Monitoring Series No. C/S-19-MSTY-1297-1

THREE-YEAR COMPREHENSIVE MONITORING REPORT

Coast 2050 Region 4

WEST HACKBERRY PLANTINGS AND SEDIMENT ENHANCEMENT
C/S-19

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

Charles M. Miller

Louisiana Department of Natural Resources
Coastal Restoration Division
P.O. Box 94396
Baton Rouge, La 70804-9396

December 1997

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

ACKNOWLEDGMENTS

We acknowledge the U.S. Geological Survey, National Wetlands Research Center (NWRC), particularly Robert Greco and Holly Gaudet, for land-water analysis and assisting in the preparation of this comprehensive report. Reviews of the draft report by Greg Steyer, Ralph Libersat, and David Soileau of LDNR/CRD, Cindy Steyer of the Natural Resources Conservation Service (NRCS), and by Dr. John A. Nyman of the Department of Biology, University of Southwestern Louisiana were helpful in improving the document.

ABSTRACT

The West Hackberry Plantings and Sediment Enhancement project (C/S-19) is located within Cameron Parish, about 6 mi (9.7 km) west of Hackberry, Louisiana. The project objectives are to restore, protect, and enhance about 300 ac (120 ha) of inland wetlands by using *Scirpus californicus* plantings to reduce wind-driven wave erosion of marsh shorelines, and using hay-bale fences to increase sediment deposition. Ponds in the project area range approximately one to three ft (0.3-0.9 m) deep. In April 1994, 6,000 linear ft (1,829 m) of hay-bale fencing was installed. In June 1994, approximately 4,750 trade-gallon-size plantings of *S. californicus* (California bulrush) were installed along 11,875 linear ft (3,620 m) of shoreline.

Initial hay bales disintegrated within three months; a second set disintegrated within two weeks. It was therefore concluded that hay bales could not reduce erosion at this site, and erosion measurements were discontinued. Decomposition of the hay, rather than wave energy, appeared to prevent hay from remaining in the fences. Results of this project suggest that hay bales are not a suitable material for enhancing sediment deposition in ponds.

Scirpus californicus plantings were initially successful, creating 4.3 ac (1.7 ha) of emergent wetland, but only 1.2 ac (0.5 ha) survived the drought of 1996. Water salinity in the area during the drought rarely fell below 20 ppt for six weeks, which probably exceeded the salinity tolerance of *S. californicus*. Plantings that survived the drought appeared to have spread more prior to the drought. This suggests that survival might have been greater if the drought had occurred after the plantings had become more established. Planting *S. californicus* is therefore still considered a viable restoration tool.

INTRODUCTION

Coastal navigation channels have played a major role in wetland loss. The losses resulting from channels are categorized as either primary losses (i.e., those resulting directly from construction) or secondary losses (i.e., those long term losses induced by the presence of channels). Primary losses include the impacts resulting from the excavation of the channel and the placement of the resulting dredge material, while secondary wetland losses are caused by 1) hydrologic modifications resulting from the channel (e.g., saltwater intrusion and disruption of natural sheet flow) and 2) erosion of the channel bank resulting from vessel-generated wave wash (Good et al. 1995).

Navigation channels have caused marsh loss near Hackberry, Louisiana, primarily via secondary mechanisms. Kelso Bayou was historically the only passageway for water exchange between Black Lake and the surrounding marshes. Construction of the Alkali Ditch, Gulf Intracoastal Waterway (GIWW), and the Calcasieu Ship Channel increased the number of passageways to Black Lake. The West Cove Canal, located in the Sabine National Wildlife Refuge, has a direct link to the Calcasieu Ship Channel. This canal, which houses the Hog Island Gully structure, is also a major factor in contributing saltwater into the West Hackberry Plantings project area via the Gulf of Mexico. This increase in exchange points has resulted in 1) increased salinities, 2) increased water fluctuations, 3) increased opportunities for saltwater intrusion, and 4) increased tidal scouring and erosion (NRCS 1993).

The West Hackberry Plantings and Sediment Enhancement project (C/S-19) is located within the Rycade Canal Marsh Management project (C/S-02) area (figure 1). Shoreline erosion has created vast expanses of shallow open water which in turn allows wind induced erosion along the remaining shorelines. Ponds within the project area are approximately one to three ft (0.3-0.9 m) deep. In order to deter further erosion, approximately 4,750 trade-gallon-size plantings of *S. californicus* were installed parallel to the 11,875 ft (3,620 m) of shoreline, and hay-bale fencing was constructed parallel to another 6,000 ft (1,829 m) of shoreline.

Salinity and water level data collected within the C/S-02 project area were used to help evaluate success of the C/S-19 vegetative plantings. Statistical analysis previously performed on C/S-02 was reviewed and compared to the statistical analysis from C/S-19 to determine project effectiveness.

The project objectives are to restore, protect, and enhance about 300 ac (120 ha) of inland wetlands by using vegetation plantings to minimize wetland erosion, and hay-bale fences to encourage sediment deposition.

The specific goals of this project are to :

1. Reduce wind-driven wave erosion of marsh shorelines using *S. californicus* plantings.
2. Increase sediment deposition adjacent to hay-bale fences.
3. Increase the amount of emergent and submersed aquatic vegetation.

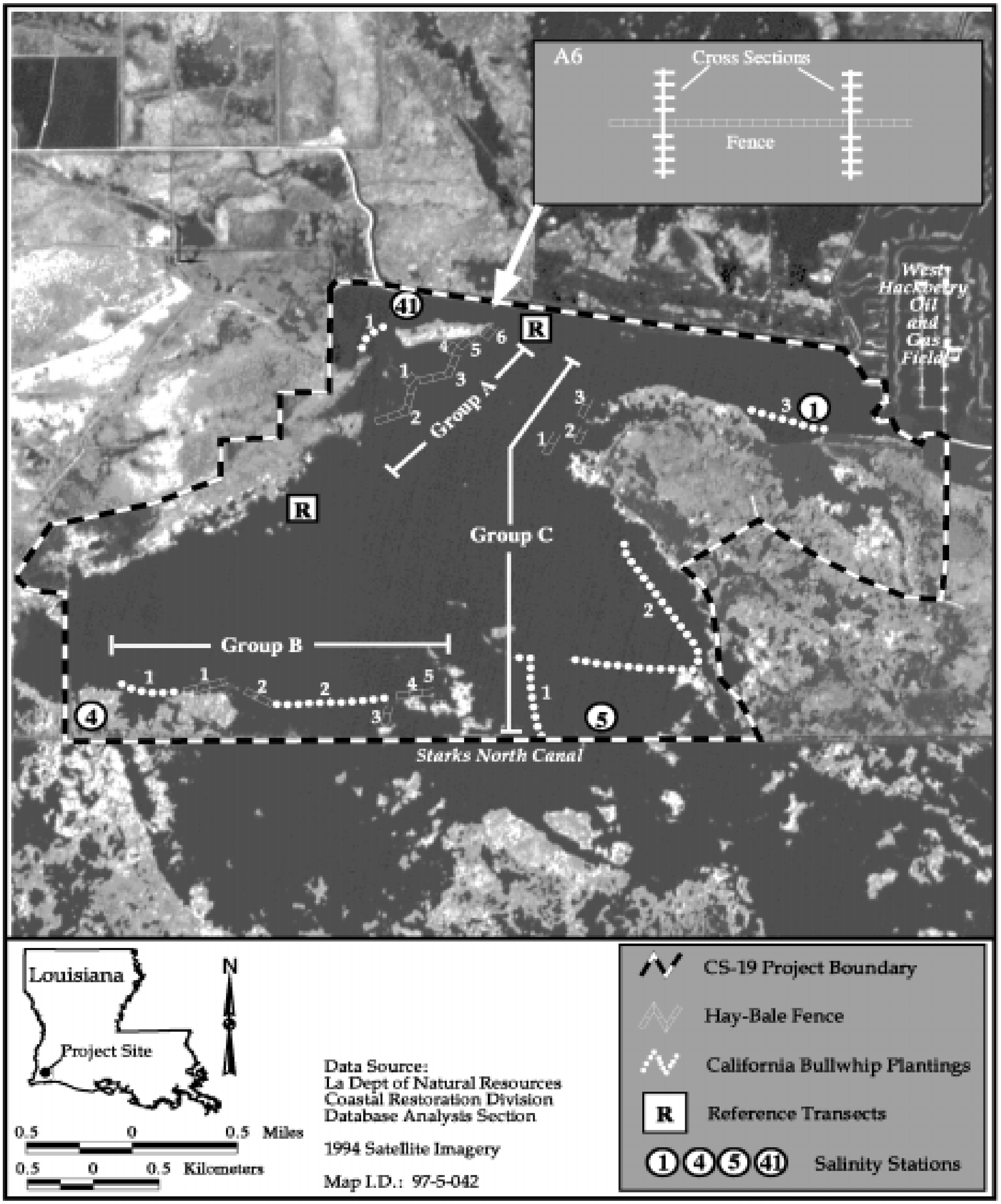


Figure 1. West Hackberry Plantings and Sediment Enhancement (C/S-19) project area showing locations of restoration features and a typical cross-section elevation survey within Group A.

METHODS

A detailed description of the monitoring design over the entire project life can be found in Miller (1994).

The National Wetlands Research Center (NWRC) in Lafayette, Louisiana obtained 1:12,000 scale near-vertical color-infrared aerial photography on November 1, 1993 (pre-construction) and November 23, 1997 (post-construction). After scanning, mosaicking, and georectifying the photography, the NWRC performed a geographic information systems (GIS) analysis to determine shoreline movement and land-water ratio within the project area. Photographs were checked for flight accuracy, color correctness, and cloudiness. The original film was archived and the duplicate photography was prepared for scanning and analysis. A digital TIFF file with a resolution of 300 pixels per inch was created from the photography. Using PCI, an image processing software, the photography was mosaicked and used to generate a base map. Optimal global positioning system points were collected in the field in order to georeference the base map in the Universal Transverse Mercator (UTM) coordinate system. The resulting preconstruction map (map i.d. #97-2-068) was then analyzed with ERDAS Imagine to determine land-water ratio. Each of these steps was completed according to the standard operating procedure described in the *Quality Management Plan for Coastal Wetlands Planning, Protection and Restoration Act* (Steyer et al. 1995). Historical changes in marsh to open water ratio were obtained from 1934 and 1982 USGS quadrangle maps.

In May and June, 1994, six hay-bale fences were randomly selected and tagged for elevational transect surveys and two reference sites were located and marked. Shoreline markers were deployed along two sections of shoreline to be surveyed, one west of fence A6, and one southwest of the Group A fences. In August 1994, a professional cross-sectional survey by Pyburn & Odom Inc. was conducted across the selected hay-bale fences and the two reference sites. In addition, the two sections of shoreline on which the shoreline markers were installed were surveyed using a Global Positioning System (GPS) to record the current position.

Sediment deposition and the occurrence of submersed aquatic vegetation (SAV) along the hay-bale fences were monitored along 16 transects established across and perpendicular to a sub-sample of 6 fences (A2, A6, B3, B4, C2, and C3). A typical cross section transect at station A6 can be seen in figure 1. For use as a reference, two additional transects were established in open water away from the fences, one north of fence A6 and one south of the Group A fences.

In July, 1994, sampling plots were randomly selected and delineated for use in vegetation monitoring. A 5% sample of the vegetation plantings, consisting of 16 randomly selected plots of 16 plants (8 plants on each of 2 rows) was monitored for survivorship (percent survival), species composition, and percent cover in August 1994, February 1995, August 1995, October 1996, and August 1997. Monitoring in October 1996 (month 27) was not initially planned, but was conducted to evaluate the effects of drought on planting survival (LDNR 1995).

Planting survival was evaluated in terms of four variables (Harper 1977), which are defined and calculated as follows:

$$\text{survival frequency} = \text{number of live plants inside plot at timepoint } x$$

$$\text{survivorship } (l_x) = \textit{probability (at planting time) of surviving until age } x = \frac{\textit{no. live plants inside plot at timepoint } x}{\textit{original no. plants inside plot}}$$

$$\text{mortality } (d_x) = \text{probability (at planting time) of dying during age interval } x, x+1 = l_x - l_{x+1}$$

$$\text{mortality rate } (q_x) = \text{probability of a planting at age } x \text{ dying before the age of } x+1 = \frac{l_x - l_{x+1}}{l_x} = \frac{d_x}{l_x}$$

Cover was initially measured in 1 m^2 sub-plots centered around one corner plant within each 16-plant sampling plot. By 6 mo postplanting, however, the selected corner plants for vegetation sampling plots B2−4, C1−3, and C2−2 were absent. To overcome this problem, percent cover was subsequently recorded for each entire 16-plant sampling plot, rather than for only the 1 m^2 sub-sample plots. These new plots averaged 40 ft (12.2 m) long and 35 ft (10.7 m) wide.

The effect of salinity on planting success was evaluated using salinity data collected from an adjacent restoration project at Rycade Canal (C/S-02). Pre-construction (September 1993 to June 1994) and post-construction (July 1994 to September 1995) salinity data from the Rycade Canal (C/S-02) project, which influences salinity in the West Hackberry Plantings area, were analyzed.

A two-way analysis of variance (ANOVA) with repeated measures was performed on the mortality and percent cover data to evaluate changes in mortality and percent cover rates among the five monitoring periods (0 to 1 mo, 1 to 6 mo, 6 to 12, and 12 to 36 mo postplanting).

RESULTS

Land/water Ratio: The GIS analysis determined that when the pre-construction aerial photography was taken, the project area consisted of 742 ac (300 ha) of land and 3,342 ac (1,353 ha) of open water, a ratio of 0.22:1 (figure 2). Analysis of the 1997 photography is ongoing.

Hay-bale Fences: Hay bales did not remain intact for very long. By July 1994, the Group A and C hay-bale fences were empty, while some hay remained in the Group B fences. In December 1995, group A, fence A3, was modified and refurbished with hay bales, and fence A2 was refurbished with hay bales wrapped in plastic geogrid fabric. Within two weeks, all of the hay was washed out of the enclosures. In March 1995, the Natural Resources Conservation Service (NRCS) and Cameron Parish installed discarded Christmas trees in fences A3-A6. As of October 23, 1996, about 70% of the Christmas trees remained in the enclosures. Subsequent post-construction surveys have been canceled due to the inability of the fences to hold hay.

The results demonstrated that hay-bale fences are ineffective at abating wave energy as designed and deployed in this environment because the hay deteriorated rapidly after exposure to water. Once this happened, even minimal wave action caused the hay bales to break apart. However, the treated lumber fences have remained intact. The fences have secondarily become wave damping fences, deterring some of the wind generated wave energy. Typical elevation profiles are provided in figures 3 and 4.

Vegetative Plantings Cover: The mean percent cover at 1, 6, 12 and 36 mo postplanting was 5%, 9%, 45.2%, and 13.1% respectively (table 1). Significant difference ($\alpha = 0.05$) in percent cover was found among the planting groups over time (table 2). Significant differences occurred among percent cover between 1 - 12 mo ($p = 0.028$), 6 -12 mo ($p = 0.005$), and 12 - 36 mo ($p = 0.003$) respectively (table 3). The largest decrease in cover was noticed after the high salinity water entered into the project area during the drought of 1996 (figure 5).

Data indicated that *S. californicus* plantings established relatively quickly where salinities did not exceed 8 ppt. After an initial period of establishment, there was a significant decrease in mortality rate and a significant increase in percent cover during the first year postplanting (figures 5 and 6). Observations in October 1996 suggest that early establishment and rapid growth may also help to buffer the more vigorous transplants from die-back resulting from extreme environmental conditions, such as high salinity.

Vegetative Plantings Survival: Survivorship (percent survival) decreased during the first 36 mo postplanting, averaging 76.2%, 59.1%, 56.4% and 23.6% at 1, 6, 12 and 36 mo postplanting, respectively (figure 6). Significant differences ($\alpha = 0.05$) occurred among survivorship at all time periods except 6 mo to 12 mo postplanting (table 4).

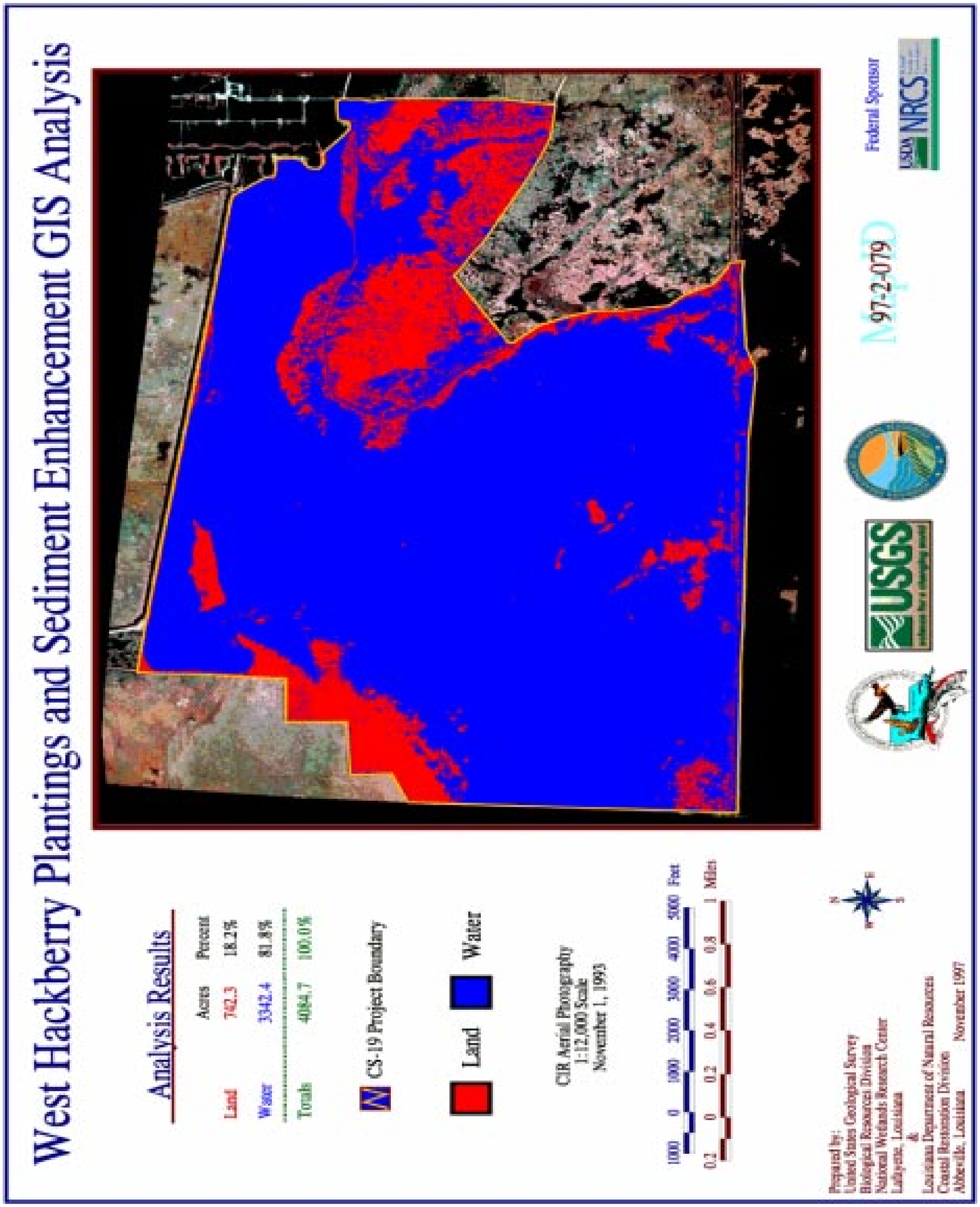
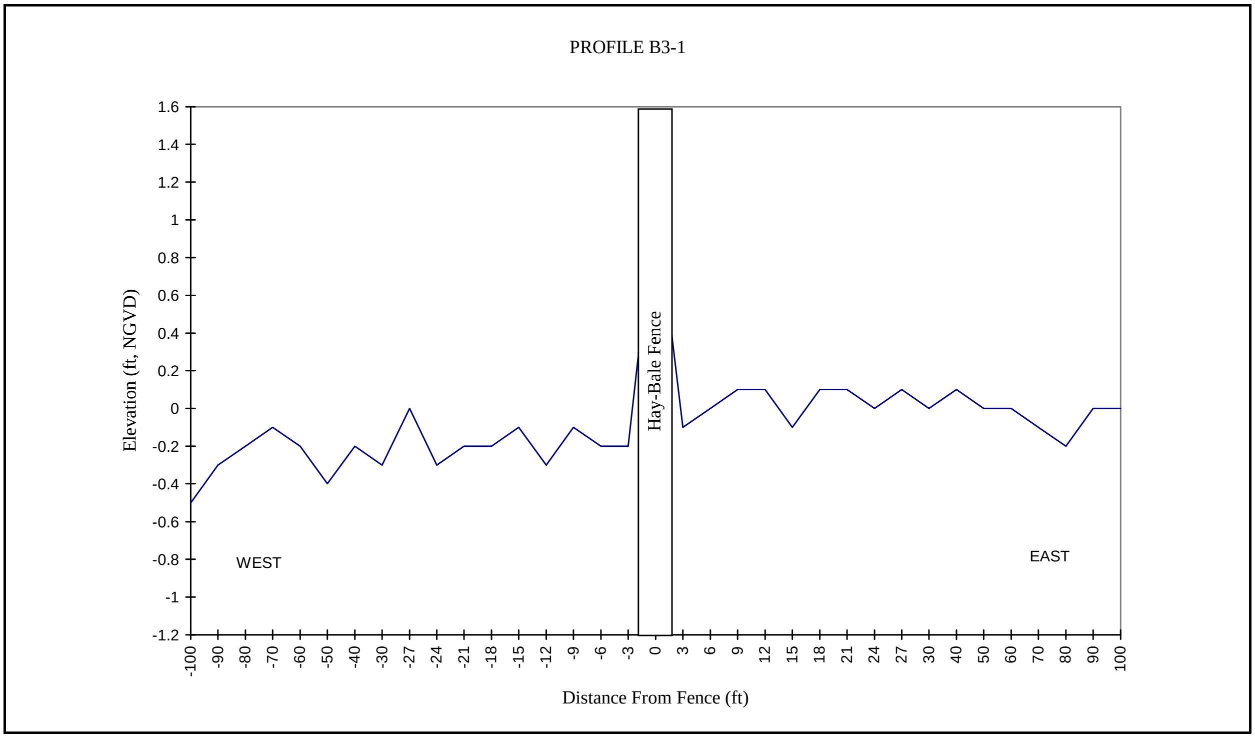


Figure 2. National Wetlands Research Center (NWRC) 1993 GIS analysis for land/water ratios within the West Hackberry Plantings and Sediment Enhancement project area.



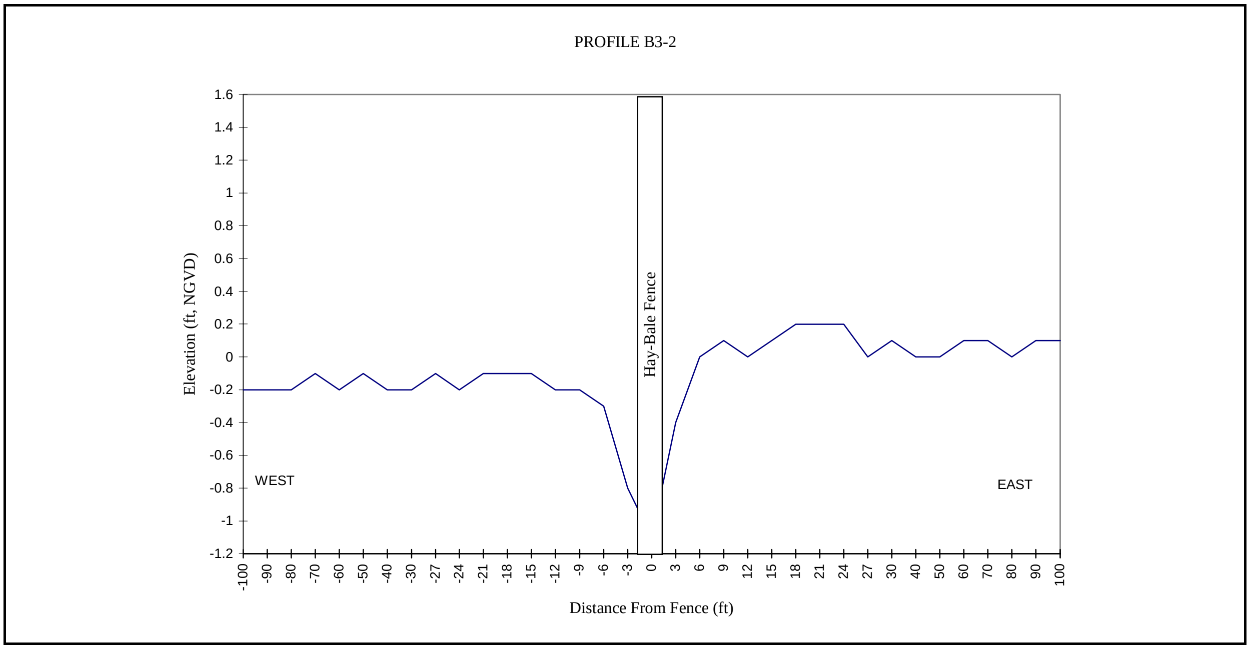
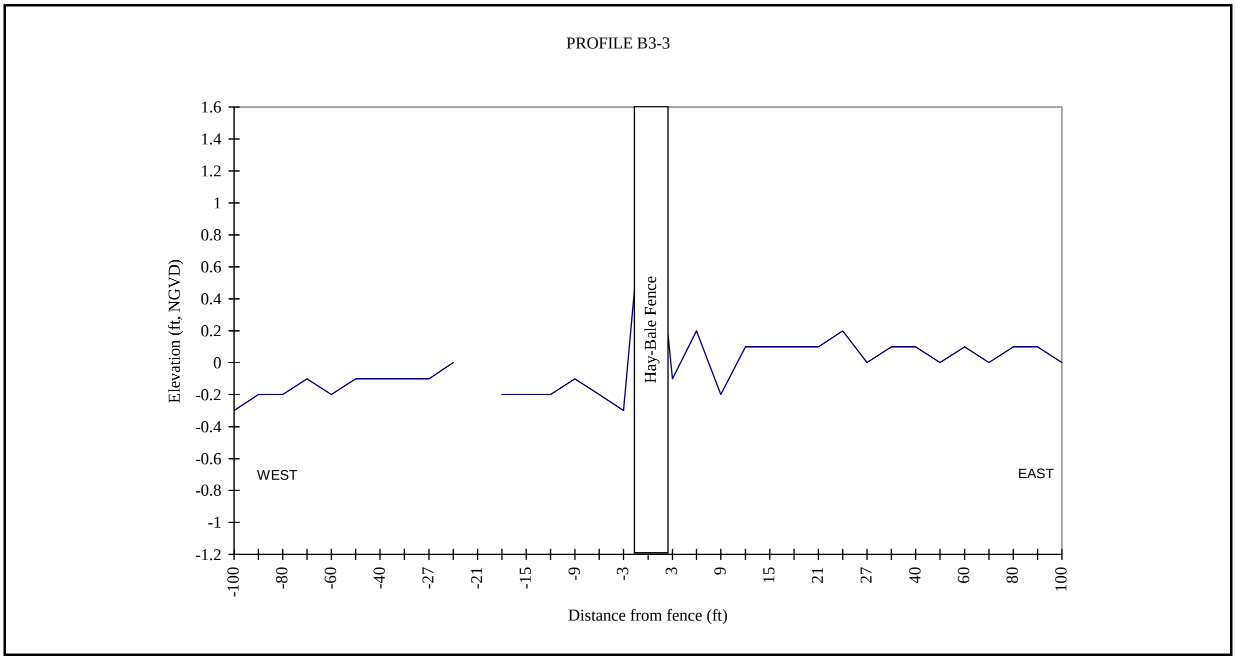


Figure 3. Elevational profile transects 1 and 2 across hay-bale fence B3 in the West Hackberry Plantings and Sediment Enhancement project area, Cameron Parish, Louisiana, surveyed August 1994. (See figure 1 for locations of fence and transects).



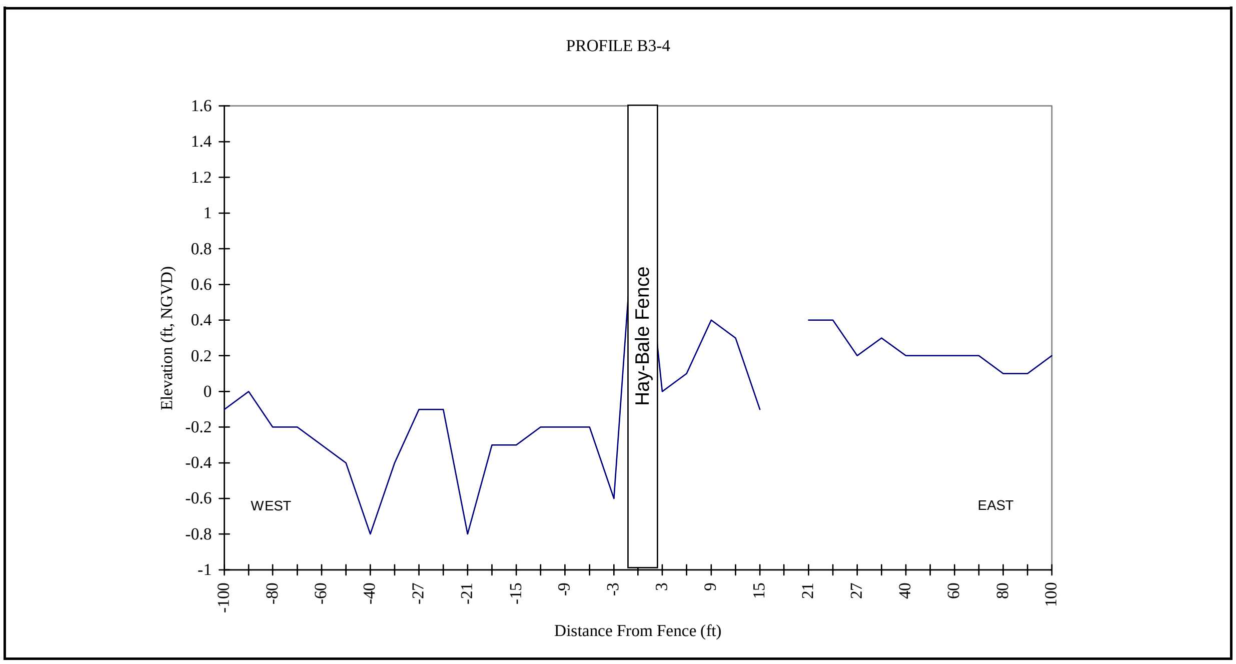


Figure 4. Elevational profile transects 3 and 4 across hay-bale fence B3 in the West Hackberry Plantings and Sediment Enhancement project area, Cameron Parish, Louisiana, surveyed August 1994. (See figure 1 for locations of fence and transects).

Table 1. Mean survivorship (percent survival) of *S. californicus* plantings in 16-plant sampling plots, and mean percent cover in associated 1-m^2 sub-sample plots, from August 1994 to July 1997, as observed at 1, 6, 12 and 36 mo postplanting (n = 16).

1 Month		**6 Months**		**12 Months**		**36 Months**	
% Survival (entire plot)	**% Cover (1-m^2 plot)**	**% Survival (entire plot)**	**% Cover (1-m^2 plot)**	**% Survival (entire plot)**	**% Cover (1-m^2 plot)**	**% Survival (entire plot)**	**% Cover (1-m^2 plot)**
80.5	5	62.1	9	60.2	45.2	25.4	13.1

Table 2. The results of a two-way ANOVA on mortality rate (n = 16) and percent cover (n = 13) of *S. californicus* plantings, from August 1994 to July 1997, as observed at 1, 6, 12 and 36 mo postplanting.

		Mortality Rate	**Percent Cover**
SOURCE	**DF**	**F-VALUE**	**F-VALUE**
Exp_unit	5	2.89 ns	1.90 ns
Time	3	11.84 [a]	4.89 [a]
Exp_unit*Time	15	1.60 ns	1.80 ns

ns = not significant; [a] = significant ($\alpha = 0.05$).

Table 3. The results on difference of least square means for percent cover between individual sampling periods from August 1994 to July 1997 ($\alpha = 0.05$).

Month	**Month**	**LS means Difference**	**p**
1	6	-.1654	.7136*
1	12	-3.0132	.0279
1	36	.5395	.2253*
6	12	-2.8478	.0052
6	36	.7049	.0927*
12	36	3.5528	.0035

* = No significant difference

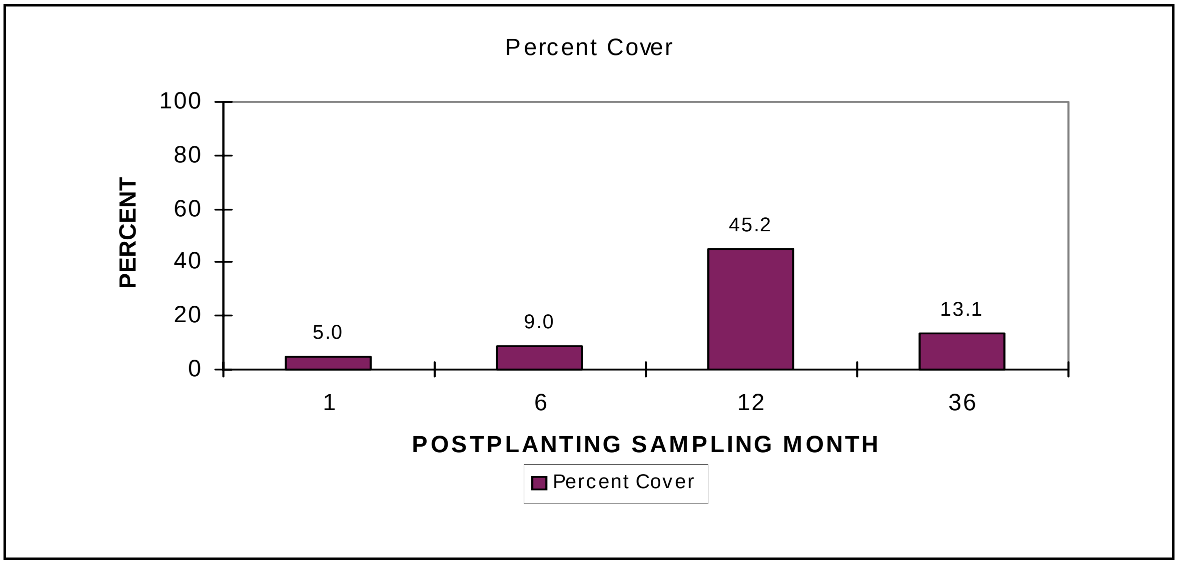


Figure 5. Percent cover of *S. californicus* plantings in 13 random sampling plots, from August 1994 to July 1997, as observed at 1, 6, 12 and 36 mo postplanting.

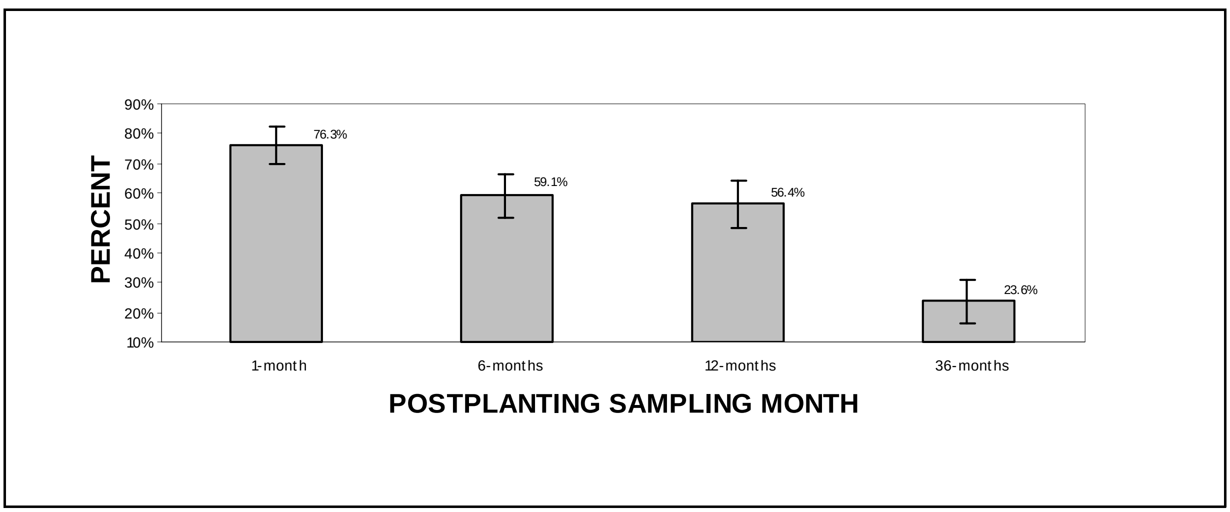


Figure 6. Mean survivorship and standard error of S. californicus plantings in 16 random sampling plots from August 1994 to July 1997. Plantings observed at 1, 6, 12, and 36 mo postplanting. The % survivorship decreased significantly ($\alpha = 0.05$) from 12 to 36 months.

Table 4. The results on difference of least square means for survivorship between individual sampling periods from August 1994 to July 1997 (α =0.05).

Month	Month	LS means Difference	p
1	6	.1715	.0073
1	12	.1982	.0047
1	36	.5260	.0002
6	12	.0267	.0698*
6	36	.3545	.0044
12	36	.3277	.0058

* = No significant difference

Salinity: Analysis of pre- (September 1993 to June 1994) and post-construction (July 1994 to September 1995) salinity data from the Rycade Canal (C/S-02) project, which influences salinity in the West Hackberry Plantings project area, indicated that salinity averaged 4.0 ppt in the vicinity of the West Hackberry plantings during that period of record (Weifenbach 1996). *S. californicus* is described as common to intermediate marshes (Chabreck 1972), but the salinity tolerance for *S. californicus* is not documented. Data collected for this project indicate that *S. californicus* plantings can easily tolerate salinities of up to 6.0 ppt for short periods. Plantings that survived appeared to have been the most vigorous before the drought, which suggests that larger stands tolerated higher salinity better than smaller stands. In addition, salinity averaged slightly higher on the eastern half than on the western half of the West Hackberry plantings area for each year, further suggesting that die-back of the plantings was associated with high salinity.

High salinity in 1996 resulted from drought conditions in southwest Louisiana from February through July 1996 (Louisiana Office of State Climatology [LOSC] 1996), brought on by below normal precipitation (table 5), with the predominant wind direction promoting northward migration of high salinity water for most months. Salinity increased dramatically throughout the West Hackberry plantings area and remained above 6 ppt from April through October 1996 (LDNR 1996). Comparison of average monthly salinity from January through October for years 1993 through 1996 (figure 7), as recorded at 4 stations in the vicinity of the West Hackberry plantings (figure 1), shows that salinity averaged less than 6 ppt at all four stations for years 1993 through 1995, but averaged over 8 ppt at all four stations for the same period of record for 1996. Between May and September 1996, salinities averaged 14.4 ppt among the 4 stations within the plantings. Average salinity fails to indicate the extreme salinities that occurred in the project area however. Examination of hourly data collected throughout 1996 indicate that salinity rarely fell below 20 ppt for six weeks during the summer of 1996 (Figure 8).

Table 5. Monthly and cumulative climate data from January through September 1996 for the southwestern Louisiana division (Allen, Beauregard, Calcasieu, Cameron, and Jefferson Davis parishes).

Month	Monthly Mean Precipitation (inches)	Cumulative Departure From Normal (inches)	Monthly Palmer Drought Severity Index	Monthly Predominant Wind Directions
Jan	3.33	-1.75	±Normal	S, N, SW, NW
Feb	1.51	-4.41	Mild	SW, S, N, NE
Mar	1.58	-6.97	Mild	S, SW, NW, N
Apr	3.22	-7.54	Mild	S, SW, SE
May	1.38	-11.52[a]	Moderate	S, SW, SE
Jun	6.01	-10.75	Mild	S, SW, SE
Jul	4.98	-11.81	Moderate	SW, SE
Aug	8.77	-8.89	±Normal	NE, E, SE, S
Sep	7.33	-6.77	Moist Spell	NE, E, SE, S, N

Source: Compiled with data from Louisiana Office of State Climatology (1996).
[a] Indicates highest May departure on record for the southwestern Louisiana division.

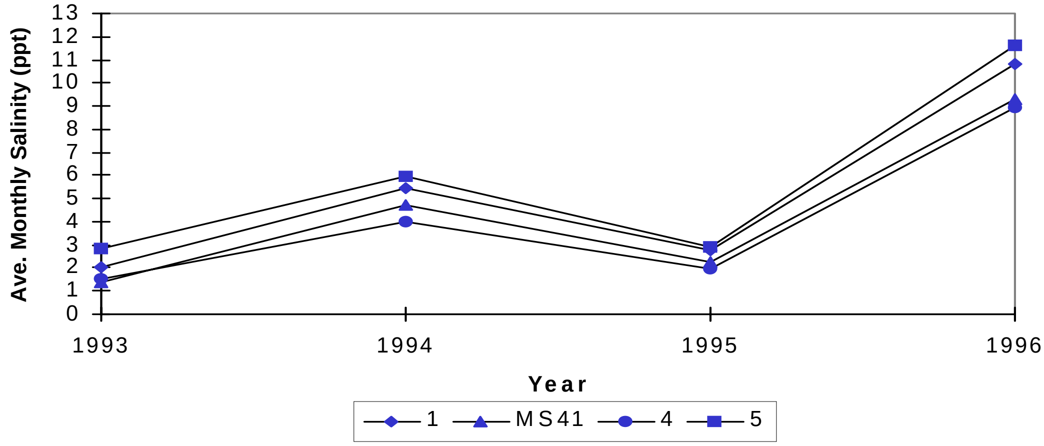


Figure 7. Average monthly salinity from January through October for years 1993 through 1996 in the West Hackberry Plantings project area at stations 1, MS41, 4, and 5. (Based on monthly and bimonthly discrete data collected by LDNR/CRD for the Rycade Canal [C/S-02] project.)

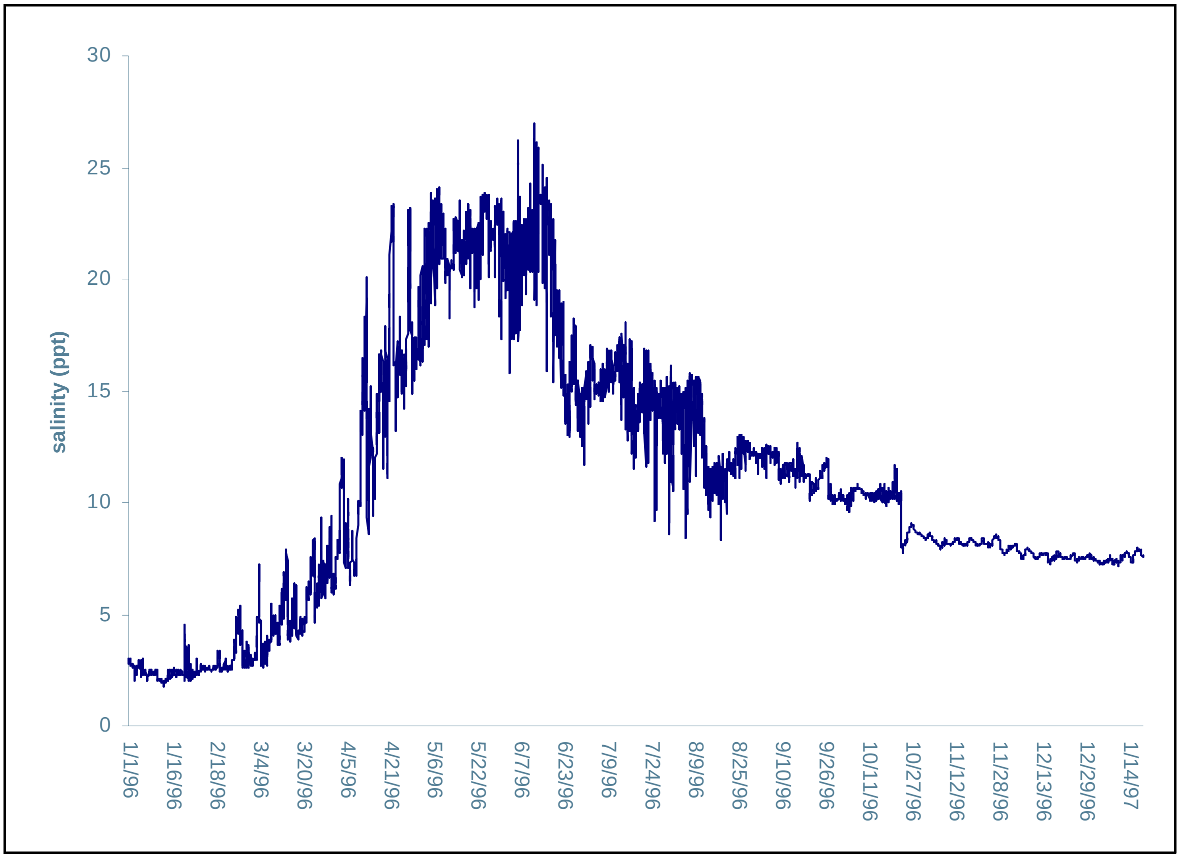


Figure 8. Continuous recorder salinity data collected from station 5 within the (C/S-19) West Hackberry Plantings project area from 1/1/96 to 1/14/97.

DISCUSSION

Land/water Ratio: Two difficulties were associated with GIS analysis of the project area. First, flight plans for pre-construction aerial photography were created according to the original project boundary. A subsequent boundary change, which resulted in a much greater project area, occurred after pre-construction photography had been obtained. As a result, neither photography nor GIS analysis is available for approximately 453 ac (183 ha) of the westernmost portion of the project area. Figure 2 shows the areal extent of the available pre-construction photography. Post-construction photography encompassed the entire project area. Second, photography of the project area included exposed, unvegetated mud flats. The NWRC included these areas in the open water category based on the recommendation of the monitoring manager.

Hay-bale fences: It has been shown that hay bales will not remain intact for prolonged periods of time. Modifications to the twine used for wrapping the hay were also nullified after the haybales broke up within weeks. It has been noticed that hay deteriorates rapidly after exposure to water, thus causing the hay bales to break apart regardless of the wrapping techniques.

While the hay bales proved to be unsuitable, the fences used to accommodate the hay bales remained intact and are still unaltered. The design of the fences has secondarily induced the fences to act as wave damping fences. Due to large spaces between the boards parallel to the water line and the fences being placed up to 100 ft (30.5 m) from the shoreline, wave erosion still occurs but possibly at a slower rate. No data have been collected to determine shoreline erosion rates behind the fences but wave calming has been observed.

Vegetative plantings survival: Before the drought all mature stems on the plantings were noticed to be dark green in appearance and had the greatest percent cover recorded. After the drought, nearly all of the mature stems on the plantings were brown and appeared to be dead, and most of the remaining transplants did not bear obvious young, green shoots. However, the plantings were growing in approximately 2 ft (0.6 m) of turbid water, and it is likely that additional new growth was submerged and was not apparent. The planting rows on the east side of the planting area showed the greatest impact. Vigorous growth of the transplants has developed only on the south end of planting row A1, and on rows B1 and B2 (figure 1).

The October 1996 observations suggest that significant decreases in survivorship have occurred since the last evaluation in July 1995 (figure 6, table 4) (Vincent and Sun 1996). In October 1996, only four of the 16 established sampling plots included growth so vigorous that the individual transplants were indistinguishable. Of the remaining 12 plots, two plots contained only two live plants, three plots were not inspected due to missing corner poles, and all remaining plots were either devoid of vegetation or appeared to be dead (table 6).

Table 6. Survivorship (percent survival) of *S. californicus* plantings in 16-plant sampling plots, and percent cover in associated 1 m^2 sub-sample plots, from August 1994 to July 1997, as observed at 1, 6, 12, and 36 mo postplanting. Mean values are for all sampling plots (n = 16) and associated sub-sample plots.

Plot	1 Month		6 Months		12 Months		36 months	
	% Survival (entire plot)	% Cover (1 m^2 plot)	% Survival (entire plot)	% Cover (1 m^2 plot)	% Survival (entire plot)	% Cover (1 m^2 plot)	% Survival (entire plot)	%Cover (1 m^2 plot)
A1–1	88	5	50	5	50	2	0	0
B1–1	75	5	69	20	69	100	100	35
B2–1	75	5	75	18	75	100	100	70
B2–2	94	5	94	15	94	100	100	60
B2–3	100	5	94	5	94	100	100	40
B2–4	94	5	75	[a]	63	[a]	0	0
C1–1	75	5	31	3	19	3	0	0
C1–2	94	5	69	3	63	3	0	0
C1–3	38	5	38	[a]	25	[a]	0	0
C2–1	38	5	0	0	0	0	0	0
C2–2	56	5	25	[a]	19	[a]	0	0
C2–3	63	5	50	10	44	50	0	0
C2–4	94	5	81	10	81	100	0	0
C2–5	94	5	75	40	75	100	6	5
C3–1	69	5	50	5	50	25	0	0
C3–2	88	5	69	10	69	40	0	0
Mean	77.1875	5	59.0625	9	55.625	45.1875	25.375	13.125

[a] Corner plant used to estimate percent cover in this associated 1m^2 plot was dead or absent at 6 and 12 mo postplanting.

In July 1997, nearly all of the plantings within the planting area were missing, except for 4 plots located within group B. The plantings within group B were brown in appearance although individual plantings could not be distinguished. The overall percent cover of the plantings within group B was 41 %. The remaining 12 vegetation plots contained only 6% survival and 5% cover (table 6). One planting with 4 stems was noticed within group C2-5, which accounted for the 5% survival within those 12 plots. Overall mean survival within the entire 16 plots was 25.4%. The highest survival rates were noticed within the westernmost part of the project area, which is the least saline part of the planting areas. Recovery of the vegetative plantings after the drought has been minimal and future rejuvenating of the plantings is not expected.

CONCLUSION

The results presented in this report have shown that hay bales cannot be used in a high wave energy system as the bales deteriorate rapidly and wash out of the fence enclosures. Future use of hay bales to control shoreline erosion is not recommended where water depths are greater than 2 ft (0.6 m). The fences, constructed of treated lumber, have remained intact and secondarily become wave damping fences. A more cost effective approach would be to install wave damping fences along the shorelines where wave erosion is occurring.

Vegetative plantings of *S. californicus* are not capable of reproduction in a brackish environment where salinities exceed 8-10 ppt for extended periods of time. While some of the plantings have become established under these conditions, vegetative cover has decreased and the plantings have become greenish-brown in appearance. Monitoring of the vegetative plantings will continue until all plots are devoid of vegetation or monitoring is no longer cost effective.

REFERENCES

Chabreck, R. H. 1972. Vegetation, water and soil characteristics of the Louisiana coastal region. Louisiana Agriculture Experiment Station bulletin no. 664. Baton Rouge: Louisiana State University. 72 pp.

Good, B., J. Buchtel, D. Meffert, J. Radford, K. Rhinehart, and R. Wilson, eds. 1995. Louisiana's major coastal navigation channels. Unpublished report. Baton Rouge: Louisiana Department of Natural Resources, Coastal Restoration Division. 57 pp.

Harper, J. L. 1977. *Population Biology of Plants*. New York: Academic Press. 892pp.

Louisiana Department of Natural Resources (LDNR) 1995. West Hackberry Plantings and Sediment Enhancement (C/S-19) Monitoring Plan. Unpublished monitoring plan. Abbeville: Coastal Restoration Division, Biological Monitoring Section.

Louisiana Department of Natural Resources (LDNR) 1996. Monthly and bimonthly discrete salinity readings from January through October for years 1993 through 1996 from monitoring stations in the West Hackberry Plantings (C/S-19) project area established to monitor the Rycade Canal (C/S-02) project. Abbeville: Coastal Restoration Division, Biological Monitoring Section. Unpublished data.

Louisiana Office of State Climatology, Southern Regional Climate Center 1996. Precipitation summaries, moisture status summaries, and windroses for selected sites. Louisiana Monthly Climate Review 16: 1-9. Baton Rouge: Louisiana Office of State Climatology, Southern Regional Climate Center.

Miller, M. 1994. West Hackberry Plantings and Sediment Enhancement (C/S-19) Monitoring Plan. Baton Rouge: Louisiana Department of Natural Resources, Coastal Restoration Division.

Natural Resources Conservation Service (NRCS) 1993. Calcasieu-Sabine cooperative river basin study report. Unpublished report. In cooperation with the Gulf Coast Soil and Water Conservation District, United States Fish and Wildlife Service, Louisiana Department of Natural Resources, Louisiana Department of Wildlife and Fisheries, and Louisiana Department of Agriculture and Forestry. 151 pp.

Steyer, G. D., R. C. Raynie, D. L. Steller, D. Fuller, and E. Swenson. 1995. Quality Management Plan for Coastal Wetlands Planning, Protection, and Restoration Act monitoring program. Open-file series no. 95-01. Baton Rouge: Louisiana Department of Natural Resources, Coastal Restoration Division.

Vincent, K. A., and B. Sun 1996. West Hackberry Plantings and Sediment Enhancement (C/S-19), Progress Report No. 2. Open-file monitoring series C/S-19-MSPR-0796-2, for the period June 29, 1994 to June 17, 1996. Baton Rouge: Louisiana Department of Natural Resources, Coastal Restoration Division.

Weifenbach, D. 1996. Rycade Canal (C/S-02), Progress Report No. 1. Open file monitoring series C/S-02-MSPR-0397-1, for the period July 1, 1994 to March 4, 1996. Baton Rouge: Louisiana Department of Natural Resources, Coastal Restoration Division.