Single Row	100	0	0
	Double Row	100	0	0
Cove	Hedge Row	100	100	50
Pond	Double Row	100	100	66
	Hedge Row	100	100	57
	Area	100	100	67

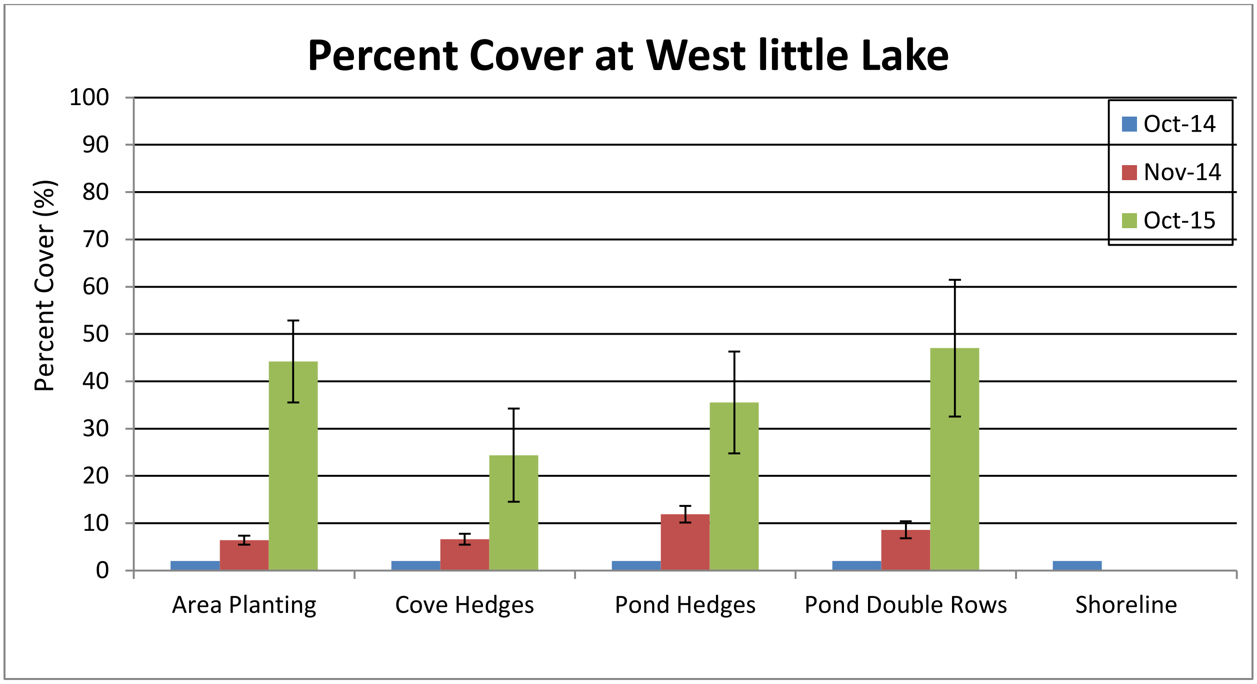


Figure VII-2. Percent cover measured from vegetation stations at LA-39 Year 2 West Little Lake from November 2014 – October 2015.

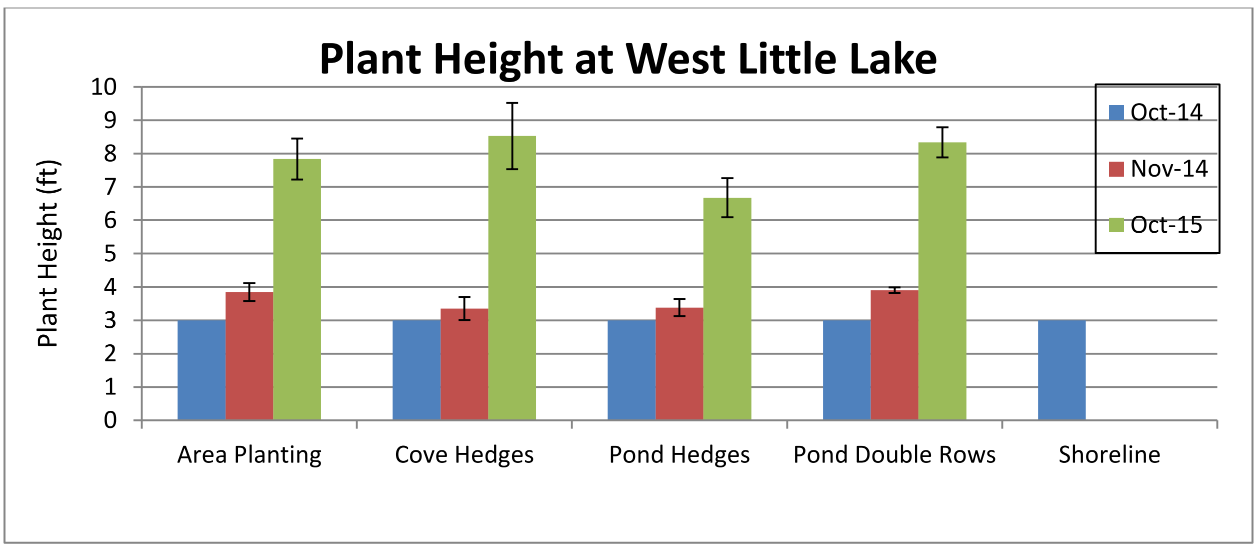


Figure VII-3. Stem heights collected from vegetation stations at LA-39 Year 2 West Little Lake from November 2014 – October 2015.

Shoreline Plantings

The shoreline plantings were destroyed or covered with wrack by the first monitoring visit (November 2014) resulting in a total loss of those plantings. No further data was collected.

Archival wind data from the National Oceanic and Atmospheric Administration's (NOAA) Center for Operational Oceanographic Products and Services (CO-OPS) database, indicates that several fronts pushed through this portion of coastal Louisiana between the time the plantings were installed in mid-October 2014 and the first data collection effort on November 10, 2014 (Fig. VII-4). Winds were predominately from the NNE and reached over 11 m/s (25 mi/hr) on several occasions. There were also several wind shifts from the SSE with equally strong winds. During this time, thick mats of floating aquatics toppled the newly planted vegetation and created conditions which did not allow the vegetation to become established. At the time of the first data collection effort, the shoreline sites 1 and 2 were devoid of plantings.

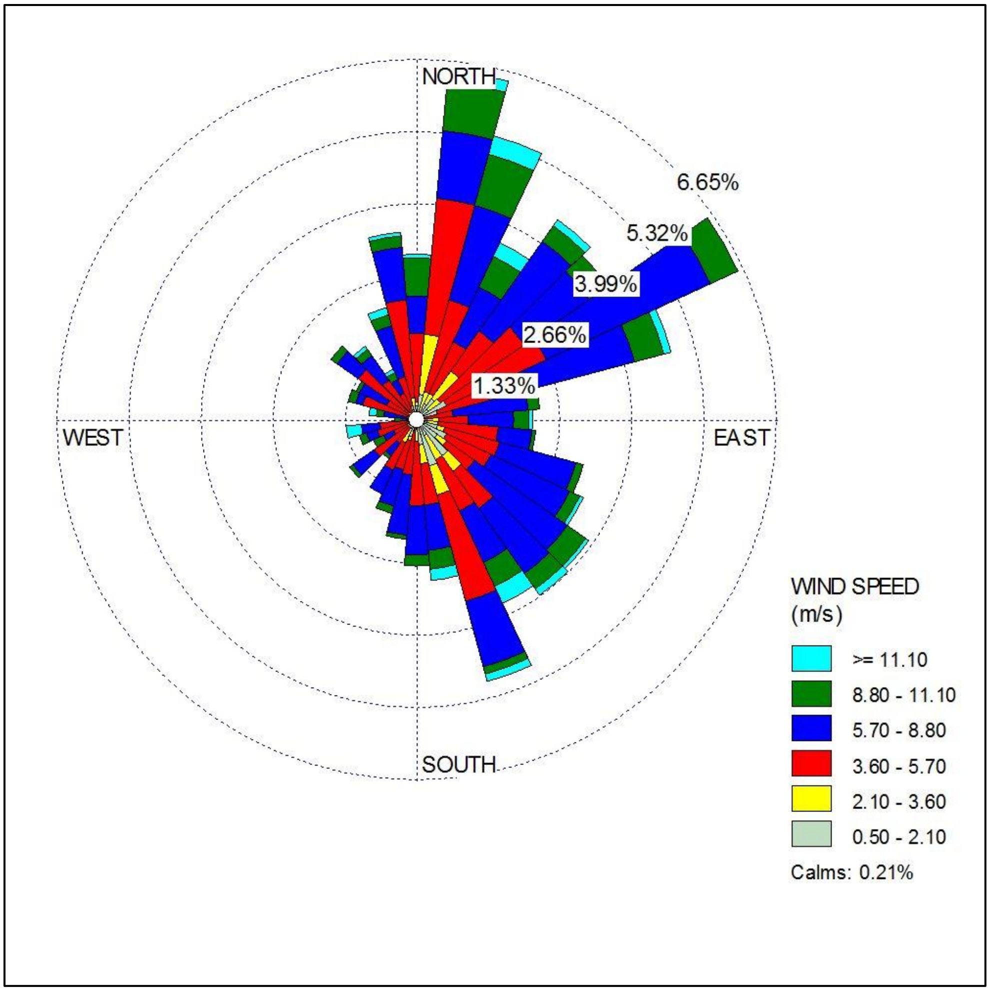


Figure VII-4. Wind rose data from NOAA's nearest CO-OPS station in Grand Isle, Louisiana. Wind history is from October 1, 2014 through November 30, 2014. The concentric rings are percentage classes which indicate the portion of time the winds occurred. The colored wedges indicate strength and direction of the winds.

Cove Hedge Row Plantings

During the first monitoring trip in November 2014, the plantings looked really healthy and were expanding; by the October 2015, remaining plantings looked healthy with continued growth (Fig. VII-5). At the vegetation station level, survival decreased by 50% (Table VII-2), while vegetative cover and stem height increased by 18% and 5.0 ft, respectively (Fig. VII-2 and 3).

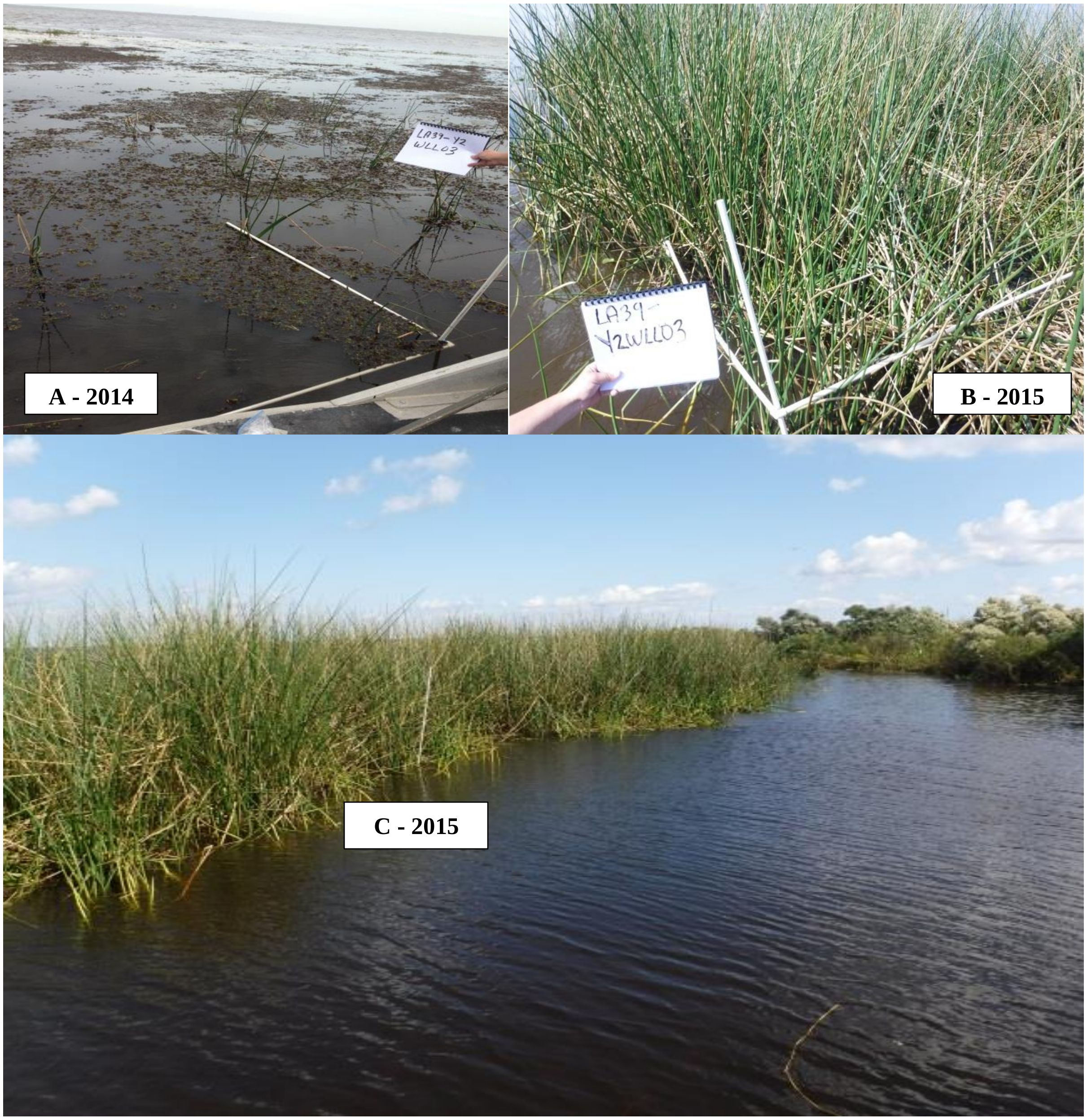


Figure VII-5. Example photographs of expansion of Cove Hedge Row plantings at the station level from November 2014 (A) to October2015 (B) and along a hedge row in October 2015 (C).

Pond Hedge Row Plantings

During the first monitoring trip in November 2014, the plantings looked really healthy and were expanding; by the October 2015, remaining plantings looked healthy with continued growth (Fig. VII-6). At the vegetation station level, survival decreased by 40% (Table VII-2), while vegetative cover and stem height increased by 24% and 3.3 ft, respectively (Fig. VII-2 and 3).

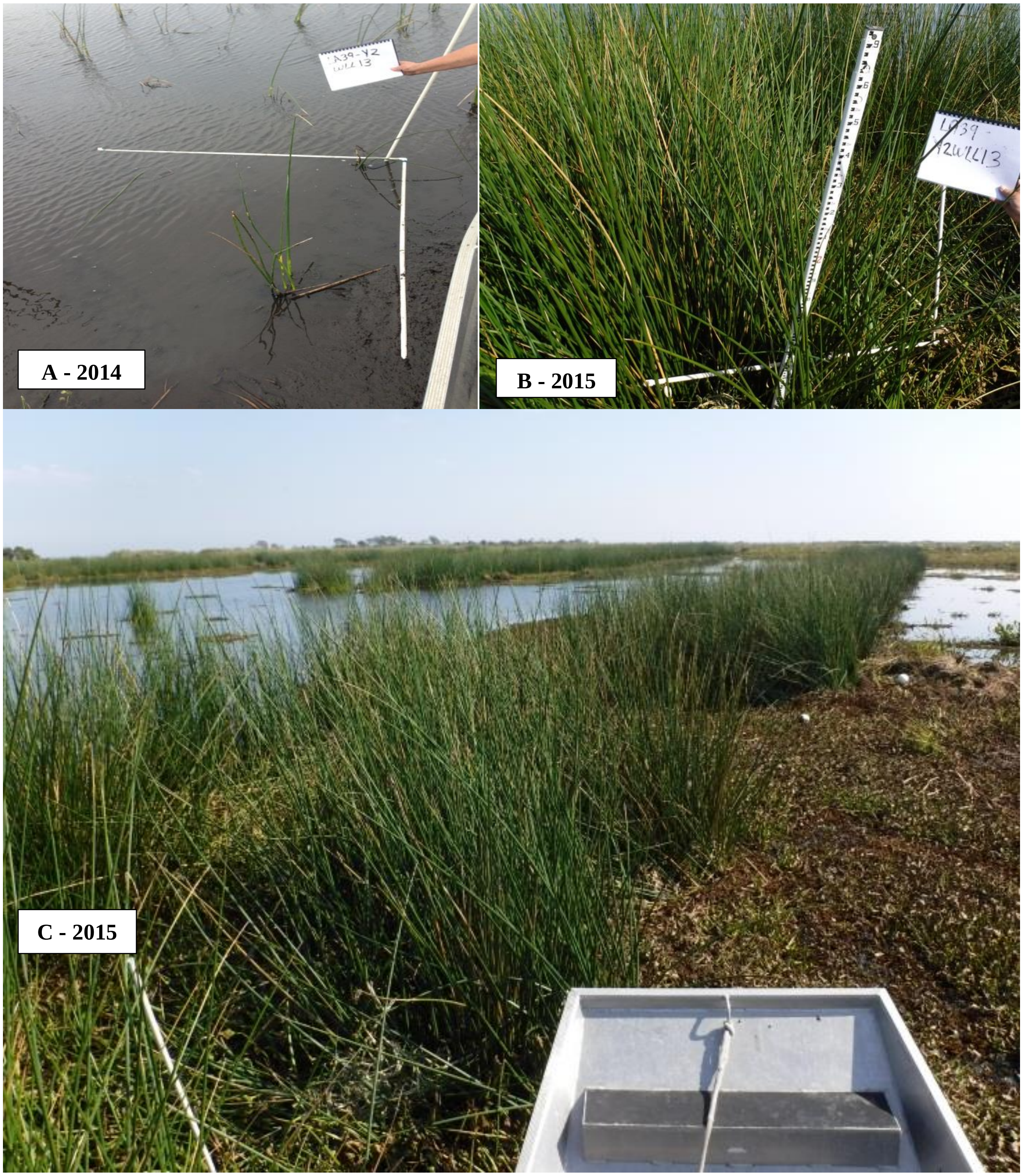


Figure VII-6. Example photographs of expansion of Pond Hedge Row plantings at the station level from November 2014 (A) to October2015 (B) and along a hedge row in October 2015 (C).

Pond Double Row Plantings

During the first monitoring trip in November 2014, the plantings looked really healthy and were expanding; by the October 2015, remaining plantings looked healthy with continued growth (Fig. VII-7). At the vegetation station level, survival decreased by 30% (Table VII-2), while vegetative cover and stem height increased by 38% and 4.4 ft, respectively (Fig. VII-2 and 3).

Figure VII-7. Example photographs of expansion of Pond Double Row plantings at the station level from November 2014 (A) to October2015 (B) and along double rows in October 2015 (C).

Pond Area Plantings

During the first monitoring trip in November 2014, the plantings looked really healthy and were expanding; by the October 2015, remaining plantings looked healthy with continued growth (Fig. VII-8). At the vegetation station level, survival decreased by 20% (Table VII-2), while vegetative cover and stem height increased by 38% and 4.0 ft, respectively (Fig. VII-2 and 3). The location of the stations along the perimeter of the area plantings underestimated survival and vegetative growth, as most of the interior space was occupied by large (10+ ft) California bulrush.

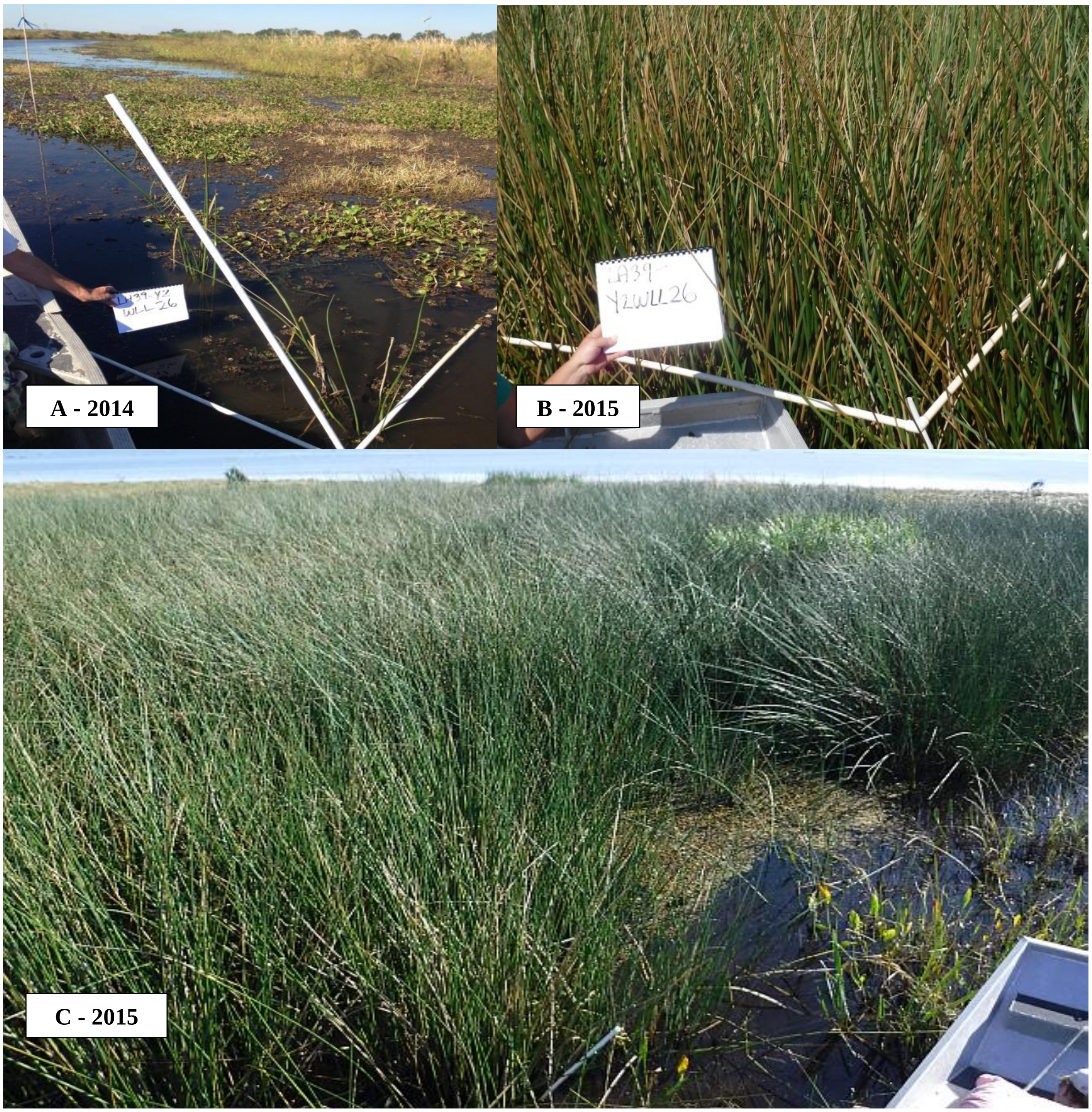


Figure VII-8. Example photographs of expansion of Pond Area plantings at the station level from November 2014 (A) to October2015 (B) and of an area planting in October 2015 (C).

b. Hydrology

Hydrologic data for the West Little Lake planting sites where obtained from CRMS4218. From September 2014 through the end of 2015, mean daily salinity at CRMS4281 was 1.9 ppt ± 0.1 SE (Fig. VII-9). *Schoenoplectus californicus* grows best in salinities between 0 – 6 ppt and can tolerate brief spikes of higher salinity (Materne and Fine 2000). The higher salinity event that occurred during the latter half of October through the beginning of November 2015, where salinities were briefly over 18 ppt was well over the reported tolerance levels for this species. The effects of the salinity pulse appeared to be minimal as it was short lived. Mean porewater salinity measured at CRMS4218 between 2014 and 2015 never reached above 3.0 ppt, within the favorable range for *S. californicus.* The porewater salinity values are an average of porewater salinity collected at 10 cm and 30 cm depth at CRMS4218.

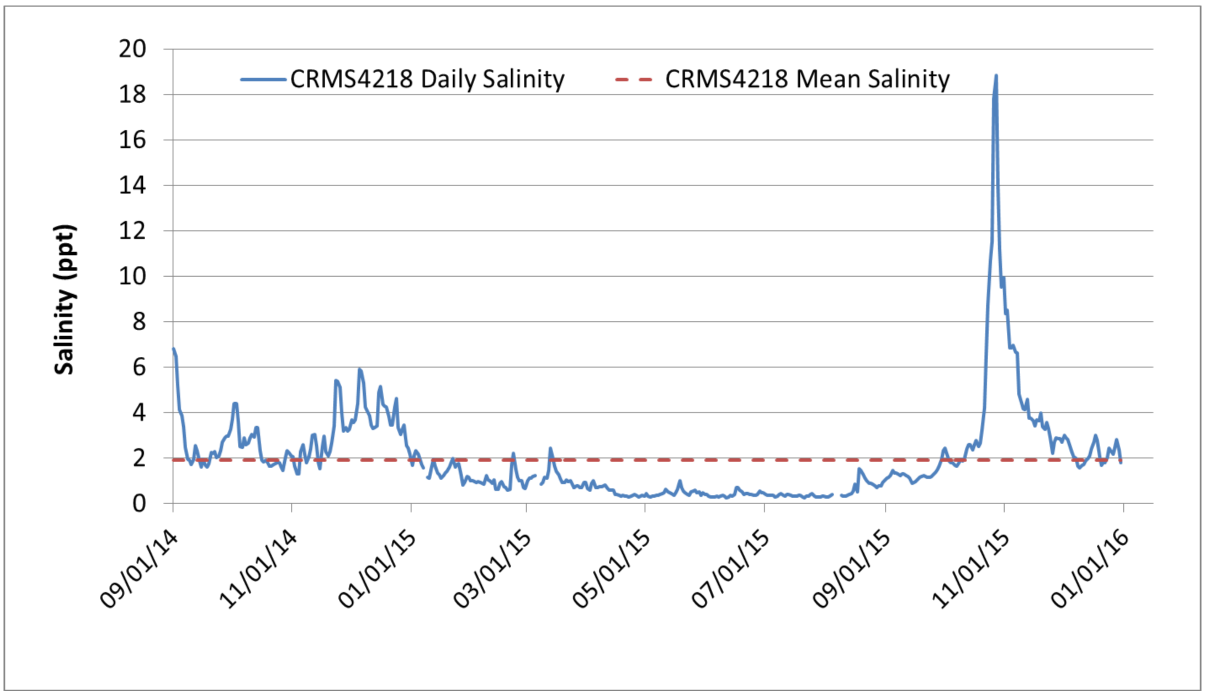


Figure VII-9. Daily and mean salinity measured at CRMS4218 near the project area.

The mean water elevation during 2014 and 2015 at CRMS4218 was +0.52 ft ± 0.02 SE (NAVD88, GEOID 12A) and ranged from a high of +2.6 ft to a low of -0.4 ft (Fig. VII-10). The same event that resulted in an increase of salinity also contributed to the increase in water elevation that occurred mid-October through November.

The plantings elevation was estimated by subtracting the water depth measured at each vegetation station during the survey, from the water elevation recorded at the corresponding time at CRMS4218. The estimated planting area elevation was calculated by averaging the elevation of all plants sampled within a planting area. The optimum water depth for establishment of *S. californicus* is reported as between 1 to 2 feet (Materne and Fine 2000). The estimated mean depth of inundation for the plants is within this range for the cove and pond plantings at 1.6 and 1.4 feet respectively.

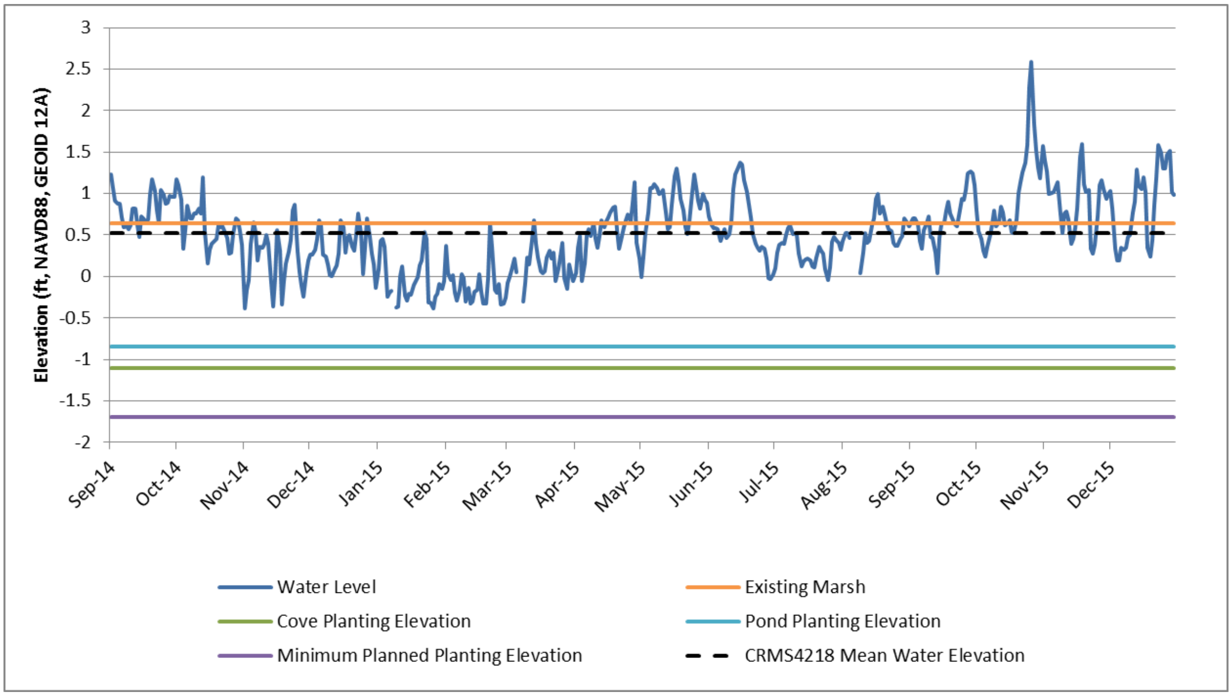


Figure VII-10. Mean daily and mean overall water elevation at CRMS4218, shown with the estimated elevation of the Cove and Pond planting area in West Little Lake.

c. Planting Failure/Success Causation

The shoreline plantings were destroyed by waves or covered with wrack within a month of installation; plantings along large water bodies are exposed to rough surf conditions and rafting by vegetation and/or debris. Most of the decrease in survival in other planting types was caused by floating aquatic vegetation (water hyacinth and giant Salvinia); the force from the floating aquatic mats being pushed by water is strong enough to topple well established California bulrush (Fig. VII-11 and 12).

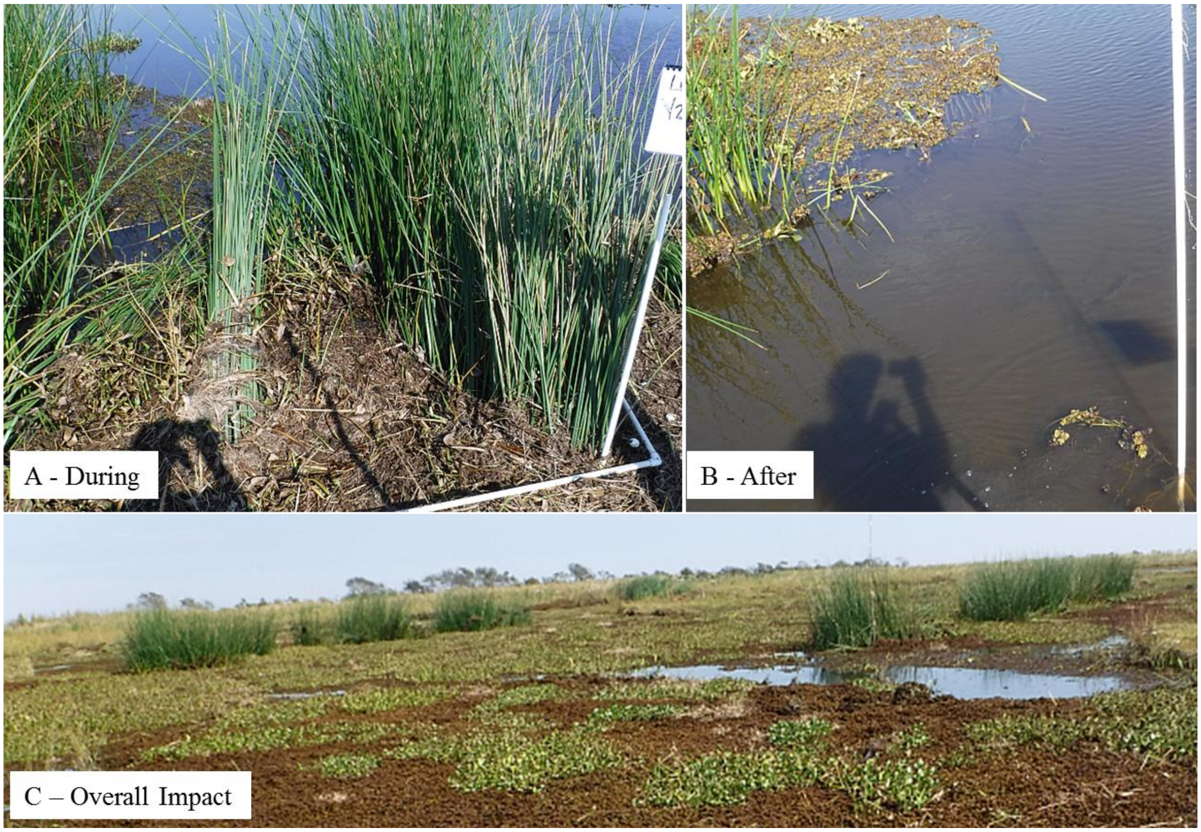


Figure VII-11. Progression of floating vegetation impacts on double row plantings.

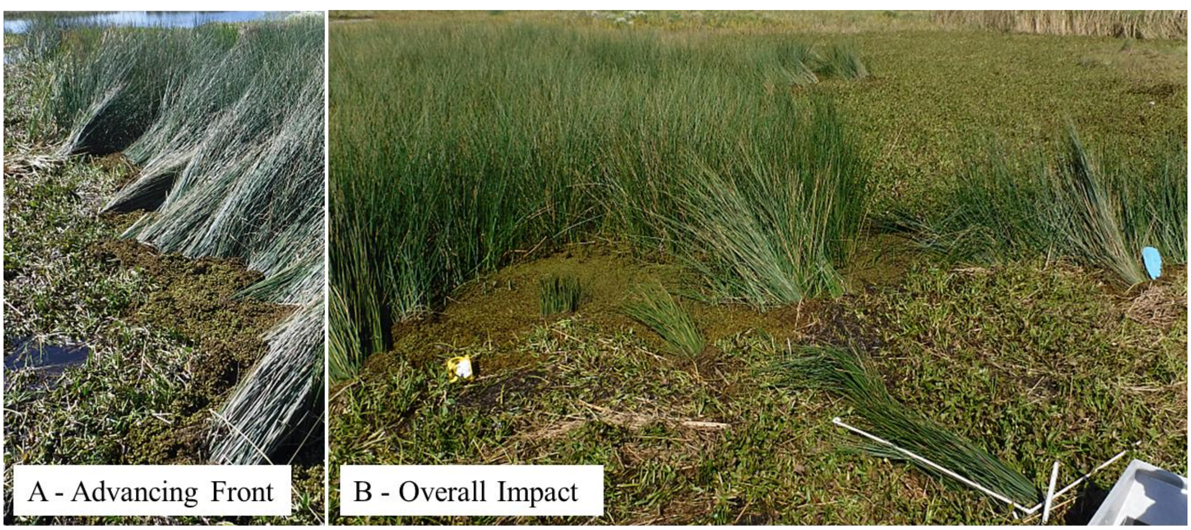


Figure VII-12. Progression of floating vegetation impacts on pond area plantings.

C. Conclusions

The first year of the Year 2 West Little Lake plantings are successful except for the shoreline plantings. Overall, all other planting types survived and expanded even though percent survival decreased. Decreases in survival were caused by damage from floating vegetation rather than physiological stress from poor planting conditions.

2. Project Effectiveness

As per the project goals:

- Shoreline plantings of smooth cordgrass and California bulrush did not survive to reinforce shorelines.
- Cove hedge row plantings of California bulrush did survive and expand within the coves along Little Lake shoreline.
- Double row plantings of California bulrush did survive and expand within the pond.
- Area plantings of California bulrush did survive and expand within the small ponds.

2. Recommended Improvements

Planting along exposed shoreline on a large water body with high wave energy coupled with large floating mats of vegetation should be avoided unless some other form of protection is provided.

3. Lessons Learned

Plantings along the exposed shoreline of a large water body is not advisable a stand-alone strategy. Planting in such areas could be used to compliment other restoration/conservation measures such as planting behind a shoreline protection measure.

Large stands of California bulrush were pushed over and smothered by floating vegetation composed mainly of giant Salvinia and water hyacinth. The occurrence of large mats of floating vegetation in recent years is attributable to recent mild winter temperatures. Planning for additional resources to be implemented for floating invasive species control may need to be considered.

VIII. Year 3 – The Jaws

Prepared by Bernard Wood – CPRA Lafayette Regional Office

A. Site and Planting Description

The Jaws, a Year 3 planting site for LA-0039, is located in St. Mary Parish, along the northeast shore of West Cote Blanche Bay in an area of confluence of several water bodies including the Charenton Canal, the Gulf Intercostal Waterway, West Cote Blanche Bay and several other smaller bayous collectively referred to as The Jaws. The approximate 100-acre project area is located within the northern portion of the Sediment Trapping at "The Jaws" (TV-0015) Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) project area, which is a set of delta splay terraces. This planting includes 23 linear hedgerows of *Schoenoplectus californicus* (California bulrush) (Fig. VIII-1 A and B). A total of 10,185 trade gallon *Schoenoplectus californicus* were planted in The Jaws by September 16th, 2014, with the final construction inspection occurring on October 25, 2014. The project area is divided into two primary areas, which are subdivided based on the proximity to the existing TV-0015 terrace field. The areas that were planted are categorized as shallow open-water habitat with some sparse emergent marsh and submerged aquatic vegetation. The dominant emergent vegetation present in the project area pre plantings was Zizaniopsis miliacea (giant cutgrass) and to a lesser extent Sagittaria platyphylla (delta arrowhead), combined covering less than 10% of the project area. The plantings are designed to establish perennial emergent vegetation in areas devoid of vegetation and/or in areas with sparse annual vegetation in order to increase water bottom friction to trap sediments. Increasing vegetation in this sediment rich environment should increase water bottom elevation and colonization of other emergent species to the area.

Northwest Plantings

Schoenoplectus californicus was planted in 14 double rows angled towards the northern TV-0015 terrace to the west of the main "delta" channel (Fig. VIII-1A). The Northwest plantings are protected by terraces. Within each double row, rows were spaced fifteen feet (15′) apart with plants on five-foot (5′) alternating centers. These plants were installed at elevations ranging from -0.3 to -1.1 ft NAVD GEOID 12A.

Northeast Plantings

Schoenoplectus californicus was planted in 9 double rows parallel to one another northeast of the TV-15 terraces on a subaqueous sediment deposit east of the main "delta" channel and west of Bayou Mascot (Fig. VIII-1B). The Northeast plantings are not protected by terraces. Within each double row, rows were spaced fifteen feet (15′) apart with plants on five-foot (5′) alternating centers. These plants were installed at elevations ranging from -0.7 to -1.1 ft NAVD GEOID 12A.

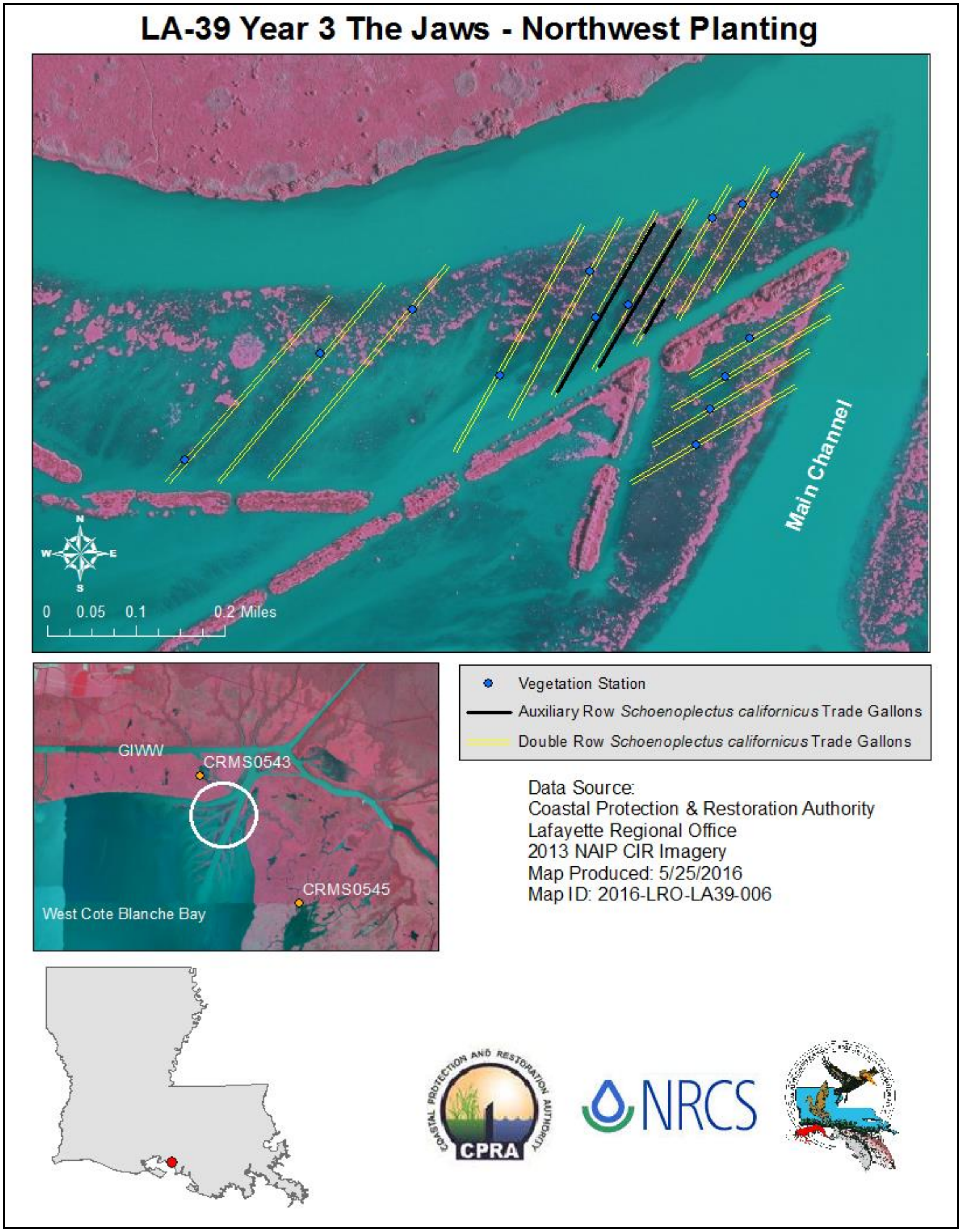


Figure VIII-1a. LA-39 Year 3 Site – The Jaws Northwest Plantings site map showing location of plantings and vegetative monitoring stations.

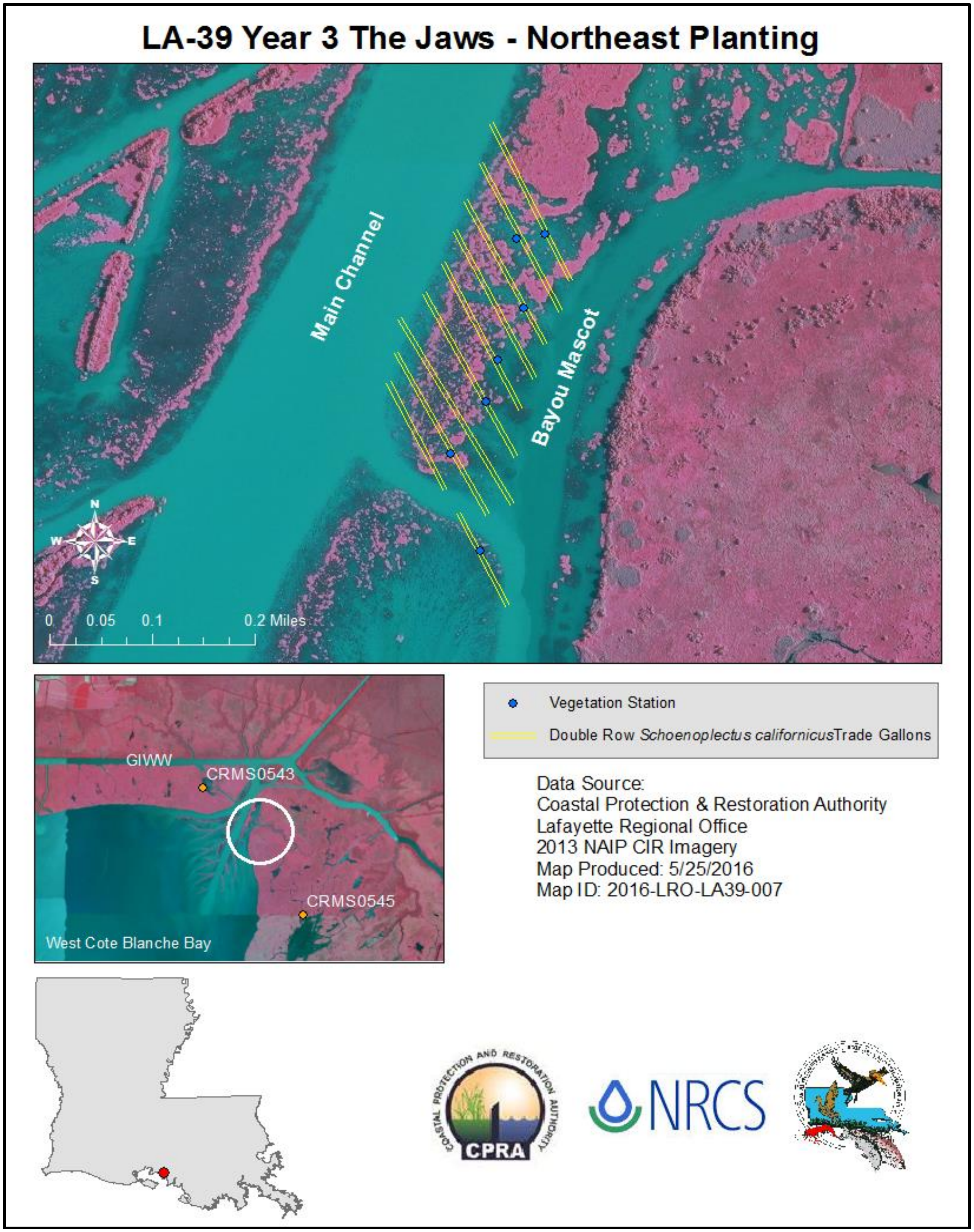


Figure VIII-1b. LA-39 Year 3 Site – The Jaws Northeast Plantings site map showing location of plantings and vegetative monitoring stations.

B. Monitoring Activity

1. Monitoring Goals

Year 3 The Jaws plantings were designed to create thick, robust hedgerows of *Schoenoplectus californicus* along pre-existing sediment flats both within and adjacent to the TV-0015 project terraces to enhance the sediment deposition and natural recruitment of volunteer species.

The goals of The Jaws plantings are:

- Northwest double row plantings in the tidal flats in and around the TV-15 terraces will survive and expand.
- Northeast double row plantings in the tidal flats east of the TV-15 terraces will survive and expand.
- Survival of the planted *Schoenoplectus californicus* (California bulrush) trade-gallons will exceed 50%.
- Recruit new emergent marsh species to the tidal flats in and around The Jaws.

2. Monitoring Elements

The monitoring elements include procedures to assess plant survival and effects on the planting area for the project plantings and the recruitment of any other emergent marsh vegetation to the area. Vegetation stations were intended to monitor planting survival and vegetative cover representative of the double row plantings within The Jaws project area over time.

Table 1. Sampling scheduled for LA-39 Year 3 site, The Jaws.

Sampling Type	T_0 2014	T_1 2014	T_2 2015	T_3 2017	T_4 2019	T_5 2024
Planting Survival	Sept	Nov	Sept	Fall	Fall	Fall
Percent Cover	Sept	Nov	Sept	Fall	Fall	Fall

<u>**Vegetation Assessment**</u>

To assess planting status, an ocular estimate of % survival and plant condition was conducted for each double row. Planting survival and % vegetative cover data was also collected at the vegetation station level; 21 vegetation stations were established randomly along the double rows. Percent survival was calculated from 10 plants (5 plants per row) at each vegetation station; plants were characterized as live or dead/absent. PVC poles were placed on both ends of the plants monitored for survival. Vegetative condition was assessed by measuring percent cover of species present, vegetative stand height, and height of dominant species in a 4 m^2 plot at each vegetation station (Folse et al. 2014). Flooding depth, surface water salinity, temperature, and, when possible, porewater salinity and temperature were also collected at all sampling stations during each sampling event. Conditions occurring outside of the stations and segments including additional species, marsh interspersion, and site-specific points of interest were noted along with photo documentation.

Northwest plantings: Fourteen stations were established along the double rows planted within the northern tidal flats surrounding the beginning of the TV-15 terrace field.

Northeast plantings: Seven stations were established along the double rows planted within the tidal flats east the main channel through the center of the TV-15 terrace field.

Hydrology

Water level elevations from nearby CRMS sites (CRMS0543 and CRMS0545) were used to convert water depth (ft) at vegetation stations to estimated planting elevations (ft, NAVD88 Geoid 12A). The water elevations and estimated planting elevations were then used to create a water-level hydrograph depicting flood levels, duration, and frequency.

Planting Failure/Success Causation

If significant loss of plants in The Jaws planting area occurs, suspected causes (soil conditions, hydrologic conditions, planting removal) will be investigated.

3. Monitoring Results and Discussion

a. Vegetative Assessment

Overall the plantings in the vegetation stations at The Jaws LA-39 planting location were performing exceptionally well, with survival rates over 90% as of the Sept 2015 sampling (Table VIII-2). The percent cover of the sample plots had increased from near 3% per sampling plot to 25-35% over a year (Figs. VIII-2, 3, and 4). This trajectory was expected to continue and as the plants became more established other emergent marsh species would likely recruit to the area; however, anecdotal evidence suggests as of summer 2016 and spring 2017 this has not been the case. The plantings have regressed and the naturally occurring marsh species have expanded extensively, this is all observational data at this point, as no numerical data will be collected until fall 2017. The project area filled in with floating aquatic vegetation in 2015 likely due to the resistance provided by the hedgerows of *Schoenoplectus californicus* stopping the rafts of *Eichhornia crassipes* (water hyacinth) from floating out into West Cote Blanche Bay (Fig. VIII-4). Along with the floating aquatic vegetation, pioneer emergent marsh species started to appear, though many of these species appeared to be anchored in the floating vegetation and not rooted to the soil beneath (Figs. VIII-5 and 6). Although the plantings expanded greatly in both locations, the NE area percent cover was greater than the NW area plantings. This was likely due to the NE area having a more robust existing marsh platform with a higher percentage of preexisting emergent marsh cover, while the NW area was planted in a more open water environment. Stem heights also increased dramatically from planting through September 2015, almost tripling in the NE area while almost doubling in the NW locations (Fig. VIII-7). The difference in planting heights between the two locations is likely due to the same mechanisms effecting percent cover.

Table VIII-2. Overall % survival of vegetation stations at LA-39 Year 3 The Jaws Northwest (NW) and Northeast (NE) tidal flat plantings of California bulrush trade gallons.

	% Overall Survival			
Areas	Number of Plants Sampled	T_0 Sept 2014	T_1 Nov 2014	T_2 Sept 2015
NW	140	100	100	93
NE	70	100	100	94

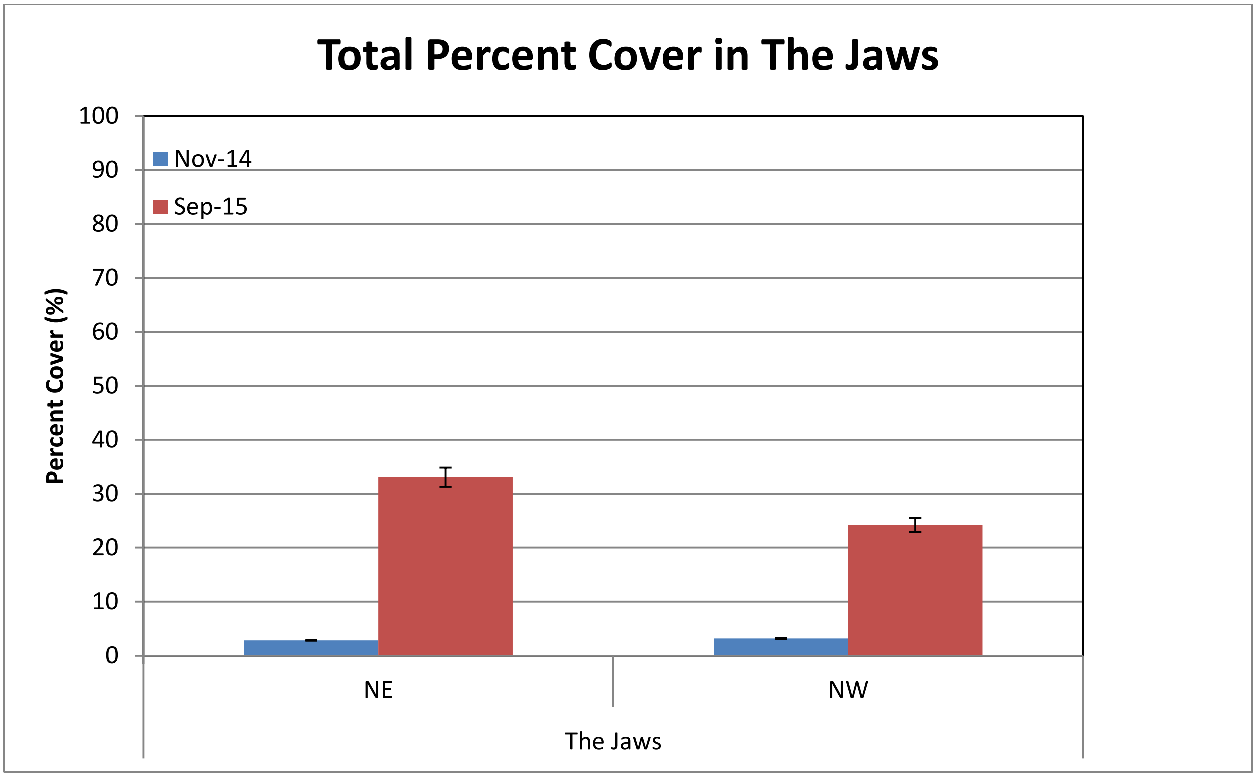


Figure VIII-2. The percent cover of emergent vegetation in the sample plots at The Jaws LA-39 planting location over time; percent cover increased by an order of magnitude in one year.

Figure VIII-3. Typical veiw of a double row planting at LA-39 Year 3 The Jaws in Nov 2014.

Figure VIII-4. Typical veiw of a double row plantings at The Jaws LA-39 just prior to the Sept 2015 sampling.

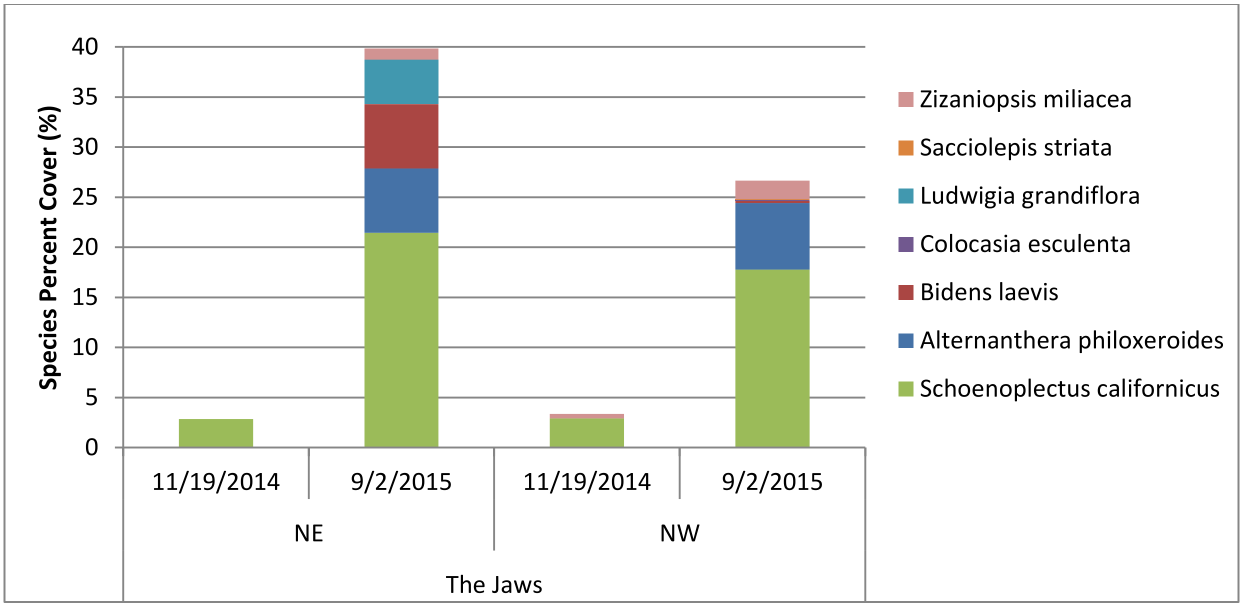


Figure VIII-5. The species specific percent cover of emergent vegetation in the planting transects at The Jaws LA-39 planting location over time as other emergent species begain recruting to the planting locations.

Figure VIII-6. Recruited species growing in and among the double row plantings during 2015 sampling including *Alternanthera philoxeroides* and *Zizaniopsis miliacea*.

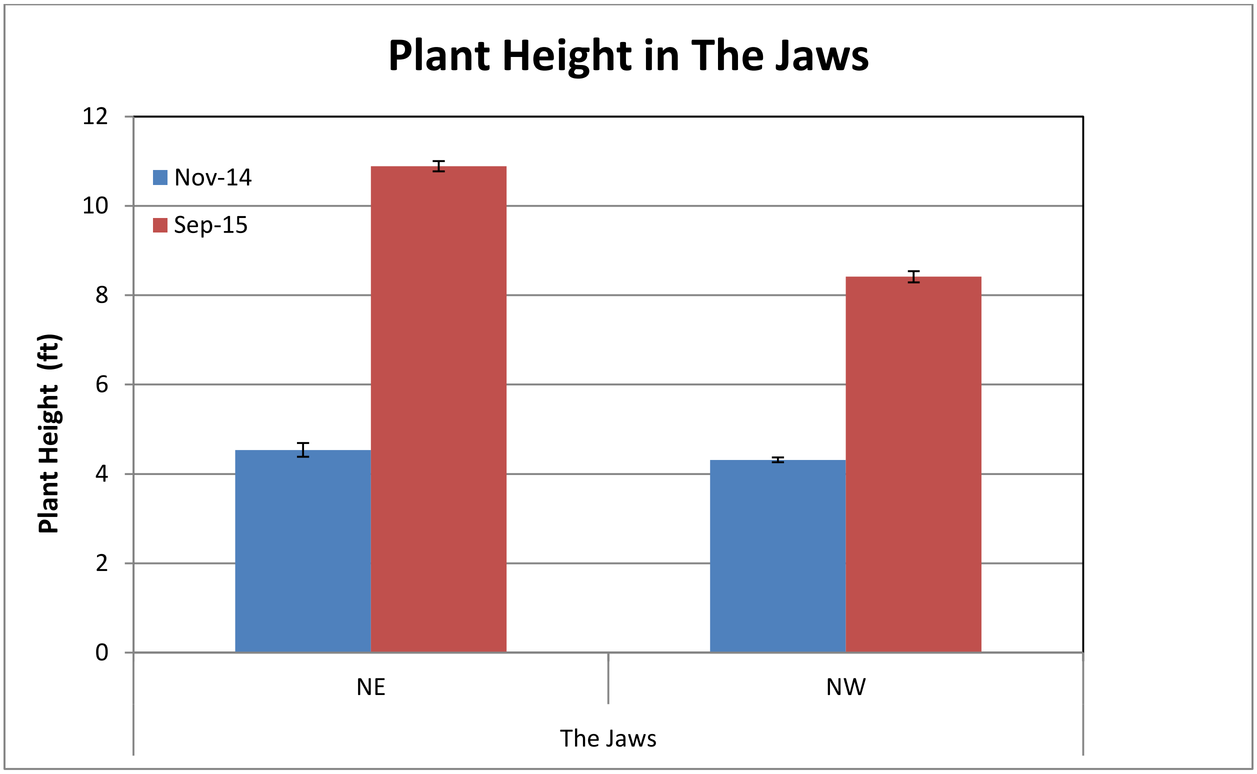


Figure VIII-7. The average height of emergent vegetation in the double row plantings at The Jaws LA-39 planting location over time; average height more than doubled in one year.

b. Hydrology

The water level in the planting area is generally quite deep, but as the plantings mature sedimentation may increase allowing for the addition of other species that thrive in deeper flood regimes to become established (Fig. VIII-8). The optimum water depth for establishment of *S. californicus* is reported as between 1 to 2 feet (Materne and Fine 2000). Water depth within this range was the standard in the project area during 2015 only routinely exceeding the 2 foot depth threshold during the winter while the plants were typically dormant.

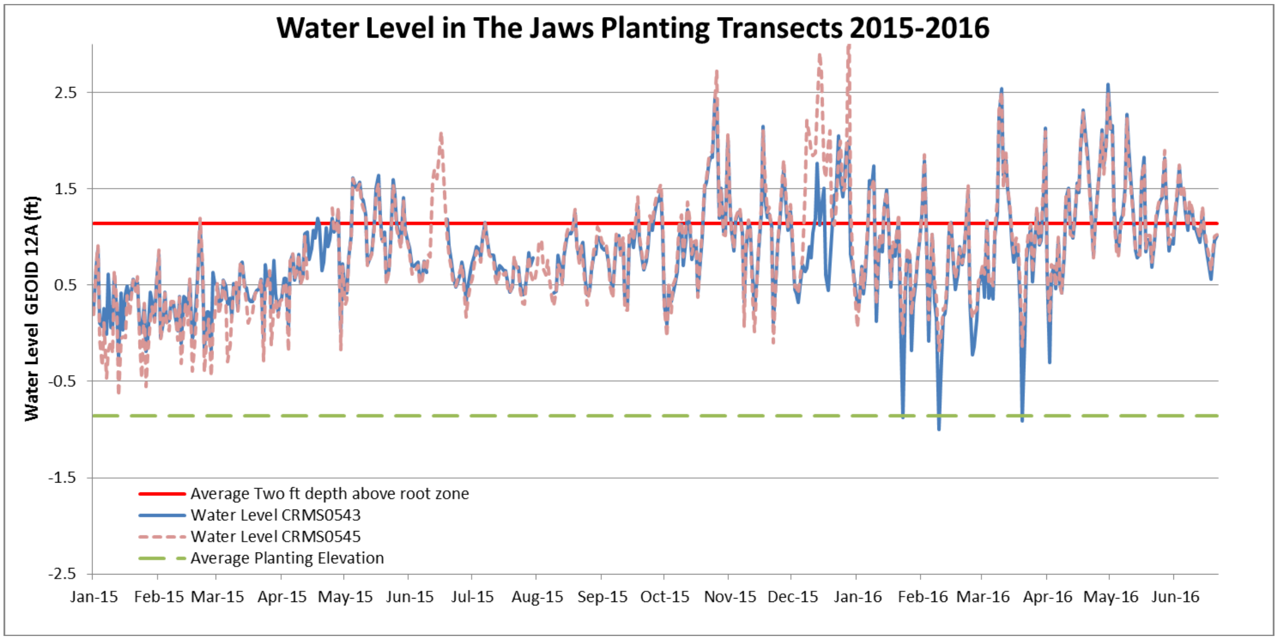


Figure VIII-8. Hydrograph of nearby CRMS sites displaying water levels and averaged planting depth for both the NW and NE planting areas in the LA-39 The Jaws during 2015 and 2016.

c. Planting Failure/Success Causation

No significant loss of plants in The Jaws planting area was observed through the first year of the planting. The one area of systemic plant failure was the southernmost double row of the NW area, just west of the main canal through the project area. The channel side row of this double row was unprotected by terraces or other plantings and suffered some mortality due to boat wake and wave energy causing rafting of *Eichhornia crassipes* (water hyacinth). The only other plant loss was isolated and random, possibly due to poor plant health at the time of planting or isolated poor environmental conditions.

The project area plantings looked very different as of both the spring and summer of 2016 in brief ocular inspections. The anecdotal evidence suggests that both percent survival and percent cover were substantially lower. Originally the spring observations were thought to be due to extensive wave activity, elevated water level, and still senesced vegetation from the winter. However the pattern of reduced survival and cover appeared to still be in place as of August 2016. This observation coincided with the apparent expansion of *Zizaniopsis miliacea* (giant cutgrass), *Sagittaria platyphylla* (delta arrowhead), and *Nelumbo lutea* (American lotus); along with multiple species of submerged aquatic vegetation (SAV). The dominant SAV species *Ceratophyllum demersum* (Coontail) and Vallisneria americana (American eelgrass) were intermixed with the naturally occurring and planted emergent marsh species. The next empirical data collection trip is scheduled for September of 2017 and will help to determine the extent of the reduction in planted California bulrush and expansion of other species of emergent marsh.

C. Conclusions

3. Project Effectiveness

As per the project goals through September 2015:

- Plantings in the tidal flats in and around the TV-15 terraces were successful, with survivorship of plantings near 95% and total vegetative cover increasing to ~33% one year after planting.
- Plantings in the tidal flats east of the TV-15 terraces were successful, with survivorship of plantings near 95% and total vegetative cover increasing to ~25% one year after planting.
- Planting survival of near 100% easily meets the 50% survival goal of the *Schoenoplectus californicus* trade gallons plantings.
- The recruitment of new emergent plants to the area has been successful though modest to this point in the project life; however, it is expected to accelerate in the future as water depth decreases.

2. Recommended Improvements

Some dense area plantings in the project may offer expedited recruitment of other emergent marsh species by offering greater protection and elevation at the interior of such plantings compared to the double row plantings.

3. Lessons Learned

The linear hedgerow plantings offered enough support and reduced the energy of the system such that a dense growth of *Eichhornia crassipes* formed in the project area. This *Eichhornia crassipes* added to the reduction of flow and some interior openings in the floating vegetation were extremely clear and filled with various SAV species. While SAV was seen in the area pre planting, the quantity and variety was more impressive post planting; also, to now have pockets of high light penetration in this muddy, sediment rich environment was remarkable. This is further evidence that additional sediments are falling out of suspension as the three dimensional structure of the area increases via the planting and recruitment.

Large stands of California bulrush were destroyed after becoming well established via physical damage by floating vegetation composed mainly of water hyacinth driven by wave action. The occurrence of large mats of floating vegetation in recent years is attributable to recent mild winter temperatures and fresh conditions. Planning for additional resources to be implemented for floating invasive species control may need to be considered.

IX. Year 3 – Little Vermillion Bay

Prepared by Bernard Wood – CPRA Lafayette Regional Office

A. Site and Planting Description

Little Vermilion Bay (LVB), a Year 3 planting site for the Coastwide Planting project (LA-0039), is located in two terrace fields in Vermilion Parish. Both areas are within Coastal Wetlands Planning, Protection and Restoration Act (CWPPRA) project areas designed to trap sediments at the confluences of multiple water bodies including the Vermillion River, the Gulf Intercostal Waterway (GIWW), Freshwater Bayou Canal (FBC), and Vermilion Bay proper. Both terrace projects have succeeded in creating mudflats between and around the constructed terraces. The eastern planting area is within the ~250 acre terrace field of the Four Mile Canal Terracing and Sediment Trapping project (TV-18) located along the western shore of the Vermilion River Cutoff Canal (VRCC), also known as Four Mile Canal, (Thibodeaux and Aucoin 2008) (Fig. IX-1). The western planting area is interspersed within the western side of approximately 200 acres of the Little Vermilion Bay Sediment Trapping (TV-12) project terraces between FBC and Little Vermilion Bay (LVB) (Wood and Aucoin 2016) (Fig. IX-2).

A combined total of 26,285 trade gallons of *Schoenoplectus californicus* (California bulrush) were planted in the east and west planting locations by September 25th, 2014, with the final construction inspection occurring on September 26th, 2014. These plantings included 14 double row and 4 area plantings of *Schoenoplectus californicus* in the east and west planting locations along with a few auxiliary rows. The areas that were planted are categorized as intertidal mudflat habitat and shallow open water. The double row plantings were designed to create thick, robust hedgerows and dense areas of *Schoenoplectus californicus* along preexisting sediment flats within both the TV-12 and TV-18 project terraces to enhance the sediment deposition and natural recruitment of volunteer species to the area. The dominant emergent vegetation present in the TV-18 project area (East) pre plantings was *Typha domingensis* (southern cattail) and to a lesser extent Sagittaria lancifolia (bulltongue arrowhead), combined covering less than 10% of the project area. The dominant emergent vegetation present in the TV-12 project area (West) pre plantings was *Schoenoplectus californicus* (California bulrush), *Spartina alterniflora* (smooth cordgrass) and to a lesser extent Sagittaria lancifolia (bulltongue arrowhead), combined covering less than 20% of the project area. The existing *Schoenoplectus californicus* and *Spartina alterniflora* vegetation in the western area were previously planted as part of the TV-12 project construction and as a small but ongoing effort by the Vermilion Soil and Water Conservation District office (SWCD). The plantings are designed to establish perennial emergent vegetation in areas devoid of vegetation and/or in areas with sparse annual vegetation in order increase water bottom friction to trap sediments. Increasing vegetation in this sediment rich environment should increase water bottom elevation and the colonization of other emergent species to the area along with the survival and expansion of the *Schoenoplectus californicus*.

East Plantings

Nine (9) double rows of *Schoenoplectus californicus* were planted in parallel rows fifteen feet (15′) apart with plants on five-foot (5′) alternating centers. The nine double rows ran primarily north to south and diagonally across shallow open water within TV-18 terrace cells. These plants were installed at elevations ranging from -0.3 ft to -1.6 ft, with an average elevation of -0.76 ft NAVD GEOID 12A. Excess plants were placed along two of the double rows for an East area total of 2,756 *Schoenoplectus californicus* trade-gallon sized plants (Fig. IX-1).

West Plantings

Schoenoplectus californicus was planted in five (5) double rows consisting of parallel rows fifteen feet (15′) apart with plants on five-foot (5′) alternating centers and in four (4) area plantings in parallel rows five feet (5′) apart with plants on five-foot (5′) alternating centers. The double row (1,474 plants) and area (22,054) planting alignments were parallel to the project terraces on the western side of the TV-12 project areas. These plants were installed at elevations ranging from -0.2 ft to -1.6 ft with an average elevation of -0.68 ft NAVD GEOID 12A. Excess plants were placed along the northernmost double row for a West area total of 23,529 *Schoenoplectus californicus* trade-gallon sized plants (Fig. IX-2).

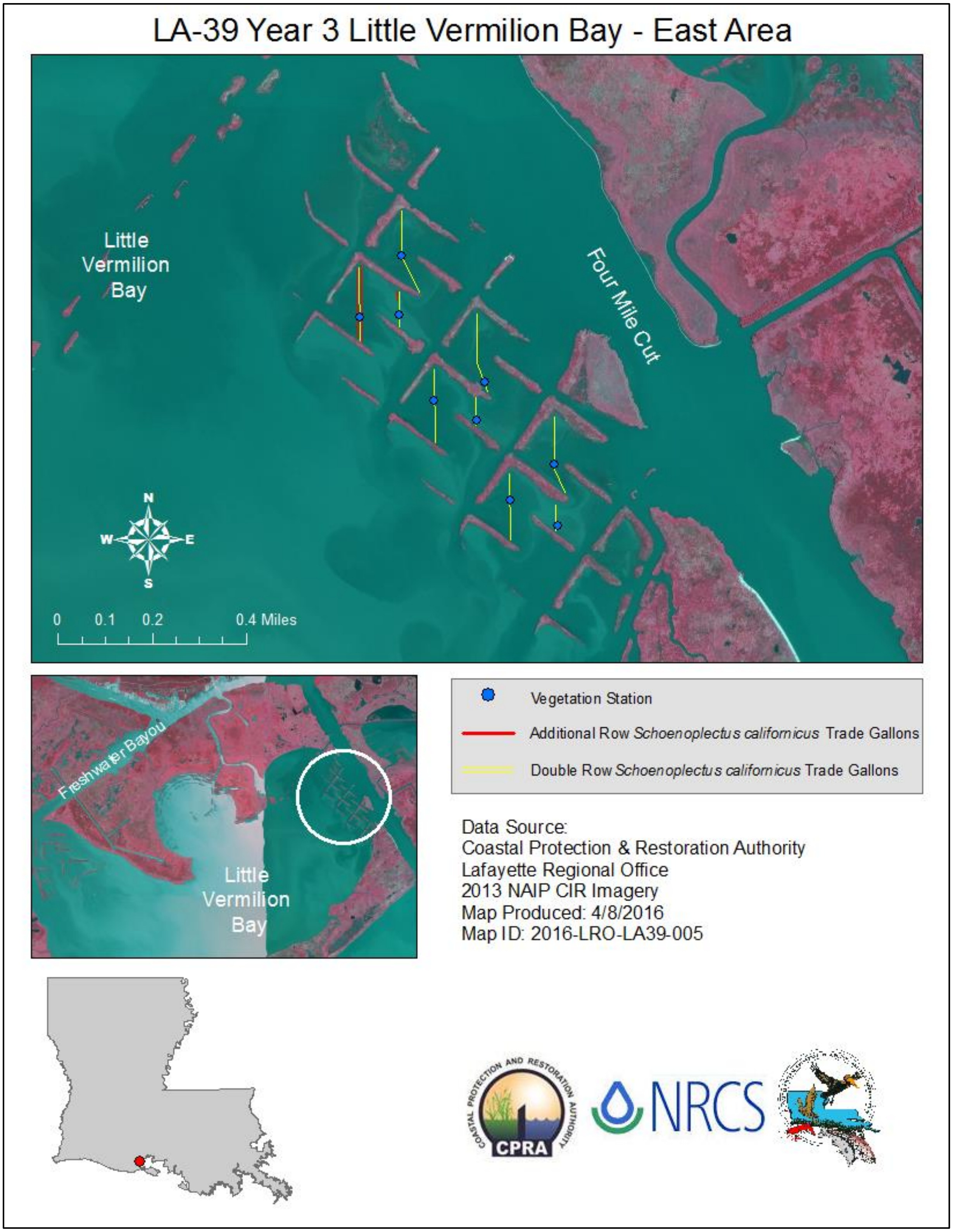


Figure IX-1. LA-39 Year 3 Site – The TV-18 East Plantings site map showing location of plantings and vegetative monitoring stations.

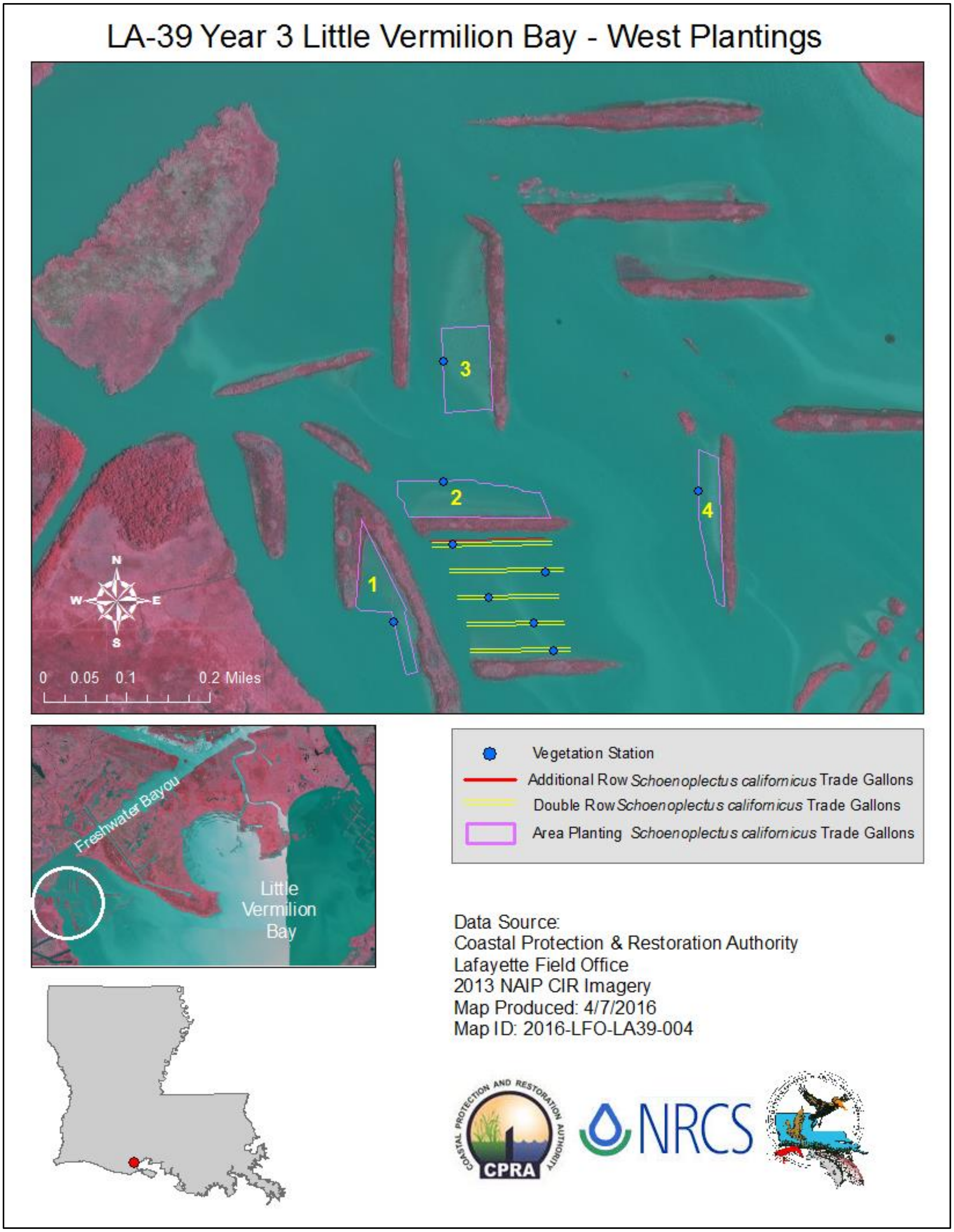


Figure IX-2. LA-39 Year 3 Site – The TV-12 West Plantings site map showing location of plantings and vegetative monitoring stations.

B. Monitoring Activity

1. Monitoring Goals

The LA-0039 Year 3 LVB plantings were designed to create thick, robust hedgerows and dense areas of *Schoenoplectus californicus* along preexisting sediment flats within both the TV-12 and TV-18 project terraces to enhance the sediment deposition and natural recruitment of volunteer species to the area.

The goals of the LVB plantings are:

- East Double Row plantings exceed 50% survival and moderately expand between terraces.
- West Double Rows plantings exceed 50% survival and moderately expand between terraces.
- West Area plantings exceed 50% survival and moderately expand among the grid area plantings.
- Recruit new emergent marsh species to the tidal flats in and around TV-12 and TV-18 plantings.

2. Monitoring Elements

The monitoring elements include procedures to assess plant survival and effects on the planting area for the project plantings and the recruitment of any other emergent marsh vegetation to the area. Vegetation stations were intended to monitor planting survival and vegetative cover representative of the double row and area plantings within the LVB project area over time.

Table IX-1. Sampling scheduled for LA-39 Year 3 site, LVB.

Sampling Type	T_0 2014	T_1 2014	T_2 2015	T_3 2017	T_4 2019	T_5 2024
Planting Survival	Sept	Nov	Oct	Fall	Fall	Fall
Percent Cover	Sept	Nov	Oct	Fall	Fall	Fall

<u>**Vegetation Assessment**</u>

To assess planting status, an ocular estimate of percent survival and plant condition was conducted for each reach, segment, and/or row. Planting survival and percent vegetative cover data was also collected at the vegetation station level; stations were established randomly among live plants. Percent survival was calculated from a set number of plants at each vegetation station; plants were characterized as live or dead/absent. PVC poles were placed on both ends of the plants monitored for survival. Percent cover of species present, vegetative stand height, and height of dominant species were measured in 4 m^2 vegetation stations (Folse et al. 2014). Flooding depth, surface water salinity and temperature, and when possible porewater salinity and temperature were also collected at all sampling stations during each sampling event. Conditions occurring outside of the stations and segments including additional species, marsh interspersion, and site-specific points of interest were noted along with photo documentation. Nearby project-specific sondes or CRMS sites (CRMS2041) were used to convert water depth (ft) to estimated planting elevations (ft, NAVD88 Geoid 12A). One vegetation station was located in each double row and along the perimeter of each area planting.

East plantings: Nine stations were established along the double rows planted within shallow open water and tidal mudflats surrounding the interior terraces of the TV-18 terrace field. Percent survival of 10 plants per station, % cover data, and height were recorded at each station.

West plantings: Five double row stations and 4 area stations were established along the double rows and area plantings within shallow open water and tidal mudflats surrounding the interior terraces of the TV-12 terrace field. Percent survival of 10 plants per station, % cover data, and height were recorded at each station.

Hydrology

Water-level elevations from the nearby site CRMS2041, located between the West and East areas were used to convert water depth (ft) at vegetation stations to estimated planting elevations (ft, NAVD88 Geoid 12A). The water elevations and estimated planting elevations were then used to create a water-level hydrograph depicting flood levels, duration, and frequency.

3. Monitoring Results and Discussion

a. Vegetative Assessment

Overall, the plantings in the LVB LA-39 west planting location have performed exceptionally well, with a survival rate of 100% as of the most recent sampling (Table IX-2). The LVB LA-39 east planting location has performed well below its counterpart due to herbivory, with a survival rate of 66.7% (Fig. IX-3). However percent cover of the east sample plots has still increased from near 3% per sampling plot to just over 25% over the course of one year (Fig. IX-4). Stem heights also increased dramatically from initial planting through October 2015, doubling in the eastern area while more than doubling in the western locations (Fig. IX-5). The difference in planting heights between the two locations is due to herbivory effecting percent cover and height as several plots which received zeros for these variables when no vegetation remained. This effect is noticeable in the error bars of the second sampling period showing a lack of consistent heights during the 2015 sampling in the eastern area. The west sample plot's cover has increased dramatically from near 3% at T_1 to just over 70% at T_2 a year later (Fig. IX-4). This trajectory is expected to continue, and as the plants become more established other emergent marsh species will likely recruit to the area. The project area remained mostly a *Schoenoplectus californicus* monoculture in 2015 likely due to the variable salinity that prevents fresh emergent vegetation as well as floating aquatics from gaining a foothold in the project area (Fig. IX-6 and 7). Some of the double row plantings were actually experiencing significant intraspecific competition at the end of one growing season (Fig. IX-8). The water level in the planting area is generally relatively deep and variable but as the plantings mature, sedimentation and accretion due to friction and below ground organic production may increase allowing for the addition of other species that thrive in intermediate salinity regimes and deeper waters to become established.

Table IX-2. Overall % survival of LA-39 Year 3 Little Vermilion Bay East and West plantings of California bulrush trade gallons.

		% Overall Survival			
LVB	Areas	Number of Plants Sampled	T_0 Sept 2014	T_1 Nov 2014	T_2 Oct 2015
	East	90	100	98	67
	West	90	100	100	100

Figure IX-3. Veiw of minor herbivory damage in the LVB east LA-39 area at T_2.

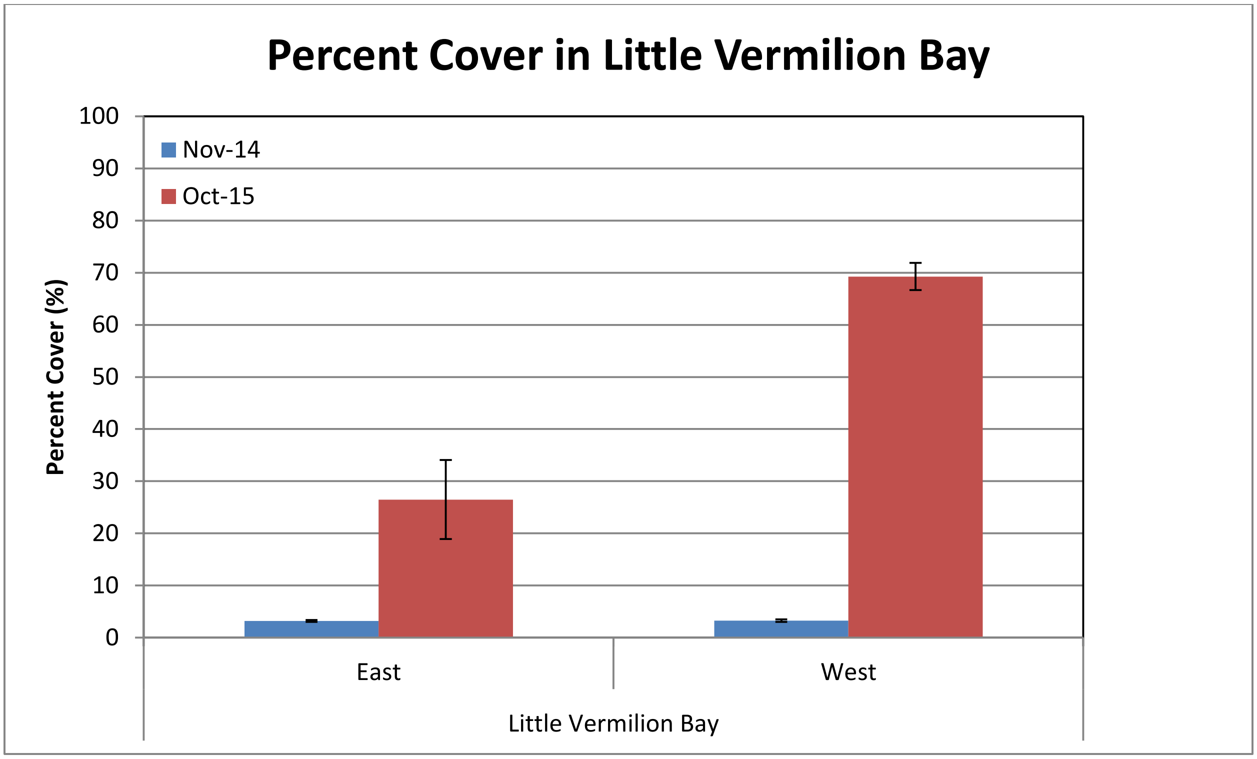


Figure IX-4. The percent cover of emergent vegetation in the planting transects at LVB LA-39 planting location over time, percent cover increased by an order of magnitude in one year.

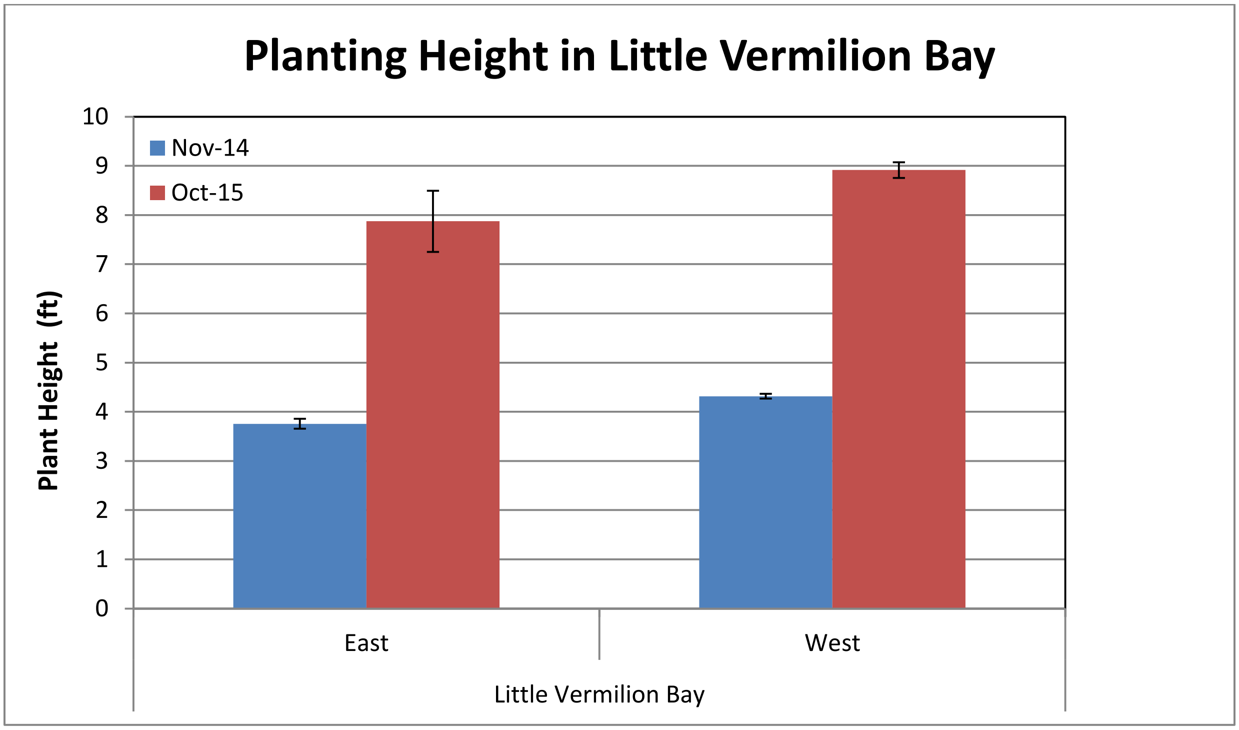


Figure IX-5. The average height of emergent vegetation in the double row and area plantings at LVB LA-39 planting location over time; average height more than doubled in one year.

Figure IX-6. Typical veiw of a LA-39 LVB west area planting at low tide during Nov 2014.

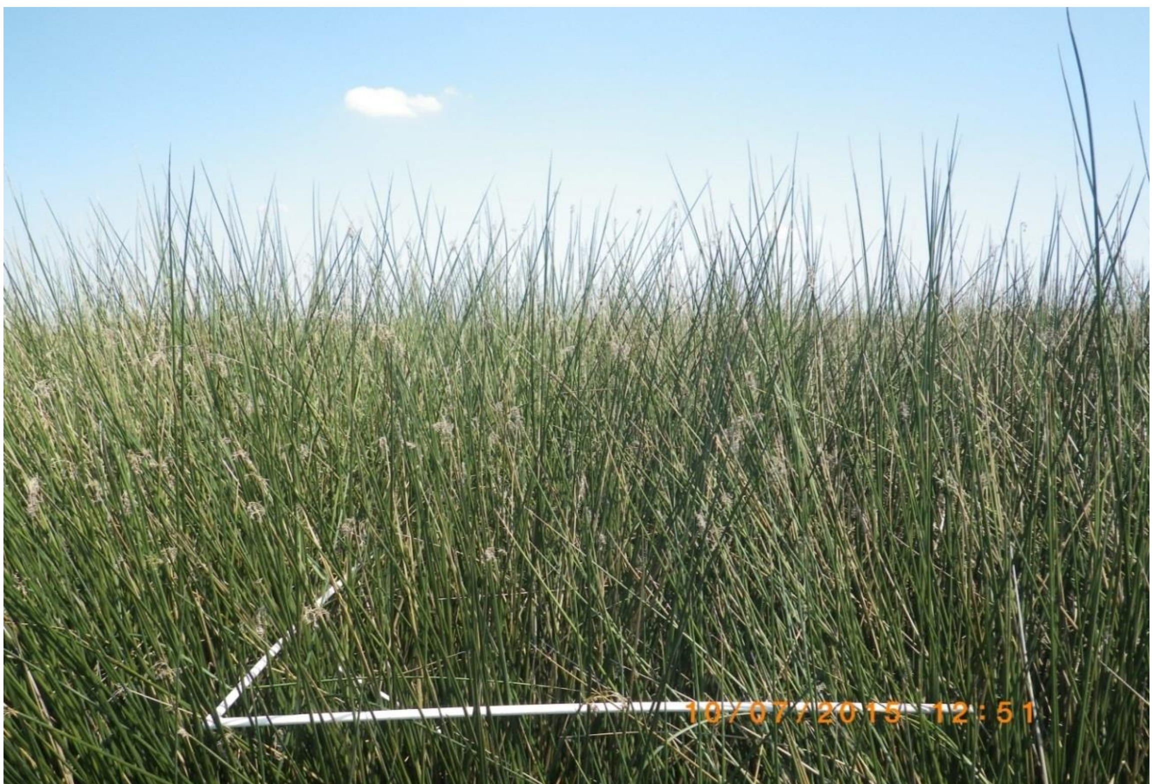


Figure IX-7. Typical veiw of a vegetation station in LA-39 LVB west area planting in Oct 2015.

Figure IX-8. The growth over one year (Nov 2015 – Oct 2014) of a typical double row in the Little Vermilion Bay west plantings.

b. Hydrology

The water level in the planting area is generally deep but variable due to tidal action. As the plantings mature sedimentation and organic deposition may increase allowing for the addition of other species that thrive in deeper flood regimes to become established (Fig. IX-9). The optimum water depth for establishment of *S. californicus* is reported as between 1 to 2 feet (Materne and Fine 2000). Water depth within this range was the standard in the project area during 2015 only routinely exceeding the 2 foot depth threshold during the winter while the plants were typically dormant. However, during the 2016 growing season to date, there have been significant periods where water levels have exceeded the root zone by well over the two foot threshold. This report does not include data from the historic flooding of August 2016 which will be well above any peak water levels during 2015 or 2016. Also, as of the writing of this report, no anecdotal evidence exists from the 2016 growing season that shows diminished growth based on these water levels; although based on The Jaws some reduction in cover and reduced expansion might be expected.

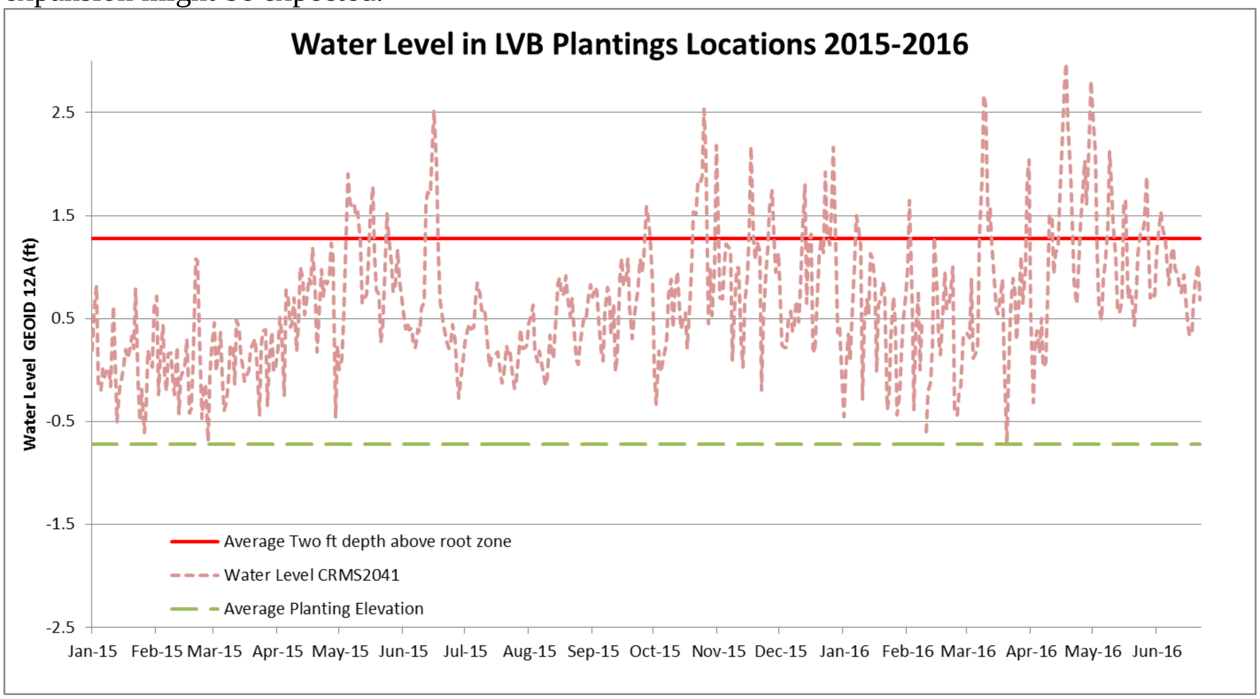


Figure IX-9. Hydrograph of nearby CRMS2041 displaying water levels in the LA-0039 Little Vermilion Bay (LVB) planting area during 2015 and 2016.

c. Planting Failure/Success Causation

Herbivory was responsible for nearly all plant mortality in the planting area. There was a significant loss of plants in the LVB East planting area's southern double rows; the loss of plants gradually increased further south in the planting area, nearing complete loss at the last double row (Fig. IX-10). These double rows suffered some mortality due to herbivory believed to be caused by *Ondatra zibethicus* (muskrats). Detached stems, tracks, and scat in and among the damaged plantings were observed during the October 2015 vegetation survey (Fig. IX-11). On the nearby TV-18 project terraces, nests and at least one individual was observed. Other than this location the only plant loss was isolated and random, either due to poor plant health at the time of planting or isolated poor environmental conditions. However, with the flood of August 2016 and the possibly continued herbivory in the area, it is reasonable to expect some loss of plants in the LVB eastern area as it is just off the main Vermilion River Cutoff Canal. This flood may however provide the area with upland sediments, increasing soil elevation and generating natural recruitment to the area, especially in proximity to the project plantings. Google Earth imagery 5/6/2016 show a complete loss of the 8th and 9th double rows (southeastern set) in the eastern LVB planting area and a notable reduction of the 7th while all others appear intact and healthy (Fig. IX-12). The western LVB plantings show no significant differences from the last data collection effort other than the predictable winter die back and spring recovery.

Figure IX-10. Active herbivory damage to the planted double rows in the LVB east location during the October 2015 sampling. The double row had extended to the terrace to the north in the background prior to herbivory.

Figure IX-11. Herbivore tracks in and among the planted double rows in the LVB east location.

Figure IX-12. Google Earth imagery of the LVB East plantings taken on 5/6/2016. The northeastern and middle sets of double rows expanded, whereas, the southeastern set of double rows were mostly removed by herbivory.

C. Conclusions

1. Project Effectiveness

As per the project goals:

- Double row plantings in the shallow open water and tidal mudflats in LVB East have been moderately successful, with total combined survivorship of plantings ~67% and total vegetative cover increasing from 3% to near 27% 1.5 years after planting.

- Double row plantings in the shallow open water and tidal mudflats in LVB West have been extremely successful, with survivorship of plantings at 100% and percent cover increasing from 3% to ~69% 1.5 years after planting.

- Area plantings in the shallow open water and tidal mudflats in LVB West have been extremely successful, with survivorship of plantings at 100% and percent cover increasing from 3% to ~63% 1.5 years after planting.

- The recruitment of new emergent plants to the area has not occurred through this point in the project life; however, it is expected to accelerate in the future.

2. Recommended Improvements

The density of plantings in the project area in both the area and double row planting could be reduced in future plantings to increase the overall coverage. The area and double row plantings were experiencing significant intraspecific competition at the end of one year; wider spaced plantings could grow for a longer period of time before resource limitations decrease growth while increasing the overall project foot print.

3. Lessons Learned

This project area has the potential for fast growth and high survival rates among transplanted trade gallons of *Schoenoplectus californicus*; however, herbivory especially in the east planting location could jeopardize these results if left unchecked. One possible solution would be to coordinate with Louisiana Department of Wildlife and Fisheries to survey the area pre planting and possibly direct local trappers to the project area.

X. Year 3 – Willow Lake

Prepared by Tommy McGinnis – CPRA Lafayette Regional Office

A. Site Description

Willow Lake, a Year 3 planting site, is in north-central Cameron Parish east of Calcasieu Lake and north of the Gulf Intracoastal Waterway (GIWW). Saltwater intrusion from Calcasieu Lake to the general area is minimized by the Calcasieu Lock on the GIWW which is part of the Mermentau Basin Project managed and operated by the Corps of Engineers. Willow Lake is within the CS-11b project boundaries; it is separated from the GIWW by a rock dike, and there was a failed attempt at erecting terraces along the northern shoreline of the lake attributed to poor soil structure for terrace construction.

The planting site is the broken marsh north and northwest of Willow Lake. The site is divided into three (3) areas (West, South, and East) and four (4) planting strategies (double rows parallel to shoreline of open ponds, double rows across open ponds, area plantings, and deeper water test sections (Fig. X-1). All plants were trade gallons of *Shoenoplectus californicus* (California bulrush, 17,367 plants) except for the deeper-water test plots which also included two (2) trade gallon California bulrush (297 plants) and two (2) trade gallon *Phragmites australis* (Roseau cane, 297 plants). Planting occurred in two phases; the California bulrush plantings were completed by October 26, 2014, and the Roseau cane plantings were completed by May 11, 2015. The final inspection of the Willow Lake planting was on May 11, 2015.

Double Row Plantings parallel to perimeters and across open-water areas were planted in all three areas with the intent to stabilize existing marsh and establish vegetation in shallow open water areas. Rows of California bulrush trade gallons were planted fifteen feet (15′) apart with plants on five-foot (5′) alternating centers no lower than -1.9 ft NAVD88, GEOID 12A.

Area plantings in small open-water areas were planted as auxiliary areas in the South and East areas to establish vegetation in areas susceptible to breaching by Willow Lake. Trade gallon California bulrush was installed in parallel rows five feet (5′) apart with plants on five-foot (5′) alternating centers no lower than -1.9 ft NAVD88, GEOID 12A.

Deeper water test plots were planted in the middle of larger ponds of the West and East areas with the intent to test plant survival and growth in deeper water. Nine (9) alternating rows of trade gallon California bulrush, two gallon California bulrush, and two gallon Roseau cane with rows 10 feet apart, with plants on five-foot (5′) alternating centers. Each row contained 11 plants. No depth limit was specified, but the pond bottoms are typically not lower than -2.5 ft NAVD88, GEOID 12A.

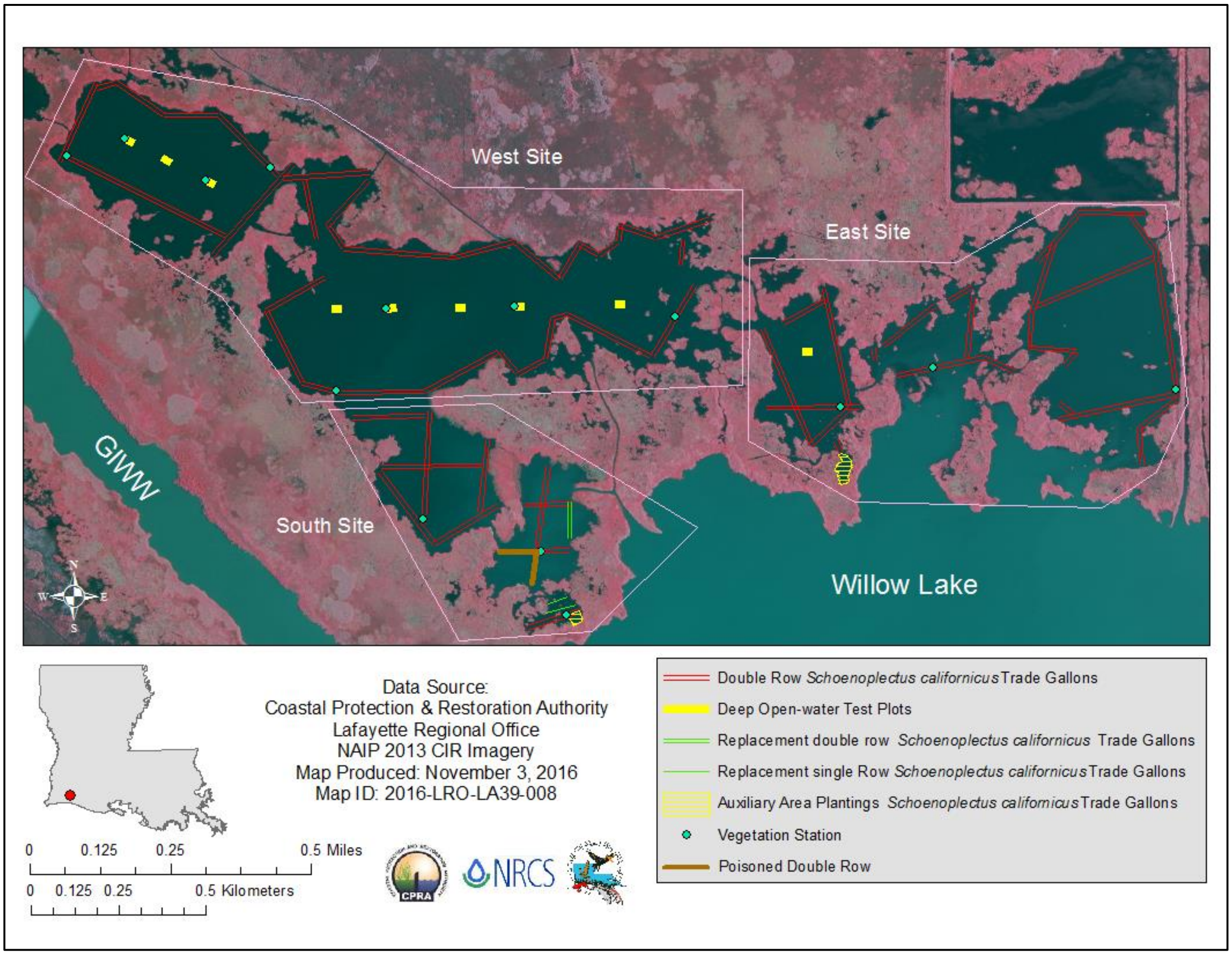


Figure X-1. LA-39 Year 3 Site – Willow Lake site map shows plantings locations and types. The vegetative monitoring stations and post planting modifications are also displayed.

B. Monitoring Activity

1. Monitoring Goals

The goals of the Willow Lake plantings are:

- Double row plantings of California bulrush along open-water perimeters will survive and expand to reinforce shorelines.
- Double row plantings of California bulrush bisecting open-water areas will survive and expand to act as hydrologic baffles.
- Deep water test plots will test the survival and growth for different sizes of California bulrush (one and two gallon sized).
- Deep water test plots will test the survival and growth for two gallon sized Roseau cane.
- Area plantings of California bulrush will survive and expand to increase vegetation in areas susceptible to breaching by Willow Lake.

2. Monitoring Elements

The monitoring elements include procedures to assess planting survival and effects on the planting area for the various types of project plantings. Vegetation stations are intended to monitor planting survival and vegetative cover representative of the variety of planting strategies over time (Table X-1). Hydrologic data from nearby CRMS sites are used to explain hydrologic influences such as flooding. The final planting inspection of May 11, 2015 is considered the beginning of the monitoring period.

Table X-1. Sampling schedule for LA-39 Year 3 site, Willow Lake. *Shoenoplectus californicus* (SCCA, California bulrush) for the double rows and deeper test plots were planted in October 2014, and Phragmites australis (PHAU, Roseau cane) for the deeper test plots were planted in May 2015.

Sampling Type	T_0 (SCCA) 2014	T_0 (PHAU) 2015	T_1 2015	T_2 2016	T_3 2018	T_4 2020	T_5 2025
Planting Survival	Oct 29	May 11	July 25	May 26	May	May	May
Percent Cover			July 25	May 26	May	May	May

Vegetation Assessment

To assess planting status, an ocular estimate of % survival and plant condition was conducted for each area and planting type while visually inspecting the site during sampling visits. Planting survival and vegetative growth data was also collected at the vegetation station level; 14 stations were established to represent the areas and planting types. Vegetation stations were different for the double row and area plantings versus at the deeper water test plots. Flooding depth, surface water salinity and temperature, and porewater salinity and temperature were also collected at all sampling stations during each sampling event. Conditions occurring outside of the vegetation stations including additional emergent species, floating and submerged vegetation, marsh interspersion, and site-specific points of interest were noted along with photographic documentation.

Double Row Plantings have ten (10) vegetation stations to monitor planting survival and vegetative cover. The West Area has four (4) stations; the East Area has three (3) stations; and the South Area has three (3) stations. Percent survival was calculated from 10 plants (five plants per row) at each vegetation station; plants were characterized as live or dead/absent. PVC poles were placed on both ends of the plants monitored for survival. Vegetative growth was assessed by measuring percent (%) cover of species present, vegetative stand height, and height of dominant species at 4 m^2 vegetation plots at the vegetation stations (Folse et al. 2014).

Area plantings in small open-water areas in the South and East Areas had ocular assessments only. A vegetation station was located adjacent to the area planting in the South Area.

Deeper Test Plots have four (4) stations to monitor planting survival and vegetative growth. All four test plots used for monitoring are in the West Area. Percent survival was determined for each of the three (3) plant types (one trade-gallon sized California bulrush, two trade-gallon sized bulrush, and two gallon sized Roseau cane) over the entire test plot, each plant type had 33 plants per test plot. Stem heights (ft) and plant diameters (ft) were measured from a subset of 6 plants for each plant type. Plant diameters were converted to area assuming radial growth:

$$Plant\ Area = \pi r^2,$$

and percent planting cover for each plant type over the whole test plot was calculated by:

$$Percent\ Planting\ Cover = \left(\frac{\text{Plant Area (ft}^2\text{)} \times \#\text{ of Live Plants}}{\text{Test Plot Area (ft}^2\text{)}}\right) \times 100,$$

where # of live plants is 0-33 plants from planting survival, and Test Plot Area is 4800 ft^2.

Plantings were assumed to have 100 percent survival upon planting. As per planting specifications, one trade-gallon sized (1 TG) California bulrush were assumed to average 42 inch (36-48") stem heights; two trade-gallon sized (2 TG) California bulrush and Roseau cane were assumed to average 56 inch (40-72") stem heights. Plant areas were assumed to be 0.22 ft^2 for 1 TG plants and 0.44 ft^2 for 2 TG plants when planted.

3. Monitoring Results and Discussion

a. Vegetation Assessment

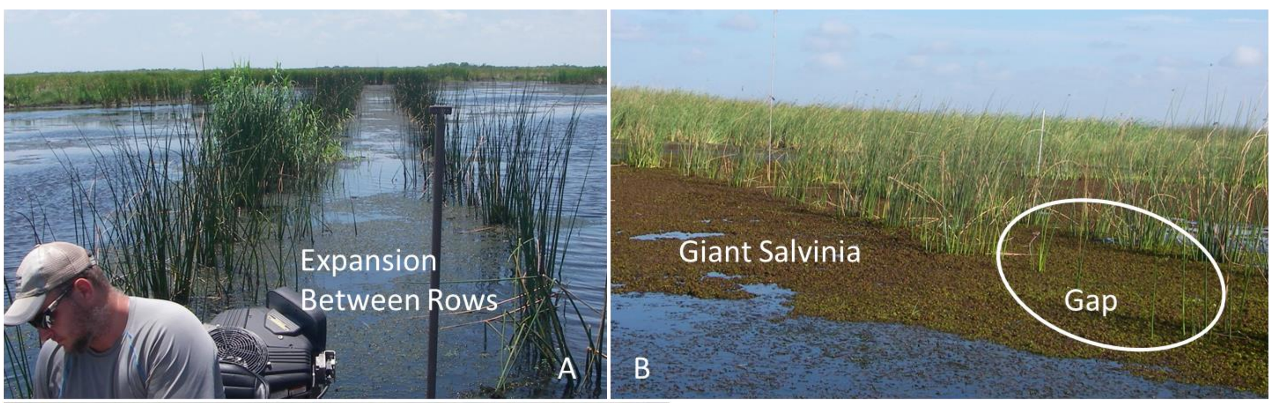
Double Row and Area Plantings

The ocular estimates of planting areas captured the overall performance of the plantings (Table X-2). Throughout the Willow Lake site during both sampling events, the open water areas had expansive growths of a fresh to intermediate mix of submerged aquatic vegetation (*Cabomba caroliniana*, *Vallisneria americana*, *Myriophyllum spicatum*) and abundant floating vegetation (*Salvinia molesta*, *Eichhornia crassipes*) that formed mats in many areas; the surrounding intermediate marsh vegetation appeared healthy. During the first monitoring trip on July 25, 2015, about 9 months following planting, the plantings looked really healthy and were expanding; survival was estimated between 85-95 % survival, and many of the California bulrush had expanded between the double rows (Fig. X-2A). Most of the missing plants were likely damaged by large patches of giant Salvinia and/or water hyacinth (Fig X-2B and C). Two transects of double rows of California bulrush were poisoned in the South area by a hunting lessee (Fig. X-3A and B), but the same number of plants were planted by the lessee in other locations within the South area later that year (Fig. X-1 and X-3C). By the second monitoring trip on May 26, 2016, remaining plantings looked healthy with continued growth; we estimated ~ 75% survival, overall (Table X-2). Curiously, although survival remained high, California bulrush in the western pond of the South area were notably smaller than other plantings (Fig. X-4). The East area had the most robust plants of all areas (Fig. X-5). Decreases in overall plant survival were typically caused by physical damage from rafting by floating vegetation mats (Fig. X-6A). The large patches of giant Salvinia and water hyacinth added other species such as alligator weed (*Altanthera philoxoides*) and Cuban sedge (*Oxycaryum cubense*) to form more robust floating mats (Fig. X-6B). Larger swaths of plantings were damaged along the northern perimeters of the West and East areas where the plantings were closer to the existing marsh (Fig. X-7). The Auxiliary area plantings appear to be expanding (Fig. X-8) which will help these areas if Willow Lake breaches into these ponds.

Table X-2. Overall % Survival of LA-39 Year 3 Willow Lake California bulrush plantings was ocularly estimated over time while conducting the final inspection and monitoring field trips.

		% Overall Survival			
Area	Planting Type	T_0 Oct 29, 2014	T_1 May 15, 2015	T_2 Jul 25, 2015	T_3 May 26, 2016
West	Double Row	100	93	93	60
South	Double Row	100	95	95	83
	Area - Auxiliary	100	90	90	70
East	Double Row	100	93	93	80
	Area - Auxiliary	100	95	95	ND
Deep Plots	One Gallon Bulrush	100	90	86	84
	Two Gallon Bulrush	100	97	96	95
	Two Gallon Roseau Cane	NP	100	81	29

*ND = Not Determined, *NP = Not Planted



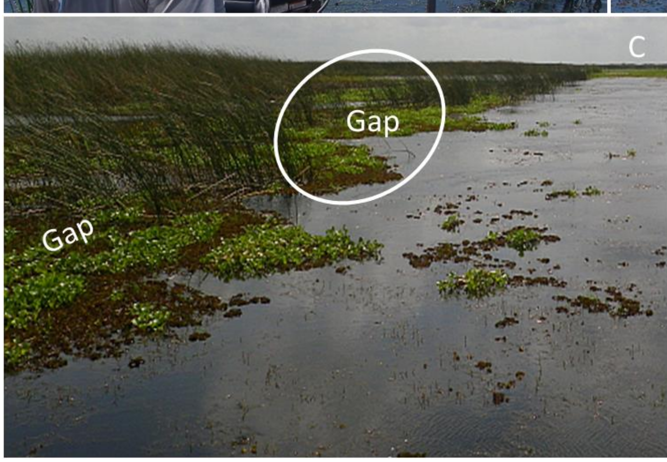


Figure X-2. Double row plantings in the LA-39 Year 3 Willow Lake - West area were expanding (A), and gaps in the plantings were probably caused by floating mats of giant Salvinia (B) by July 25, 2015. By May 29, 2016 (C), standing plantings had grown; however, gaps increased as floating vegetation mats expanded to include water hyacinth. Some plantings trap the floating mats between rows and existing marsh.

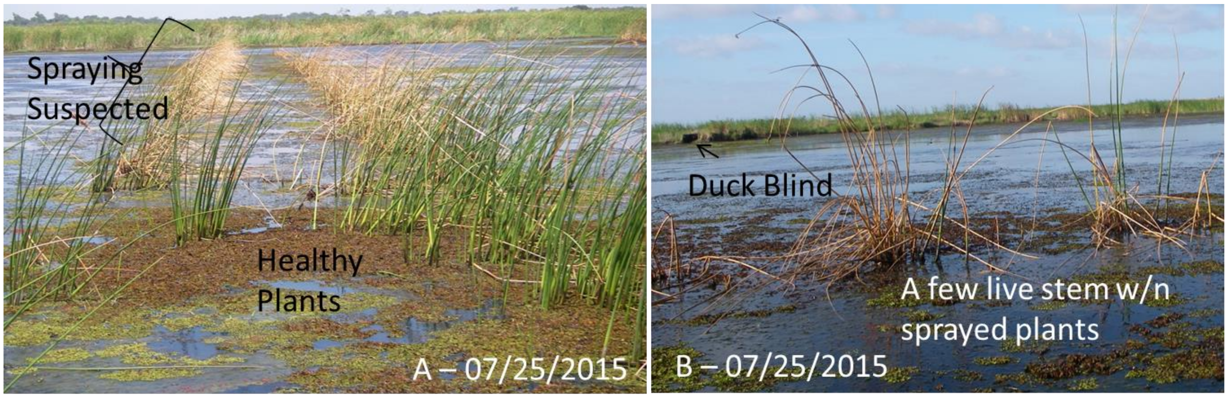


Figure X-3. Two sections of double row plantings in the eastern pond of the LA-39 Year 3 Willow Lake - South area were poisoned by a lessee for duck hunting (A and B). The plants were subsequently replaced by the lessee in other parts of the pond to help secure against breaching from Willow Lake (C). See site map for locations (Fig. X-1).

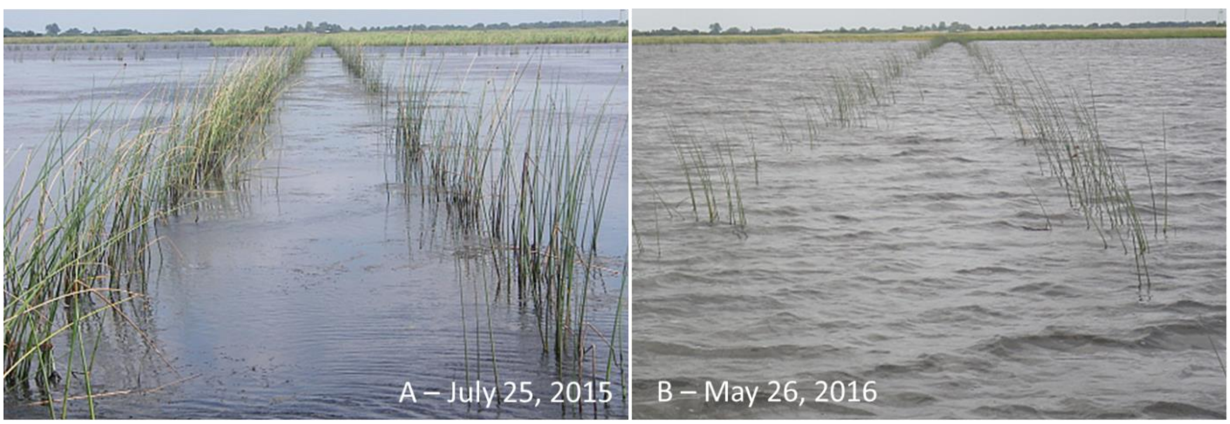


Figure X-4. Pictures were taken about 9 months (A) and 19 months (B and C) after planting in the western pond of the LA-39 Year 3 Willow Lake - South area. The foreground is between rows of a south to north double row; (A) shows expansion towards the middle despite plants not being as big as in other areas, and (B and C) show a lack of expansion yet still healthy plants. Note the larger flowering plants in (C) which are typical of plants in other areas. West to east double rows are in the background. Water levels were about 1' higher in (B and C) than (A), so less of the plants are showing.

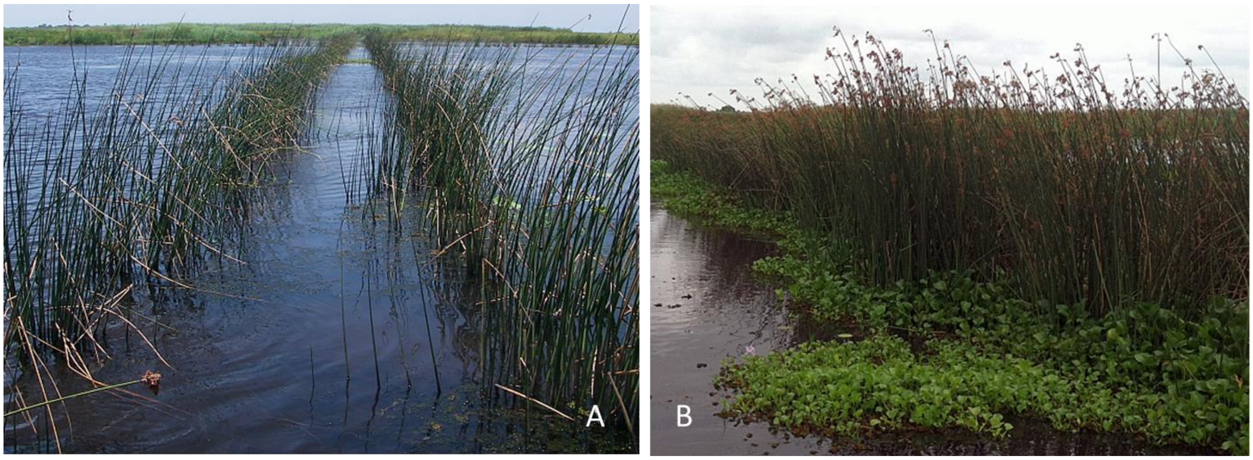


Figure X-5. The planting in the East area of the LA-39 Year 3 Willow Lake site were the most robust. Plants were growing across the double rows by July 2015, nine months after planting (A). The double rows were almost indistinguishable and the stems were 10+ feet tall by May 2016, about 19 months after planting (B). Water levels were about 1 foot higher in A (July 2015) than B (May 2016).

Figure X-6. Large floating vegetation mats lead to planting loss even among the more robust plantings in the LA-39 Year 3 Willow Lake - East area. Floating mats consisted of water hyacinth (A) and combinations of water hyacinth, giant Salvinia, and otherwise emergent vegetation (B).

Figure X-7. Damage from floating vegetation mats was noted to be more severe where the plantings were closer to the existing marsh within the LA-39 Year 3 Willow Lake site, especially along the northern portion of the West and East areas.

Figure X-8. Auxiliary plants were used for area plantings to help vegetate areas susceptible to breaching from Willow Lake. Pictured is the East Area Auxiliary planting on July 25, 2015.

Vegetation station data suggests California bulrush double row plantings performed well over the first year and a half since planting (Fig. X-9A and B). Plantings were assumed to have 100 percent survival, occupy a 2% of a 4 m^2 vegetation station based on number of plants in the cover plot, and to have 42 inch average (36-48") stem heights upon planting in October 2014 as per planting specifications. Planting survival averaged a high 80% across all areas. Most loss was caused by floating vegetation mats. Growth among the planting areas was more variable. California bulrush was more robust in the East area. The South area planting continued to grow, but cover expanded about 55% slower and stem height grew about 20% less than the East area. Growth was least robust or non-existent in the South area.

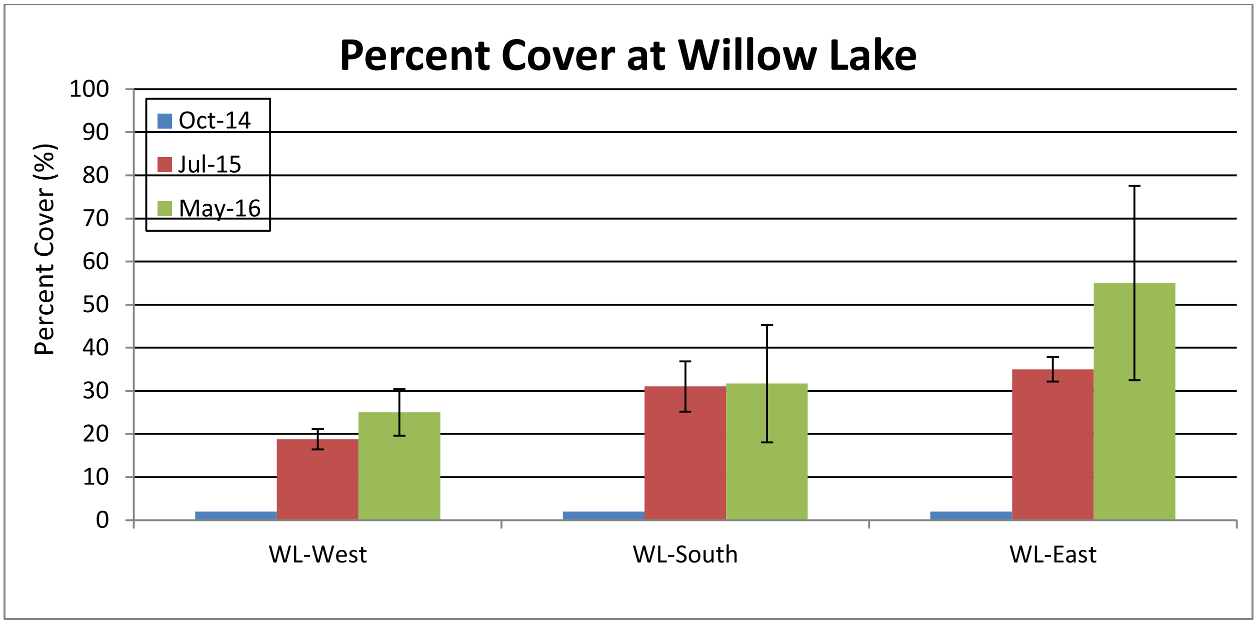


Figure X-9A. Percent vegetation cover was collected in the different areas of double row plantings in LA-39 Year 3 Willow Lake over one and half years since planting.

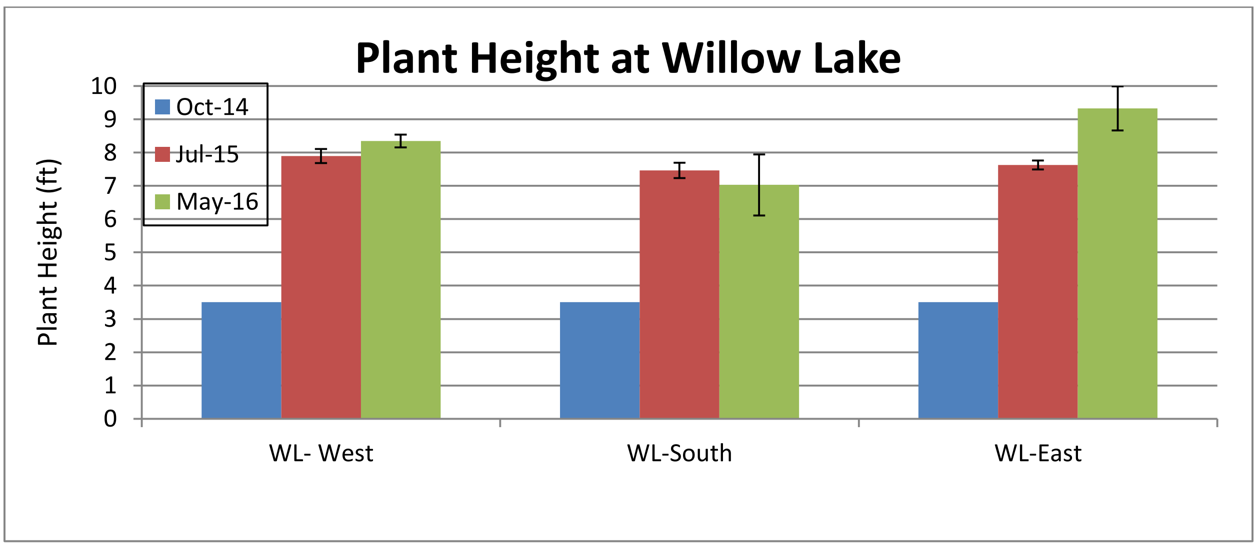


Figure X-9B. Percent vegetation cover was collected in the different areas of double row plantings in LA-39 Year 3 Willow Lake over one and half years since planting.

Deeper Test Plots

Vegetation station data collected at four of the nine test plots captured performance over the first year and a half since planting for California bulrush (SCCA in Fig. X-10A and B) and the first year for Roseau cane (SCCA in Fig. X-10A and B). Both 1 and 2 TG California bulrush plantings had high survival and good growth by a year and half after planting (Fig. X-11). The larger, 2 TG California bulrush had greater and more consistent survival and growth than the smaller, 1 TG which had more variable survival and growth (Table X-2). The 1 TG California bulrush has handled the deeper conditions, but the larger, 2 TG California bulrush may be more resistant to damage from floating vegetation mats (Fig. X-11). Roseau cane survival was highly variable but poor overall, and its growth did not progress following initial modest growth (Fig. X-10A and B). The new Roseau cane stems were very spindly and laid on top of the water where they were easily covered and displaced by surrounding SAV, algae, and floating vegetation (Fig. X-12).

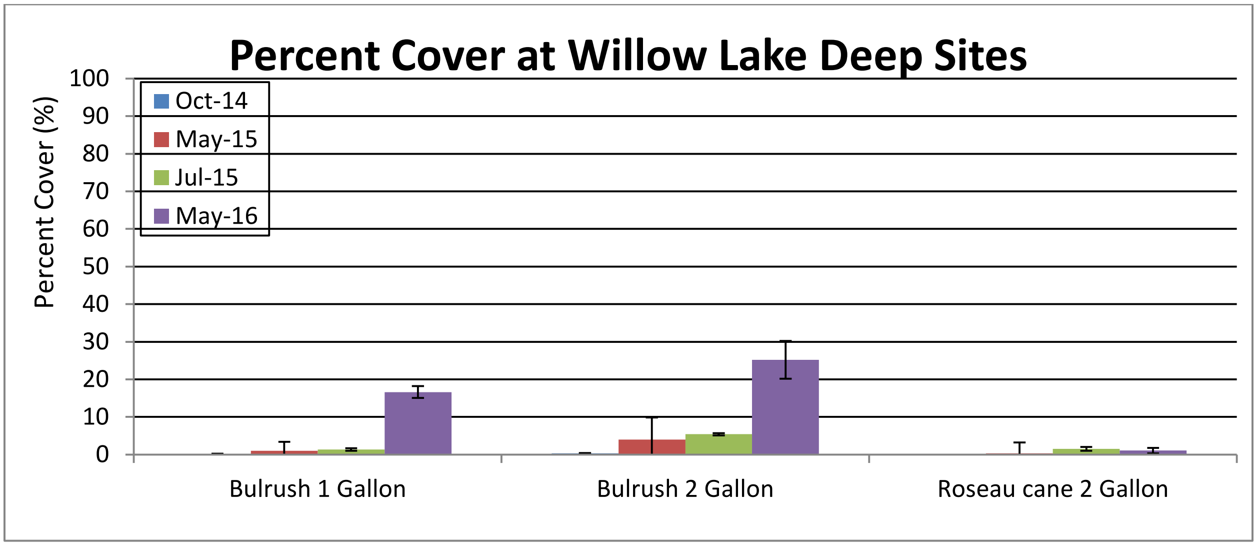


Figure X-10A. Percent cover was determined from one and two gallon *Schoenoplectus californicus* (bulrush) and 2 gallon *Phragmites australis* (Roseau cane) planted in the deep test plots in LA-39 Year 3 Willow Lake.

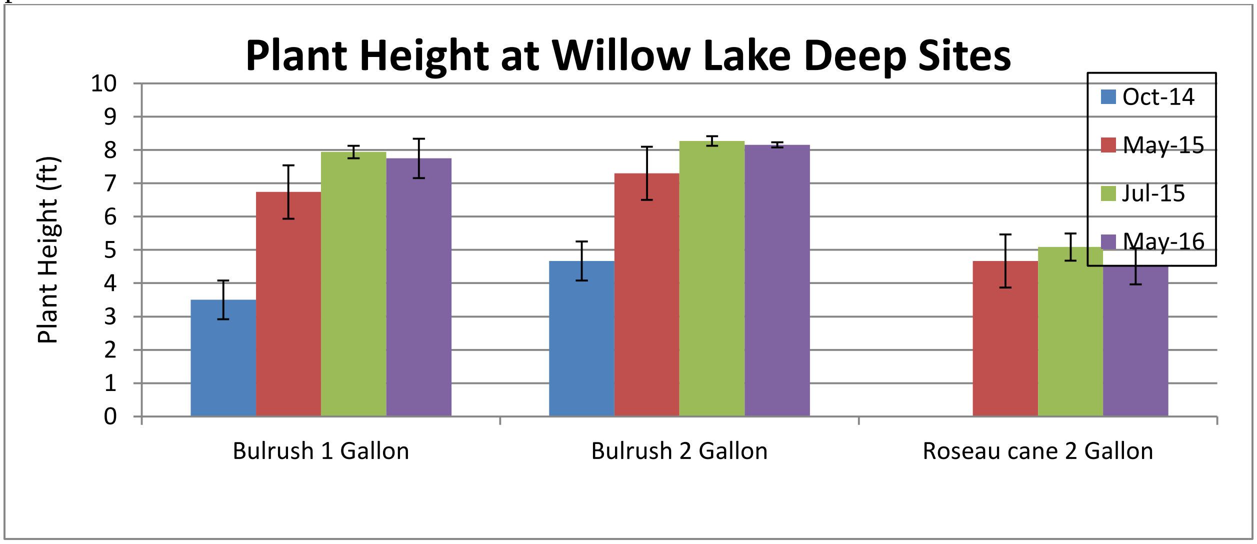


Figure X-10B. Plant height was determined from one and two gallon *Schoenoplectus californicus* (bulrush) and 2 gallon *Phragmites australis* (Roseau cane) planted in the deep test plots in LA-39 Year 3 Willow Lake.

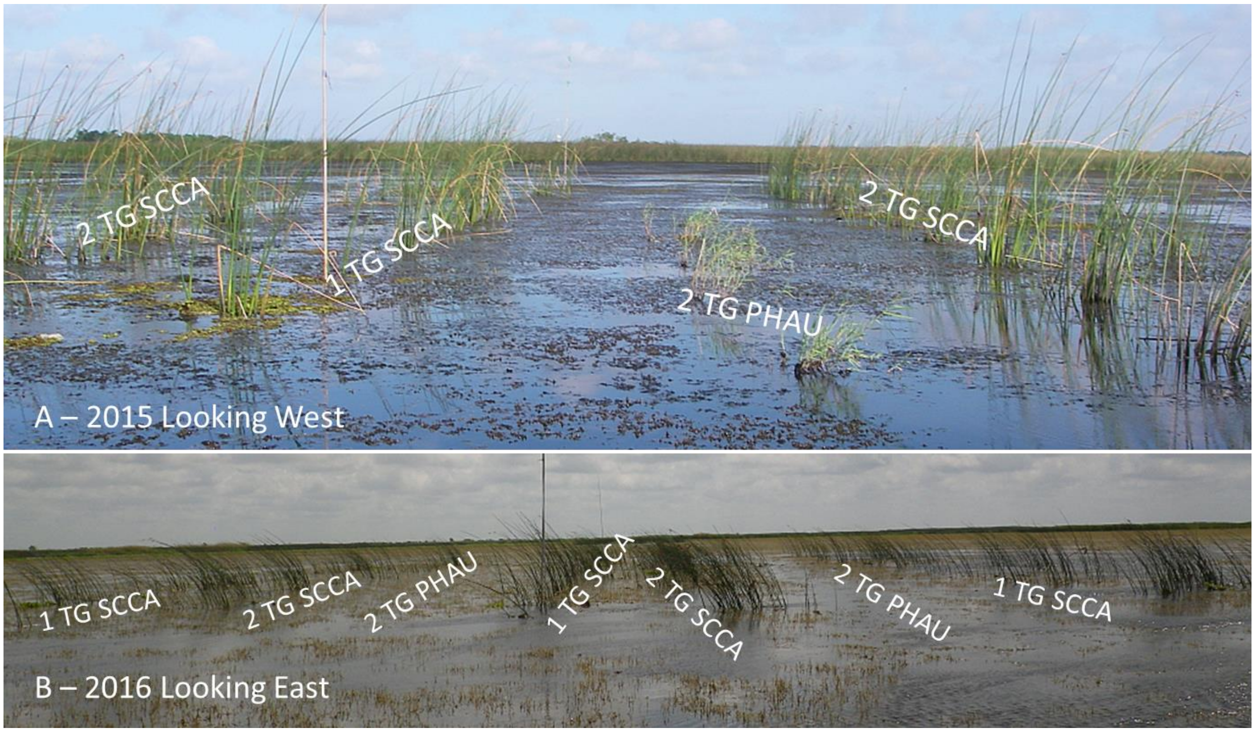


Figure X-11. The deeper test plots from LA-39 Year 3 Willow Lake were observed on 07/25/2015 (A) and 05/26/2016 (B). The test plots consisted of rows of 1 and 2 Trade Gallon sized (1 and 2 TG) *Schoenoplectus californicus* (SCCA, California bulrush) and 2 TG *Phragmites australis* (PHAU, Roseau cane). The submerged aquatic vegetation in both pictures is *Cabomba caroliniana*. Note the absence of visible PHAU in 2016 (B, see Fig. X-12). Water was about one foot deeper in 2016 than 2015.

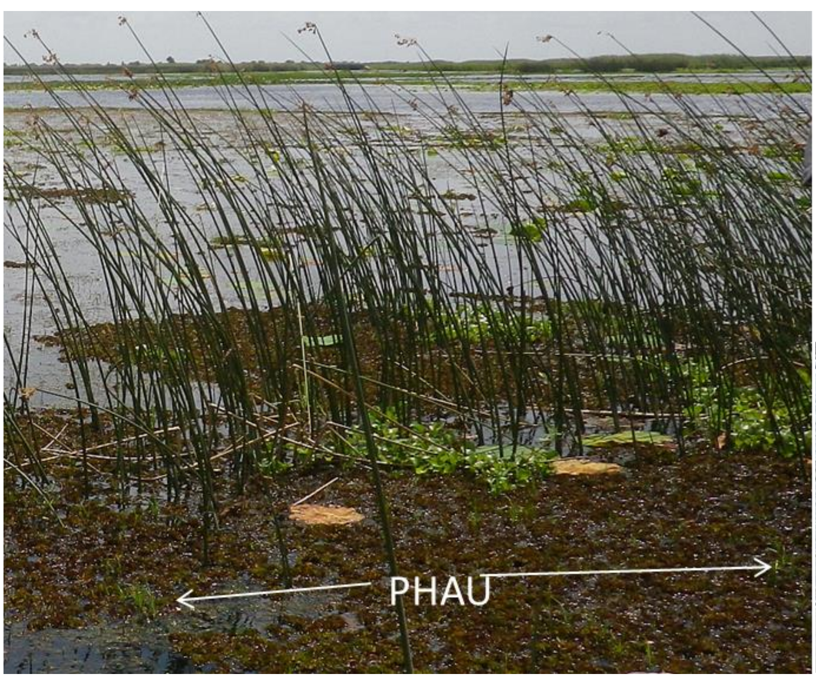


Figure X-12. Growth of *Phragmites australis* (PHAU, Roseau cane) from two trade-gallon sized containers was limited by competition from submerged and floating aquatic vegetation. California bullwhip was also susceptible to floating vegetation during higher water.

b. Hydrology

Hydrologic data for the Willow Lake planting sites was obtained from CRMS0691. The mean water elevation during 2014 through 2016 at CRMS0691 was +0.84 ft ± 0.02 SE (NAVD88, GEOID 12A) and ranged from a high of +2.25 ft to a low of -0.06 ft (Fig. X-13). There were multiple high water events that resulted in an increased water level of over three feet above the planting elevation that occurred mid-2015 through 2016. The highest of these being the August 2016 flood that effected much of coastal Louisiana.

The planting elevation was estimated by subtracting the water depth measured at each vegetation station during the survey, from the water elevation recorded at the corresponding time at CRMS0691. The estimated planting area elevation was calculated by averaging the elevation of all plants sampled within a planting area. The optimum water depth for establishment of *S. californicus* is reported as between 1 to 2 feet (Materne and Fine 2000). The estimated mean depth of inundation for the plants is slightly above this range for the Willow Lake plantings at 2.2 feet.

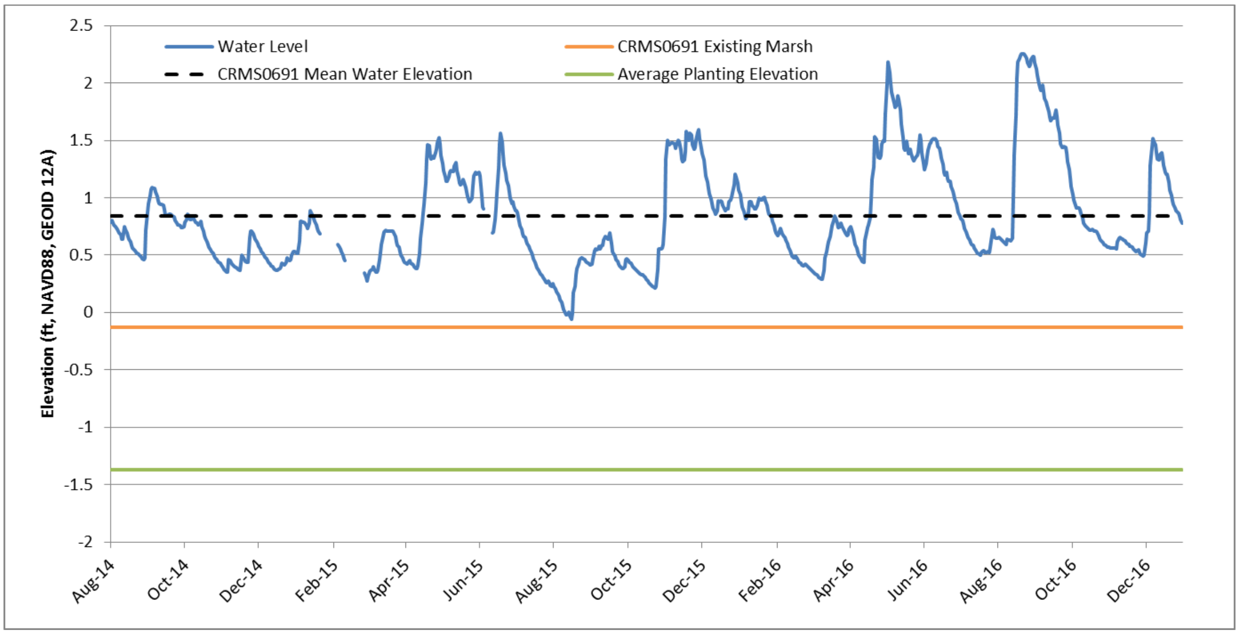


Figure X-13. Hydrograph of CRMS0691 displaying water levels in the LA-0039 Willow Lake planting area from August 2014 through 2016.

c. Planting Failure/Success Causation

The double row northern shoreline plantings were severely hampered due to rafting by FAV and SAV likely as a result of mostly southerly winds. Most of the decrease in survival in other planting types and locations was caused by floating aquatic vegetation but was less concentrated and more random, with the exception of the poisoned double rows of plants. Both sizes of California bulrush did reasonable well in the deeper test plots while the Roseau cane did very poor.

C. Conclusions

The first year of the Year 3 Willow Lake plantings was successful. Overall, California bulrush plantings survived and expanded despite some loses from rafting by floating vegetation (mainly giant Salvinia and/or water hyacinth). Deeper test plots had mixed results as both 1 and 2 trade gallon California bulrush plantings survived and expanded while Roseau cane experienced low survival and growth.

1. Project Effectiveness

As per the project goals:

- Double row plantings of bulrush along open-water perimeters have survived and expanded to reinforce shorelines.
- Double row plantings of bulrush bisecting open-water areas have survived and expanded to act as hydrologic baffles.
- Both one and two trade-gallon sized California bulrush have survived and expanded in deeper water test plots.
- Roseau cane survival and growth was low in the deeper water test plots, especially compared to that of California bulrush.
- Area plantings of bulrush have survived and expanded to increase vegetation in areas susceptible to breaching by Willow Lake.

2. Recommended Improvements

Consider using cut stalks of larger, adult Roseau cane for deeper water applications rather than new, wispy growth sprouting from two (2) trade-gallon sized containers.

3. Lessons Learned

The one (1) trade gallon California bulrush fared well in the deeper, open-water test plots. Although the two (2) gallon sized plants are more robust; the one (1) trade gallon plants are a more cost effective option.

Large areas of California bulrush were pushed over and smothered by floating vegetation composed mainly of giant Salvinia and water hyacinth. The occurrence of large mats of floating vegetation is attributable to recent mild winter temperatures. Planning for floating invasive species control may need to be considered.

XI. <u>Year 4 – Green Island Bayou</u>

Prepared by Tommy McGinnis – CPRA Lafayette Regional Office

A. Site Description

Green Island Bayou, a Year 4 planting site, is in eastern Vermilion Parish between the Gulf Intracoastal Waterway (GIWW) and Vermilion Bay. The site is intermediate marsh within a passively managed hydrologic area that has been subdivided by petroleum exploration canals. The main intent of the planting effort is to stabilize existing marsh along large open-water areas that have expanded from initial marsh loss that occurred from 1932-1956 and 1956-1973.

The Green Island Bayou site (GIB) is divided into five (5) areas (West, Southwest, East, Central, and North) and has three (3) planting strategies (shoreline plantings, double rows, and area plantings in smaller ponds) (Fig. XI-1). All strategies were planted with trade gallons of *Shoenoplectus californicus* (California bulrush, 31,840 plants) no lower than -0.6 ft, NAVD88 (Geoid 99), or -1.6 ft NAVD88 (Geoid 12A). The final inspection of the GIB planting was on September 11, 2015.

Area plantings in small open-water areas were planted in the North, West, and Southwest areas to establish vegetation in smaller open-water areas along larger open-water bodies. California bulrush was planted in parallel rows five (5) ft apart with plants on five-foot (5) alternating centers.

Shoreline Plantings of a single row were planted in the West and East areas to reinforce the shoreline of large open-water bodies. California bulrush was planted every three (3) ft as close as possible to the marsh edge. An additional row of auxiliary plants was added three (3) ft from some single row segments.

Double Row Plantings parallel to perimeters were planted in the North, Central, and East areas with the intent to stabilize existing marsh shoreline and establish vegetation in shallow open water areas. Rows of California bulrush were planted fifteen (15) ft apart with plants on five (5) ft alternating centers. **Double Row Plantings across open-water areas** were also installed in the North area to establish vegetation in shallow open-water areas.

B. Monitoring Activity

1. Monitoring Goals

The goals of the California bulrush plantings in GIB are:

- Area plantings will survive and expand to increase vegetation in smaller open-water area adjacent to larger open-water areas.
- Shoreline Plantings will survive and expand to reinforce the shoreline of open-water bodies.
- Double row plantings will survive and expand to stabilize existing marsh shorelines and establish vegetation in shallow open water areas.

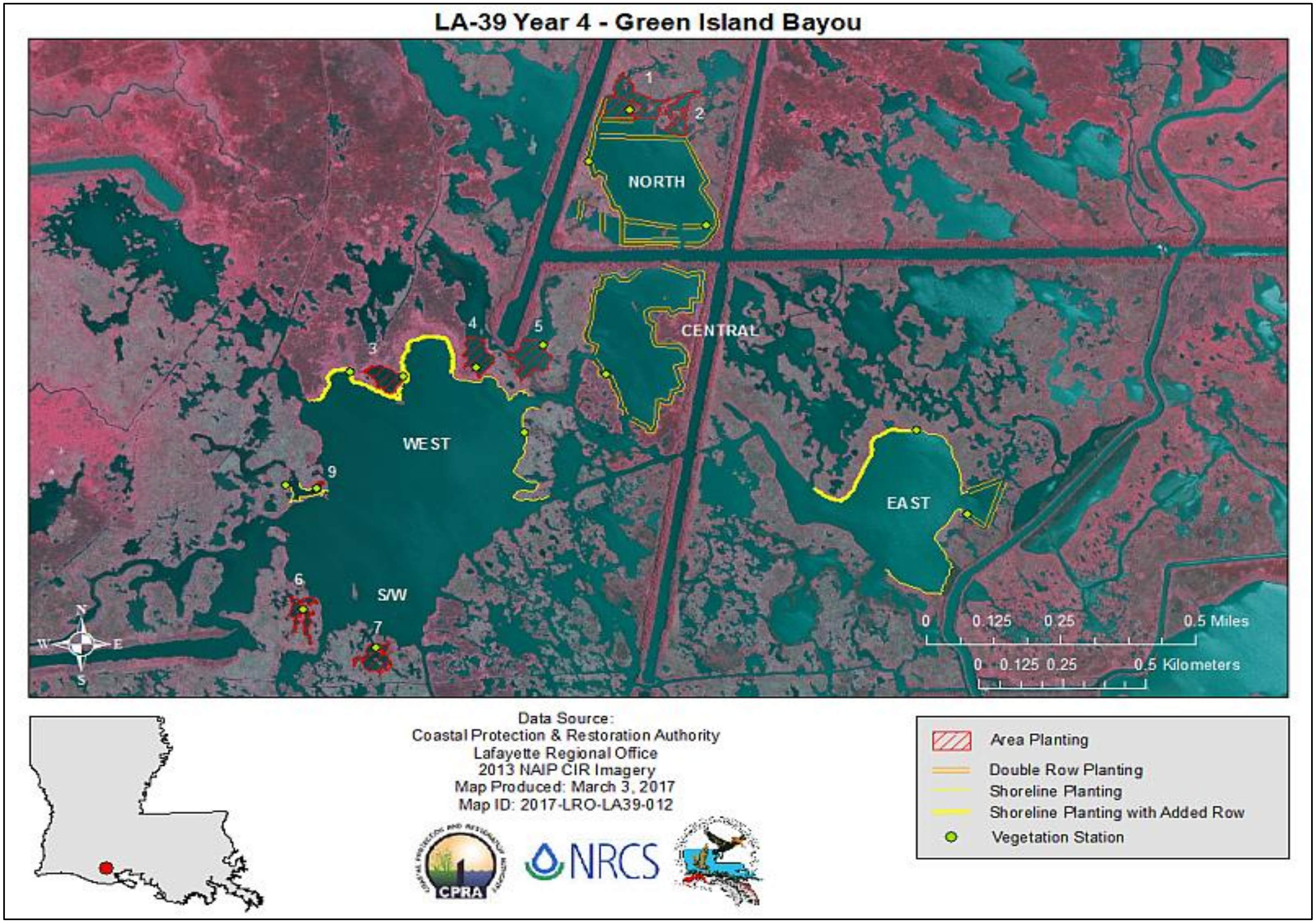


Figure XI-1. LA-39 Year 4 Green Island Bayou site map shows plantings areas and types. The vegetative monitoring stations are also displayed.

2. Monitoring Elements

The monitoring elements include procedures to assess planting survival and effects on the planting site for the three main types of project plantings, existing marsh edge stabilization in single and double rows and interior area coverage. An ocular assessment of all area and planting type combinations was conducted during each site visit. Vegetation stations were established to monitor planting survival and vegetative cover representative of the variety of planting strategies over time (Table XI-1). Hydrologic data from a nearby CRMS site, CRMS1650, is used to explain hydrologic influences such as flooding and salinity. The final planting inspection of September 11, 2015 is considered the beginning of the monitoring period; 100% survival is assumed for this date.

Table XI-1. Sampling scheduled for LA-39 Year 4 site, Green Island Bayou.

Sampling Type	T_0 2015	T_1 2015	T_2 2016	T_3 2018	T_4 2020	T_5 2025
Planting Survival	Sep 11	Oct 28	Oct 18	Sep	Sep	Sep
Percent Cover		Oct 28	Oct 18	Sep	Sep	Sep

Vegetation Assessment

To assess planting status, an ocular estimate of survival and plant condition was conducted for each area and planting type while visually inspecting the site during sampling visits. Planting survival and percent vegetative growth data was also collected at the vegetation station level; 15 stations were established with a PVC pole marking the start of the station. Percent survival was calculated from ten (10) plants at each vegetation station; plants were characterized as live or dead/absent. Vegetative growth was assessed by measuring percent cover of species present, vegetative stand height, and height of dominant species at 4 m^2 vegetation plots at the vegetation stations (Folse et al. 2014). Flooding depth, surface water salinity and temperature, and porewater salinity and temperature were also collected at all sampling stations during each sampling event. Conditions occurring outside of the stations and segments including additional species, marsh interspersion, and site-specific points of interest were noted along with photographic documentation.

Area plantings in small open-water areas had seven (7) vegetation stations distributed throughout the West (4 stations), Southwest (2 stations), and North (1 station) areas. The 10 survival plants extend along two rows (5 plants per row), and the vegetative growth plot is 2 × 2 m (4 m^2) and incorporates two rows.

Shoreline Plantings had four (4) stations distributed among the West (3 stations) and East (1 station) areas; three (3) stations are within single rows and one (1) station has an additional row. For the single row stations, the 10 survival plants extend along the shoreline while the vegetative growth plot is 4 m long × 1 m wide (4 m^2) incorporating the single row along the shoreline and the existing marsh equally. For the station with the additional row, the 10 survival plants are divided between the two rows (5 plants per row) while the vegetative growth plot is 4 m long × 1 m wide (4 m^2) incorporating both rows along the shoreline and a smaller portion of the existing marsh.

Double Row Plantings had four (4) stations distributed among the North (2 stations), Central (1 station), and East (1 station) areas; three stations, one in each area, are in a double row along water body perimeters, and one North station is within a double row across the open-water body. The 10 survival plants extend along the two rows (5 plants per row), and the vegetative growth plot is 2 × 2 m (4 m^2) that incorporates one row.

<u>Planting Loss/Success Causation</u>

Hydrologic data from CRMS1650-H01, located just northeast of the GIB, will be used to describe area water-level trends and salinity that may adversely affect the plantings. Other factors contributing to planting loss will also be discussed.

3. Monitoring Results and Discussion

a. Vegetation Assessment

The ocular estimates of planting areas and types capture the overall performance of the plantings (Table X1-2). During the October 2015 monitoring trip, which was about six weeks after planting, the northern Vermilion Bay area was experiencing a sustained, high water/salinity event (Fig. XI-8), and low salt-tolerant plant species in the existing marsh and previously existing California bulrush plantings were visibly stressed. Plantings in firmer water bottoms to the north (North Area and northern area plantings of West Area) had good survival (Table XI-2) and growth from plantings (new and longer stems). Plantings in the southern half of the site (shorelines and southwestern area planting in North area and all other areas) with unconsolidated water bottoms had low survival (Table XI-2), and little to no new growth was observed in surviving plants. By the October 2016 monitoring trip, the general vicinity had freshened to average salinities, and the existing marsh and previously existing California bulrush appeared healthy. Typically, planting areas continued to perform as they started; plantings in the northern areas continued to have a high percentage of survival and expand while the more southern areas and shorelines did not rebound from the initial low performance and continued to diminish (Table XI-2).

Table XI-2. Overall survival of LA-39 Year 4 Green Island Bayou plantings was estimated over time while conducting the final inspection and monitoring field trips.

			Overall Survival (%)		
Area	Planting Type	Subset	T_0 Sept 11, 2015	T_1 Oct 28, 2015	T_2 Oct 18, 2016
North	Area	Pond 1	100	95	100
		Pond 2	100	85	95
	Double Row	Perimeter	100	80	50
		Across	100	70	60
West	Area - Northern	Pond 3	100	70	35
		Pond 4	100	60	45
		Pond 5	100	90	90
	Area - Southern	Pond 9	100	20	0
	Shoreline	Northern	100	40	5
		Western	100	55	<1
		Southwestern	100	40	8
Southwest	Area - Southern	Pond 6	100	45	<10
		Pond 7	100	30	<5
Central	Double Row	Perimeter	100	50	30
East	Shoreline	Northern	100	30	0.5
		Southern	100	20	0
	Double Row		100	90	40

Upon installation in September 2015, plantings were assumed to have 100 percent survival, occupy a percentage of a 4 m^2 vegetation station based on plant spacing, and have 42 inch (3.5 ft) stem heights as per planting specifications. Vegetation station data collected one year after installation captured planting survival and growth (percent cover and stem heights). Stations were grouped by planting types, and the Area plantings were sub-divided into Northern (1 North and 3 West stations) and Southern (1 West and 2 Southwest stations) halves of the GIB based on performance similarities.

Area Plantings – Northern

The Area Plantings in the northern half of the GIB had the greatest survival and most robust growth of all the groupings (Table XI-2 and Fig. XI-2A and B). After the initial loss of 30 percent over the first two months post planting, the northern Area Plantings only loss 10 percent more over the next year. By one year after planting, vegetative cover increased by ~33 % and stem heights grew by ~5.5 ft. In order to avoid damaging the plantings while accessing the stations, vegetation stations were located along the perimeter of Area plantings resulting in underestimates for three of the four stations. Values in the graph are representative of the variability among the Area Plantings – Northern ponds (Fig. XI-3 and 4).

Area Plantings – Southern

The Area Plantings in the southern half of the GIB starkly contrasted the northern half (Fig. XI-2 through 5). At the vegetation stations, more than half of the plants were lost over the first two months and the rest of the plants (47%) were lost over the next year. Remaining plants were sparse and ~ 6 feet tall (Fig. XI-5). The southern ponds had the most unconsolidated soil of all planting types.

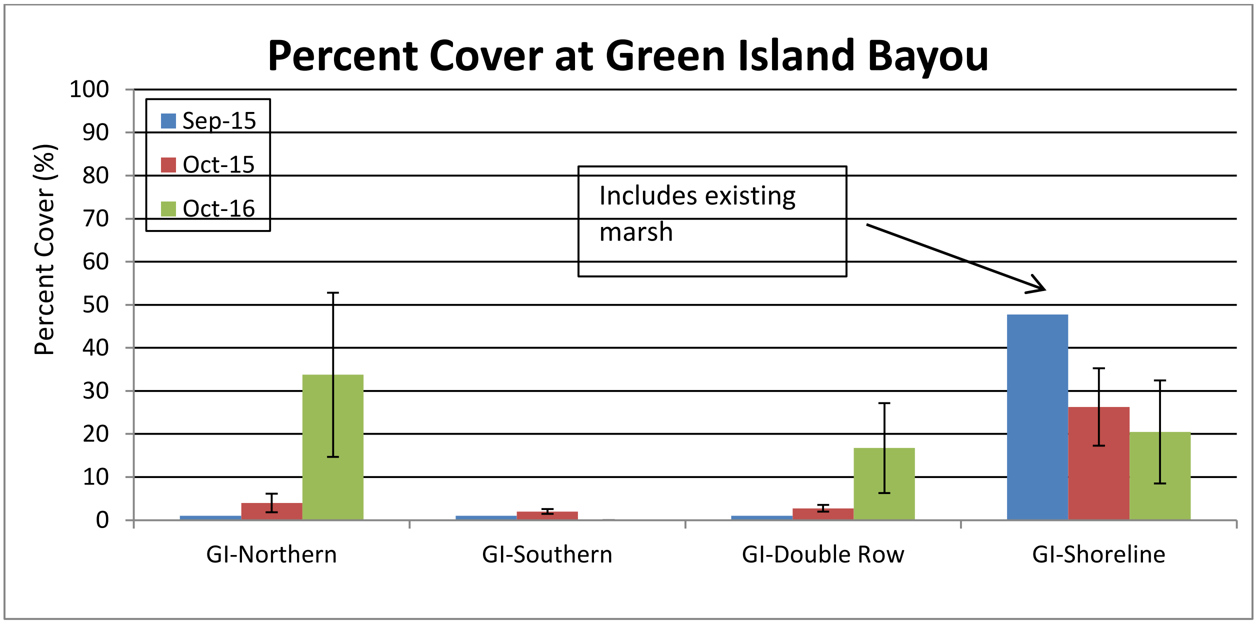


Figure XI-2A. Percent cover was determined at 15 vegetation stations throughout the different planting strategies of *Shoenoplectus californicus* in the LA-39 Year 4 Green Island Bayou site.

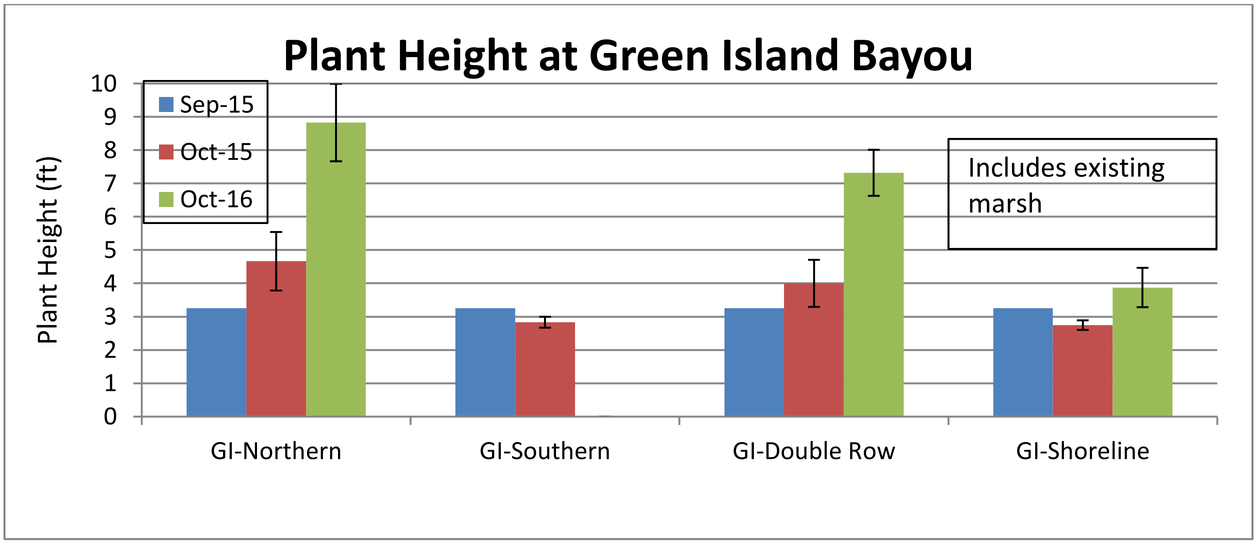


Figure XI-2B. Plant height was determined at 15 vegetation stations throughout the different planting strategies of *Shoenoplectus californicus* in the LA-39 Year 4 Green Island Bayou site.

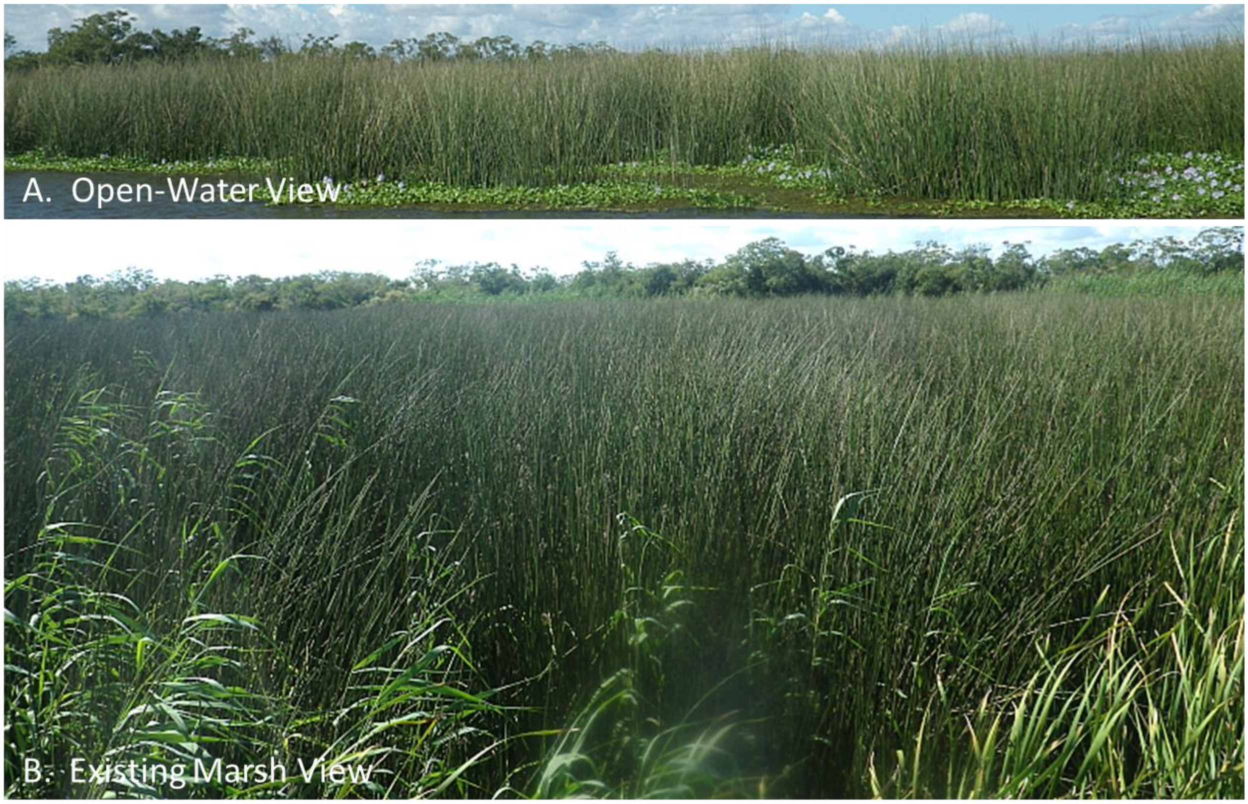


Figure XI-3. Plantings in the North area (Ponds 1 and 2) experienced the best survival and growth (12+ ft stems) of the Green Island Bayou plantings. Marsh vegetation (Roseau cane and cattails) are creeping into the area planting (B). Water depth is the same as the other plantings, but the water bottom is firmer here; the soil contains a clay/silt mix in the top 5 inches, then a silt/organic mix down to a clay lens at about 12 inches, then peat below.

Figure XI-4. Area Plantings – The northern half of the West area experienced varying degrees of success. (A) Pond 3 had the least survival and growth (stems 6-7 ft tall) which was limited to the middle of the pond while survival and stature of plant decreases towards the edges. (B) Pond 4 also had a similar pattern as Pond 3 but with greater survivorship and growth (stems 7-8 ft tall). (C) Pond 5 had excellent survivorship and growth (stems 8-10 ft tall); individual plantings are indistinguishable with a small gap along the pond edge. Coincidentally, the water bottom was noticeably firmer from Pond 3 to Pond 5.

Figure XI-5. The southern portions of the west and southwest areas had very low success. Survival was limited to the middle of Southwest Area Ponds 6 (A) and 7 (B). Surviving plants were dark green but had not grown much; individual plants were ~6ft tall and highly distinguishable. Survival was sparser in Pond 7, possible because of the high occurrence of giant

Salvina. (C) Pond 9 had no survival. Southern water bottoms had few inches of silt/organic mix at the surface over peat.

Double Row Plantings

The double row plantings were moderately successful and highly variable (Figs. XI-2A, B, and 6). After an initial loss of 35 percent over the first two months after planting, the double row plantings only loss another 15 percent over the next year. By one year after planting, vegetative cover increased by ~16 % and stem heights grew by ~3.3 ft. The North Area had greater survival and growth; the Central area was intermediate; and, the East Area has the least survival and growth (Table XI-2; Fig. XI-6).

Figure XI-6. Double rows were planted in the North, Central, and East areas. (A) The North had 40-70% survival; plants are growing well (8-10 ft stems) and expanding. (B) The Central had highly variable survival (0-70%) among reaches; plants are growing well (stems ~8 ft) and expanding. The marshside row is performing better than the pondside row. (C) The East had ~40% survival but not much growth (stems 5-6 ft tall) or expansion of surviving plants.

Shoreline Plantings

The shoreline plantings were not successful (Fig. XI-2 and 7). Surviving plants were targeted for vegetation station locations. After a sharp initial loss of 57 percent of survival over the first two months after planting, the shoreline plantings lost another 37 percent over the next year. By one year after planting, vegetative cover, which also includes existing marsh along the shoreline, decreased by ~27% and stem heights grew a modest 0.6 ft.

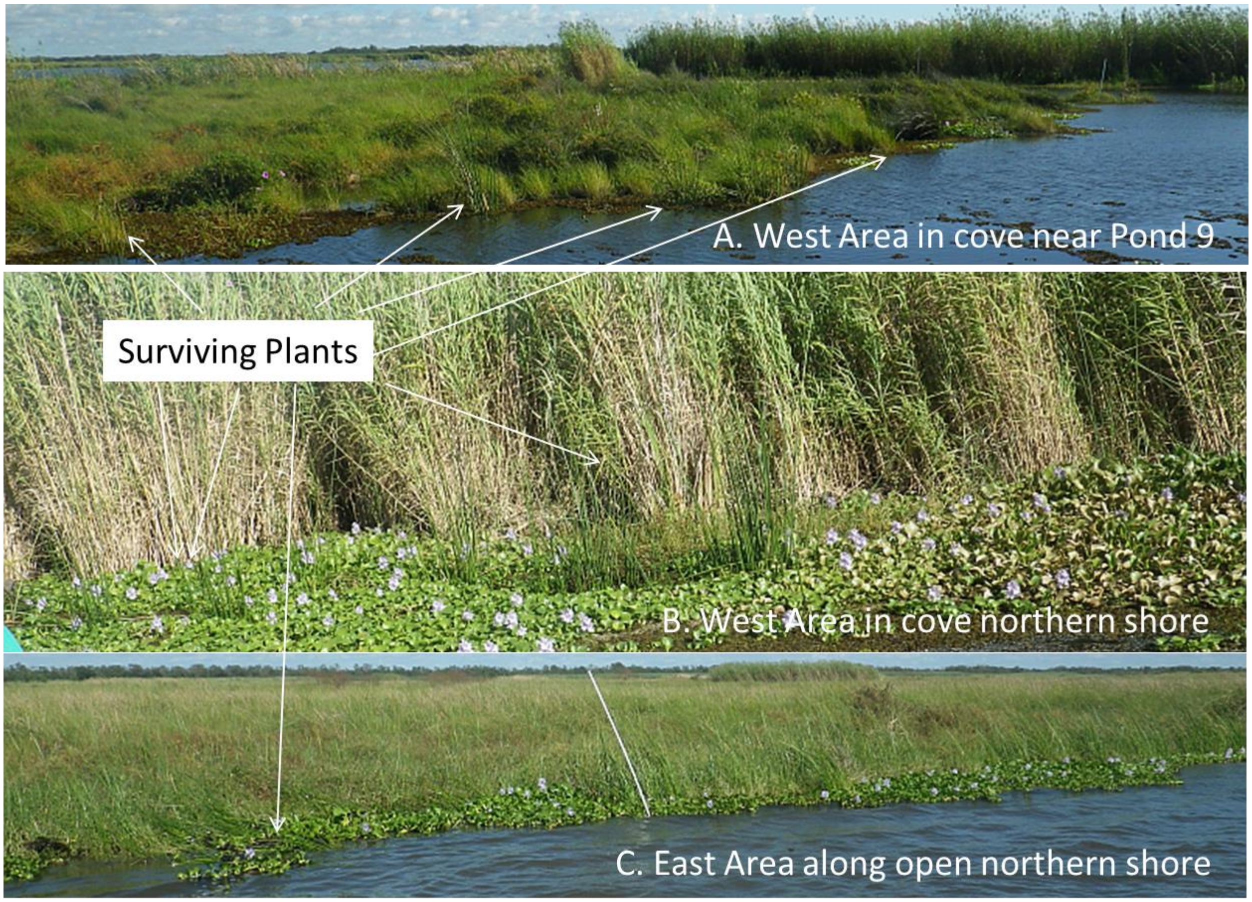


Figure X1-7. The Shoreline Planting pictures taken on October 16, 2016 targeted remaining plants. (A) The southwestern shoreline plantings of the West Area were in a cove off of the main open-water body; survival was sparse, but this stretch of shoreline plantings had the highest survival of all the shoreline plantings. (B) Much of the northern and western shorelines of the West site survivors were limited to protected areas and stems were only 3-4 ft tall. (C) Shoreline plantings north and south of the double row cover had <1% survival. Isolated, surviving plants in the NW corner were very small (~3 ft).

b. Planting Failure/Success Causation

Low survivorship was prompted by a sustained, high salinity event that occurred during the critical time of plant installation and establishment (Fig. XI-8). From late July to early November 2015, water salinities were typically greater than five (5) parts per thousand (ppt) which is the upper-limit salinity for newly planted California bulrush (Fine and Thomassie. 2000). Water salinity reached a maximum of 13 ppt during this event. Such a high and sustained salinity event is anomalous for this area.

Curiously, not all plantings were affected by the salinity. Salinity and planting depths were typically uniform throughout the Green Island Bayou site during monitoring trips, and the CRMS1650 station is northeast of the site, closest to the North area. Water bottom soils were more unconsolidated in the area plantings in the south (Ponds 6, 7, and 9) where survival was lowest while water bottom soils were more firm in the area plantings to the north (Ponds 1-5) where survival was greater. The firmer soils are less porous and may provide more protection against salt intrusion from the above water column; firmer soils also hold plants in place better during high water/wind events.

Plantings along the shoreline of the larger water bodies were also exposed to higher wave energy than the other planting types. Survival was higher among shoreline plantings where the shoreline was more protected, such as in coves.

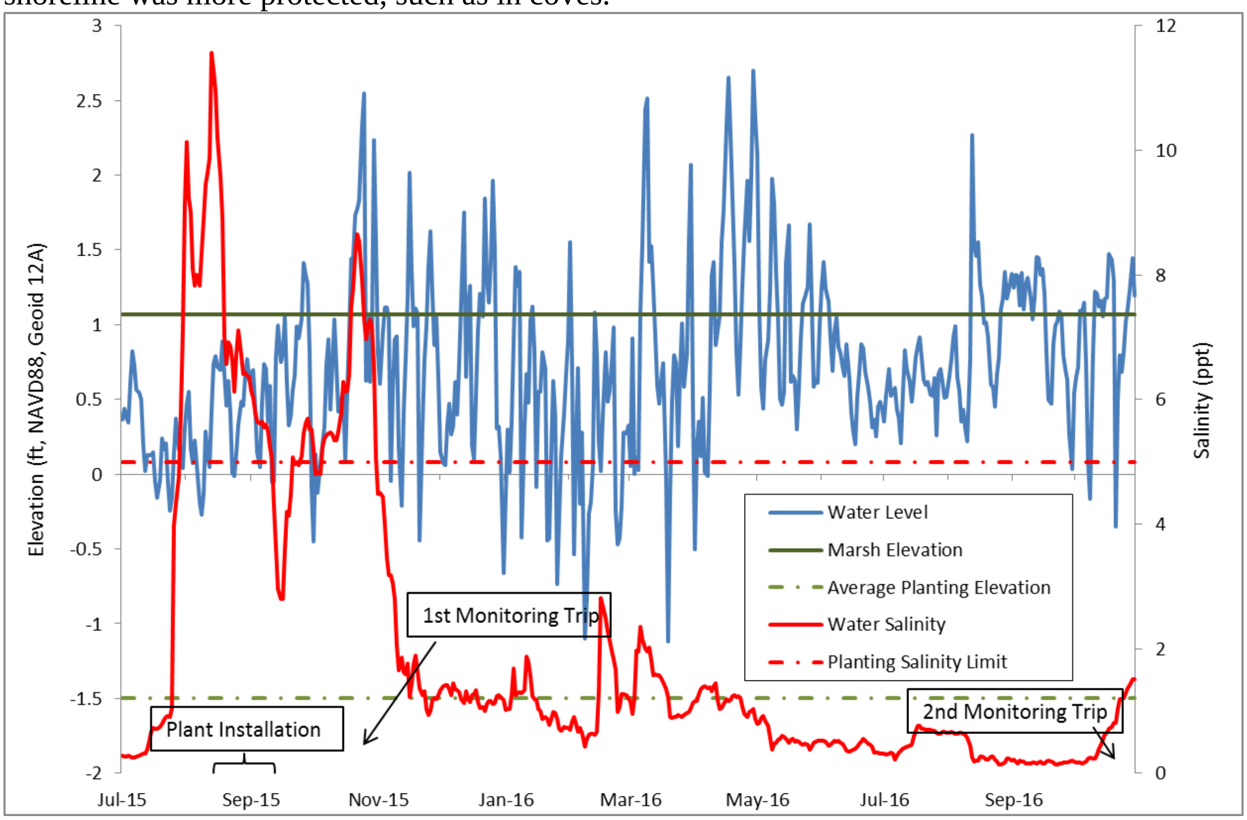


Figure XI-8. Daily averages of water-level elevation (left y-axis) and salinity (right y-axis) from CRMS1650-H01 are plotted relative to average planting elevation (left y-axis) and upper-limit salinity (right y-axis).

C. Conclusions

The Green Island Bayou plantings have had mixed success to this point in their post planting monitoring. The Area plantings to the north have performed far better than those to the south. Overall the double row plantings have had above average success and the shoreline plantings failed to thrive. The California bulrush area plantings in the north and along sections of the double rows survived and expanded despite some initial loses from unusually high salinity at the time of plant installation. The north south proximity of the plantings which reflected some variation in soil conditions seemed to be a consistent predictor of success or failure, possibly due to soil porosity and high salinity surface water conditions at the time of planting.

1. Project Effectiveness

As per the project goals:

- Northern Area Plantings have survived and expanded to increase vegetation in smaller open-water area adjacent to larger open-water areas, but Southern Area Plantings have not.
- Shoreline plantings did not survive and expand to reinforce the shoreline of open-water bodies.
- Double row plantings have survived and expanded.

2. Recommended Improvements

Regardless of the period selected for plant installation, it is recommended that project sponsors incorporate flexibility in planting dates to provide some opportunity to avoid planting during high salinity events.

Re-planting of Shoreline Plantings is not recommended. Re-planting of Double Row and southern Area Plantings is recommended.

3. Lessons Learned

A provision in the planting specifications like the one for high water levels should be added for high salinity conditions relative to the species being planted. Once established, stands of California bulrush can withstand high salinity waters in the project area without any long term negative effects. This area shows that after establishment the plantings are far more resilient to salinity variation above the area average and future plantings in the area will likely be successful.

XII. Year 4 – Rockefeller Unit 4

Prepared by Mark Mouledous – CPRA Lafayette Regional Office

A. Site Description

Rockefeller State Wildlife Refuge is located in Vermilion and Cameron Parishes between the Gulf of Mexico and LA Hwy 82. The LA-0039 Year 4 – Rockefeller Unit 4 plantings were planted within the northwestern portion of the Refuge's Unit 4, which is managed by the Louisiana Department of Wildlife and Fisheries as a multi-use area to provide controlled access to estuarine organisms (Fig. XII-1). The plantings were designed to establish perennial emergent vegetation in areas devoid of vegetation and/or in areas with sparse annual vegetation.

The areas that were planted are categorized as shallow open-water habitats with some very sparse emergent marsh. Twenty-two double rows of trade-gallon sized *Schoenoplectus californicus* (California bulrush) were planted (Fig. XII-1). Each double row consisted of parallel rows fifteen feet (15 ft) apart with plants on five foot (5 ft) alternating centers. The double row alignment was designed to bisect some of the open water areas and create wave breaks. A total of 11,350 plants were planted between April 20 – April 24, 2015.

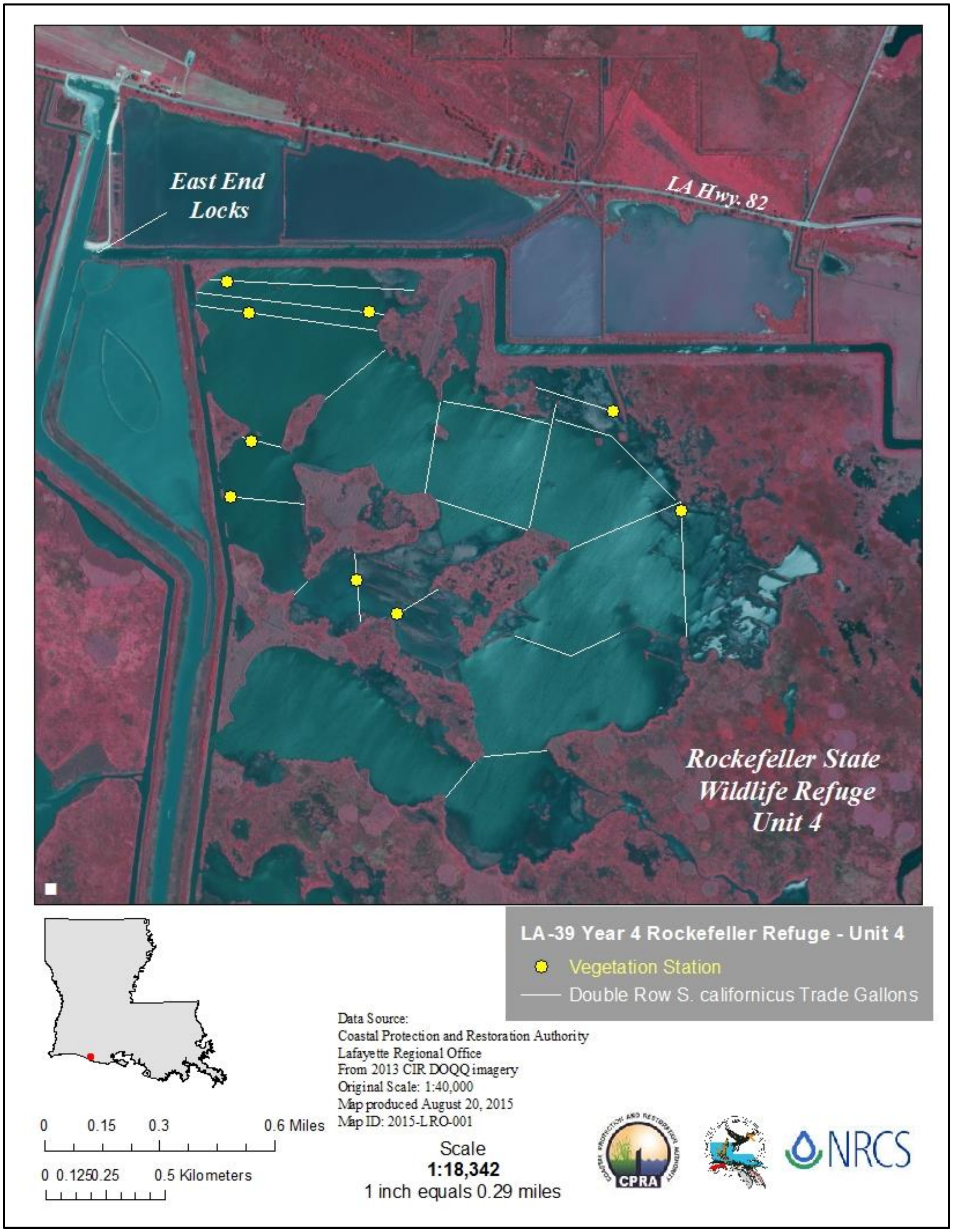


Figure XII-1. LA-39 Year 4 Site – Rockefeller Unit 4 Plantings site map showing location of plantings and vegetative monitoring stations.

B. Monitoring Activity

1. Monitoring Goals

The Year 4 Rockefeller Unit 4 plantings were designed to create thick hedgerows of *Schoenoplectus californicus* within open water areas to protect project area shorelines and decrease wind driven wave fetch.

The goals of the Rockefeller Unit 4 plantings are:

- Double row plantings of *Schoenoplectus californicus* in close proximity to pond shorelines will achieve at least 50% survival and expand cover.
- Double row plantings of *Schoenoplectus californicus* across open-water areas will achieve at least 50% survival and expand cover.

2. Monitoring Elements

The monitoring elements include procedures to assess plant survival, effects on the planting area, and the recruitment of any other emergent marsh vegetation to the area. Vegetation stations were intended to monitor planting survival and vegetative cover throughout the Rockefeller Unit 4 planting area over time (Table XII-1). However, sampling stations were limited to locations with surviving plants because planting survival was low (25%) during the initial monitoring trip on August 6, 2015 (T_1), three and a half months following the planting inspection (T_0).

Table XII-1. Sampling scheduled for LA-39 Year 4 site, Rockefeller Unit 4.

Sampling Type	T_0 2015	T_1 2015	T_2 2016	T_3 2018	T_4 2020
Planting Survival	April	August	August	Spring	Spring
Percent Cover	April	August	August	Spring	Spring

<u>Vegetation Assessment</u>

To assess planting status, an ocular estimate of % survival and plant condition was conducted for each double row. Planting survival and % vegetative cover data was also collected at the vegetation station level. Vegetation stations were limited to locations with remaining live plants; therefore nine (9) stations were established along the double row plantings. Percent survival was calculated from a set of 10 plants at each vegetation station; plants were characterized as live or dead/absent. PVC poles were placed on both ends of the plants monitored for survival over time. Percent cover of the species present and planting heights was measured in 4 m^2 vegetation stations (Folse et al. 2014). Surface water depth, salinity, and temperature were also collected at all sampling stations during each sampling event. Conditions occurring outside of the stations and segments including additional species, marsh interspersion, and site-specific points of interest were noted along with photo documentation. At the time of the planting inspection (T_0 – April 24, 2015), planting survival was assumed to be 100% overall; vegetation station level %

planting survival, % cover, and stem heights were assumed to be 100%, 3%, and 91 cm (36 inches), respectively.

Planting Failure/Success Causation

Hydrologic data from CRMS0581-H01 located within the southeastern area of Unit 4, a temporary staff gauge installed during construction by NRCS staff, and Louisiana Department of Wildlife and Fisheries staff records were used to convert water depth (ft) to estimated planting elevations (ft, NAVD88 Geoid12a) to describe area water-level trends during and after plant installation. The water-level data were tied to water depths collected within the planting areas to estimate flood depths in the project area.

3. Monitoring Results and Discussion

a. Vegetation Assessment

Overall, percent survival of the plantings was low at around 25% during the August 2015 sampling (Table XII-2). Lowest survival occurred along rows planted in large open water areas. In these areas, plant survival was limited to the ends of rows near the shoreline, and even these plants appeared somewhat sparse and stressed (Fig. XII-3). Orientation of the rows did not seem to matter as much as the size of the pond area. By August 2016, percent survival decreased to 16%. Moderate survival was observed in areas that were planted near terraces or within broken marsh sections that provided the plantings with protection from wind and wave action. In these areas, percent survival as high as 85% was observed. In August 2016, percent survival dropped even further, but the remaining plantings looked healthy and were forming clumps and even spreading some in the northeastern protected area (Fig. XII-4). The percent cover of the sample plots increased from 3% per sampling plot to near 17% over the course of one year (Figs. XII-2A and B). Average stem height nearly doubled as well from 4.2 ft in 2015 to ~8 ft in 2016. Very few plantings remain outside of well protected areas, and those that have survived showed poor condition (Figs. XII-3 and 6).

Table XII-2. Overall % Survival of LA-39 Year 4 Rockefeller Refuge plantings were estimated over time while conducting monitoring field trips.

	% Overall Survival		
Planting Type	T_0 Apr 2015	T_1 Aug 2015	T_2 Aug 2016
Double Row plantings	100	27	16

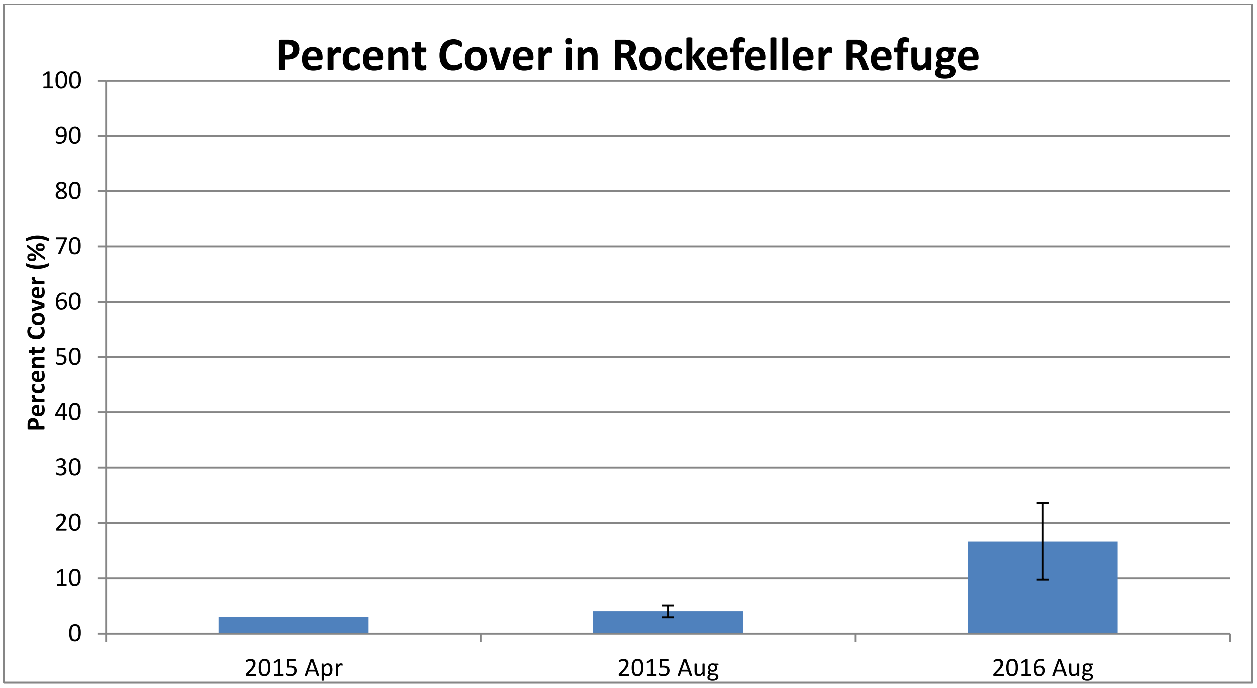


Figure XII-2A. Percent cover collected from vegetation stations at Rockefeller Unit 4 from April 2015 – August 2016. Error bars represent standard error.

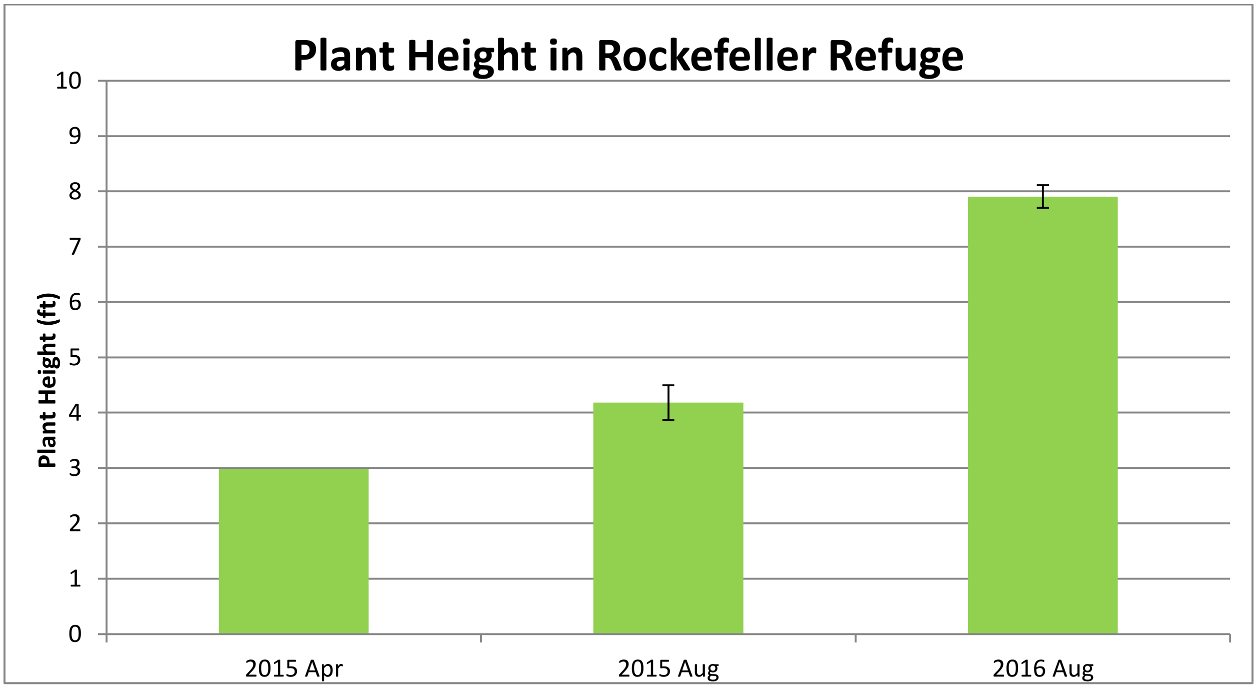


Figure XII-2B. Plant heights collected from vegetation stations at Rockefeller Unit 4 from April 2015 – August 2016. Error bars represent standard error.

Figure XII-3. View of surviving S. californicus plantings on end of row across northern open water area in August 2015.

Figure XII-4. View of healthy *S. californicus* forming clumps in the protected, northeast double row in August 2016.

b. Planting Failure/Success Causation

The low survival of plantings was likely caused by high water/flooded conditions and wave energy, contributing to uprooting of plants in those areas that had minimal protection from the elements and were not well established. Water levels following construction were fairly consistent, around 0 ft NAVD88, until mid-June when a heavy rain caused water levels to rise by over a half a foot within Unit 4 (Fig. XII-5). Water levels during this period exceeded the maximum water elevation of 0.43 ft NAVD88 (Geoid12a) established for the planting period within the plans and specs by the NRCS Contracting Officer. Given that the average height of the plants at installation was 36", there would have been about 1.5 ft of stem above the water line at planting and less than a foot for June 14-19. Granted, this was not during the planting period; however the plantings were still becoming established and had not firmly rooted themselves to the substrate. In addition, rafts of algae were observed in many of these areas growing along and on the remaining plantings, adding further stress to the young plantings (Fig. XII-6). Depth of water did not seem to be a factor on plant survival as water depths were fairly consistent throughout the project area and planting success did not seem to vary from the shallower areas to the deeper areas. Salinities did not affect survival, either, as average salinities during the 2015 and 2016 surveys were 3.5 ppt and 2.5 ppt, respectively. Consistency of pond bottoms varied from firm to soft but also did not appear to contribute to planting success as much as protection from the elements.

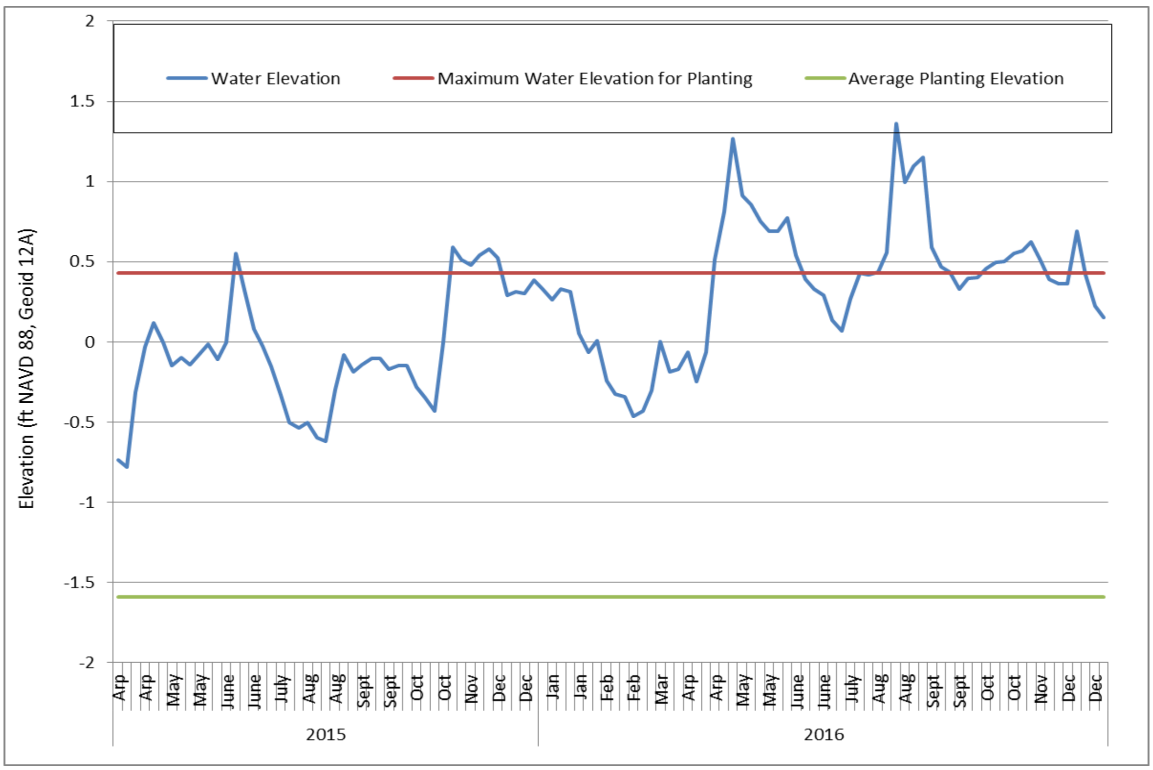


Figure XII-5. Hydrograph of nearby CRMS0581 displaying daily water levels in the LA-39 Rockefeller Unit 4 planting area from planting through the end of 2016.

Figure XII-6. Example of algal rafts collecting on stressed *S. californicus* plantings in August 2015.

C. Conclusions

1. Project Effectiveness

As per the project goals:

- Double row plantings in close proximity to pond shorelines were not successful in forming hedges to protect shorelines. Planting survival was low (25%) three and a half months after planting and decreased over the first year. Remaining plants were sparse and stressed except for an area protected by broken marsh and other double rows.
- Double row plantings across open-water areas were not successful in forming hedges to disrupt fetch. Survival within the large open water areas of the project was typically < 5%.

2. Recommended Improvements

Limit *Schoenoplectus californicus* plantings to areas protected from wind and wave energy due to the low survival of plantings that were exposed to these conditions directly after planting. Consideration could be given to increasing the density of plantings if this planting strategy is repeated in future projects.

3. Lessons Learned

Fetch across the large open water areas was too great for survival of newly installed plants, especially during elevated water levels that occurred within the 8 weeks following the planting effort. Although storm systems are unpredictable, if the plants would have had time to become more firmly rooted, performance would likely have improved.

XIII. Summary

A. Project Effectiveness

The LA-0039 Coastwide Planting project has successfully developed a program to facilitate a consistent and responsive planting effort in coastal Louisiana that is flexible enough to routinely plant on a large scale and be able to rapidly respond to locations of need following storms or other damaging events. Within the traditional CWPPRA project process, the time from project selection to construction typically takes 5-10 years. Within LA-0039, a site selected for planting can be planned, bid for contract, awarded, and planted within 1-2 years. This is a much more expedited time frame than other CWPPRA projects. As such, the monitoring portion of the project must also be efficient in data collection and analysis to put information back into the planning process to move the capabilities of the project forward.

Overall *Schoenoplectus californicus* (California bulrush) plants have been successfully transplanted and established at many LA-0039 project locations (Table XIII-1). This has led to the expanded usage of this species in more recent planting sites. However, *Spartina alterniflora* Vermilion (smooth cordgrass) has not been shown to adapt well after transplant in the sites selected by LA-0039. This is likely due to the depth of many of the planting locations, but other factors such as wave erosion, lack of tidal exchange, organic soils, and rafting vegetation are also factors causing mortality in smooth cordgrass plantings. As the planting locations are selected, planted, and monitored, the selection process is refined in an adaptive management framework allowing for both, a more streamlined approach to site selection and better planting outcomes.

B. Recommended Improvements

Many of the plantings are installed at or near the depth thresholds for the successful establishment of California bulrush, leaving the new plants susceptible to unforeseen flood events. Focusing the plantings on slightly higher elevations may provide increased survivorship in the event of flooding conditions immediately following plant installation. Even in locations that have been successfully colonized with new plantings, negative long-term outcomes are still possible due to the physical smothering of plants with floating aquatic vegetation rafts. This is typically only a concern in fresh locations. Plant species selection and planting design may be able to mitigate some of these losses in the future by avoiding long linear rows and using *Zizaniopsis miliacea* (giant cutgrass) which appears to be less susceptible to this form of damage. The density at which rows and areas are planted may need to be refined as California bulrush plantings seem to cause interspecific competition by year one post planting when survival is high; this limits the area of impact for the specific location and the growth potential of individual plants. Also California bulrush appears to rapidly cycle through the resources in a given location, failing to maintain vigorous growth through years two and three in some locations depending on nutrient and sediment input. Overall, California bulrush has shown good potential in many fresh to intermediate planting locations and should continue to be the main focus while still employing other species in limited applications to expand the available species and habitats types in which LA-0039 can operate successfully.

C. Lessons Learned

Shoreline plantings along large water bodies with wind fetch created waves have failed to become established and as such have not proven beneficial in reducing shoreline erosion. Even in cases where shoreline plantings have been established such as Boston Canal/Vermilion Bay Shoreline Stabilization Project (TV-0009), the reduction in erosion may not be significant. Therefore, focusing the resources of the LA-0039 project on more protected locations would likely increase the overall successes rate of plantings. These interior locations however don't appear to be favorable to smooth cordgrass as that species has failed when planted in continuously flooded interior areas with diminished tidal cycles. Smooth cordgrass has repeatedly been very successful in conjunction with terrace construction, marsh creation, and naturally accreting mudflats as a pioneer species either planted or naturally occurring. Therefore, areas with tidal flow and undergoing siltation may be good candidates to be planted with smooth cordgrass.

Table XIII-1. Summary of LA-39 planting variables and observations from monitoring field trips through 2016.

LA-39 Planting Area	Year	Planting Type	Species Planted	Current Percent Survival (%)	Current Percent Cover (%)	Average Salinity (ppt)	Average Planting Elevation (ft, NAVD 88, GEOID 12A)	Average Water Elevation (ft, NAVD 88, GEOID 12A)	Floating Vegetation or Rafting Observed	Cause of any Major Plant Loss
South Lake DeCade	1	Shoreline Broken Marsh	Smooth Cord, Cal Bul	4	6	1.8	-1.2	0.5	Yes, SAV and FAV	Flooding/Rafting by FAV
Cameron Creole	1	Interior Broken marsh	Smooth Cord	0	0	11.1	-0.3	0.6	Yes, SAV	Flooding/Rafting by SAV
Marsh Island	1	Shoreline Interior	Smooth Cord, Cal Bul	0	0	4.7	0.3, -0.5	0.6	No	Shoreline erosion/Flooding
The Prairie	2	Open water Shoreline	Cal Bul, Smooth Cord	~100	78	1.1	-0.7	0.5	Yes, FAV no rafting	NA
West Little Lake	2	Interior Shoreline	Cal Bul, Smooth Cord	48	30	1.9	-1.0	0.5	Yes, FAV and SAV	Shoreline erosion/Rafting
The Jaws	3	Open water Shoreline	Cal Bul	93*	20*	0.4	-0.9	0.9	Yes, FAV.	Rafting from Water Hyacinth
Little Vermilion Bay	3	Interior	Cal Bul	84	48	1.6	-0.7	0.7	No	Herbivory by nutria/muskrat
Willow Lake	3	Shoreline Open water	Cal Bul, Roseau	80	36	0.4	-1.4	0.8	Yes SAV and FAV	Rafting/ Herbicide
Green Island Bayou	4	Shoreline Interior	Cal Bul	29	18	2.0	-1.5	0.7	Yes some FAV	High salinity at planting
Rockefeller Unit Four	4	Open water	Cal Bul	16	17	3.0	-1.6	0.2	Some algae	High water just after planting

Cal Bul = California bulrush, Smooth Cord = Smooth cordgrass, Roseau = Roseau cane
*Almost completely destroyed by rafts of water hyacinth as of recent observations.

XIV. References

Byrnes, M.R., J.L Berlinghoff, S.F. Griffee, S.G. Underwood, D.M. Lee, and S. Khalil. In Press. Louisiana Barrier Island Comprehensive Monitoring Program (BICM): Phase 2 – Shoreline Compilation and Change Assessment. Prepared for Louisiana Coastal Protection and Restoration Authority (CPRA) by Applied Coastal Research and Engineering, Baton Rouge, LA. ## pp.

Coastal Protection and Restoration Authority (CPRA) of Louisiana. 2017. Coastwide Reference Monitoring System-Wetlands Monitoring Data. Retrieved from Coastal Information Management System (CIMS) database. http://cims.coastal.louisiana.gov.

Couvillion, B.R.; Barras, J.A.; Steyer, G.D.; Sleavin, William; Fischer, Michelle; Beck, Holly; Trahan, Nadine; Griffin, Brad; and Heckman, David, 2011, Land area change in coastal Louisiana from 1932 to 2010: U.S. Geological Survey Scientific Investigations Map 3164, scale 1:265,000, 12 p. pamphlet.

Crain, C.M., B.R. Silliman, S.L. Bertness, and M.D Bertness. 2004. Physical and biotic drivers of plant distribution across estuarine salinity gradients. *Ecology* 85: 2539−2549.

Fine, G. and G. Thomassie. 2000. Release Brochure Vermilion smooth Cordgrass (*Spartina alterniflora*). Golden Meadow Plant Materials Center. Galliano, LA. (USDA/NRCS ID# 5830).

Folse, T.M, L.A. Sharp, J.L. West, M.K. Hymel, J.P. Troutman, T.E. McGinnis, D. Weifenbach, L.B. Rodrigue, W.M. Boshart, D.C. Richardi, W.B. Wood, and C.M. Miller. 2008, revised 2014. A Standard Operating Procedures Manual for the Coastwide Reference Monitoring System-*Wetlands*: Methods for Site Establishment, Data Collection, and Quality Assurance/Quality Control. Louisiana Coastal Protection and Restoration Authority. Baton Rouge, LA. 228 pp.

Materne, M. and G. Fine. 2000. Plant Guide *Schoenoplectus californicus* California bulrush. Baton Rouge, LA. Sept. 2000. 6p. (USDA/NRCS ID# 5831).

NOAA National Centers for Environmental Information, State of the Climate: Drought for Annual 2011, published online January 2012, retrieved on January 26, 2017 from http://www.ncdc.noaa.gov/sotc/drought/201113.

NOAA National Centers for Environmental Information, State of the Climate: Drought for Annual 2012, published online January 2013, retrieved on January 26, 2017 from http://www.ncdc.noaa.gov/sotc/drought/201213.

NOAA National Centers for Environmental Information, State of the Climate: Drought for Annual 2013, published online January 2014, retrieved on January 26, 2017 from http://www.ncdc.noaa.gov/sotc/drought/201313.

NOAA National Centers for Environmental Information, State of the Climate: Drought for Annual 2014, published online January 2015, retrieved on January 26, 2017 from http://www.ncdc.noaa.gov/sotc/drought/201413.

NOAA National Centers for Environmental Information, State of the Climate: Drought for Annual 2015, published online January 2016, retrieved on January 26, 2017 from http://www.ncdc.noaa.gov/sotc/drought/201513.

NOAA National Centers for Environmental Information, State of the Climate: Drought for Annual 2016, published online January 2017, retrieved on January 26, 2017 from http://www.ncdc.noaa.gov/sotc/drought/201613.

NOAA Tides and Currents, Meteorological Observations: Wind Speed and Direction, published online October 2014, retrieved on May, 2017 from https://tidesandcurrents.noaa.gov/met.html?id=8762482.

Natural Resources Conservation Service (NRCS). 2010. Coastwide Planting Project: Project Information Sheet for Wetland Value Assessment. Coastal Wetlands Planning, Protection and Restoration Act 20th Priority Project List. 20 pp.

O'Neil, T. and G.A. Snedden. 1999. Three-Year Comprehensive Monitoring Report: Turtle Cove Shoreline Protection (PO-10). Louisiana Department of Natural Resources, Coastal Restoration Division. Baton Rouge, LA. 25 pp.

Thibodeaux, C., and S. Aucoin 2008. 2008 Operations, Maintenance, and Monitoring Report for the Four-Mile Canal Terracing and Sediment Trapping (TV-18), Coastal Protection and Restoration Authority of Louisiana, Office of Coastal Protection and Restoration, Lafayette, Louisiana 37 pp.

USACE. 2014. SEA-500a Manchac WMA Shoreline Protection Modification Additional Borrow. USACE, Regional Planning and Environmental Division South. 38 pp.

Wood, B. and Guidry, M. 2014. 2014 Operations, Maintenance, and Monitoring Report for Boston Canal/Vermilion Bay Shoreline Stabilization (TV-09), Coastal Protection and Restoration Authority of Louisiana, Lafayette, Louisiana 40pp and Appendices.

Wood, B., and S. Aucoin 2016. 2016 Operations, Maintenance, and Monitoring Report for Little Vermilion Bay Sediment Trapping (TV-12), Coastal Protection and Restoration Authority of Louisiana, Lafayette, Louisiana. 45pp and Appendices.