THREE-YEAR COMPREHENSIVE MONITORING REPORT

COAST 2050 REGION 4
EAST MUD LAKE MARSH MANAGEMENT
CS-20

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

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INTRODUCTION

Louisiana possesses a significant percentage of the total coastal wetland acreage in the contiguous United States. These wetlands are in a severe state of degradation due to natural and anthropogenic causes (Turner 1990). Mass harvesting of cypress timber beginning in the early 1900's and dredging of oil and gas access canals beginning in the 1940's led to a dramatic change in the landscape of coastal Louisiana (Myers et al. 1995; Reed and Rozas 1995). Various marsh management methods have been utilized in an attempt to mitigate wetland loss.

Marsh management has been widely used in coastal Louisiana for decades to improve conditions for waterfowl and furbearers (Chabreck 1960). Presently, marsh management techniques employ impoundments and a variety of water control structures such as fixed and variable crest weirs, flapgates and culverts to prevent the conversion of marsh into shallow open water areas. Water control structures are operated to moderate water level variability, reduce saltwater introduction, and seasonally change the volume of water in management areas for the benefit of both vegetation and wildlife. Results from previous studies indicate that this type of management can enhance vegetation growth when proper drawdown is achieved and increase waterfowl and wildlife numbers in management areas (Hess et al. 1989). However, in two conflicting studies located in the Chenier Plain of southwest Louisiana, marsh accretion rates have been reported to be lower in managed marshes than in comparable unmanaged reference marshes (Cahoon 1994), but not in others (Foret 1997).

The Chenier Plain developed approximately 3,000 years ago through westward littoral transport of Mississippi River delta sediments, combined with deposition of local fluvial sediments (Howe et al., 1935, Van Lopik and McIntire, 1957, Byrne et al., 1959; DeLaune et al., 1983). The development of cheniers (recessional beach ridges) coincided with eastward shifts in the course of the Mississippi River (Byrne et al., 1959, Gould and McFarlan, 1959: DeLaune et al., 1983). Intervening mudflats (marshes) are associated with westward shifts in the river's course. The Calcasieu River has historically maintained a channel through the central portion of Calcasieu Lake (Van Sickle 1977). The first human modifications occurred in 1874 when a 5 ft. deep and 80 ft. wide channel was dug through sandbars and shell reefs at the mouth of Calcasieu Pass. To further facilitate navigation, the Calcasieu Ship Channel (CSC), as it became known, has been intermittently dredged, from 32.8 ft (10 m) deep in 1937, to 39.36 ft (12 m) in 1946, and deepened in 1963 to 49.2 ft (15 m) with a final width of 400 ft (122 m) (USACE 1971). East Mud Lake is an irregularly shaped lake to the west of the CSC, probably created from an abandoned river or tidal stream course (Gosselink et al. 1979).

The East Mud Lake Marsh Management project area is comprised of 8,054 acres (3,222 ha) located in the Calcasieu/Sabine Basin in Cameron Parish, Louisiana. The project is bounded by the southern Apache Louisiana Minerals, Inc. (Apache) property line to the south, La. Hwy. 27 to the west, the Sabine National Wildlife Refuge north of Magnolia Road, and an existing levee and property line near Oyster Bayou to the east (figure 1). The Calcasieu/Sabine Basin suffers from anthropogenic hydrologic changes to the system, which have led to the deterioration of the marsh since 1953 (U.S. Department of Agriculture-Soil Conservation Service [USDA-SCS] 1993). The CSC is 1 mi (1.6 km) east of the project area and provides an avenue for high

Figure 1. East Mud Lake (CS-20) project map depicting project boundaries, conservation treatment unit boundaries, reference area boundaries, and project features.

salinity water (4-32 ppt) and rapid water movement into the East Mud Lake project area via West Cove, Oyster Bayou, and Mud Bayou (figure 1). These connections may increase turbidity and scouring within the project area. The construction of La. Hwy. 27 in 1936 reduced the connection to freshwater sources from the west (USDA-SCS 1994). In the 1950's, portions of the project area were impounded by construction of Magnolia Road and a levee system on the north, east, and south (figure 1). Analysis of aerial photos of the project area indicates a marsh loss rate of 76 ac/yr (30.4 ha/yr) from 1953 to 1983 (USDA-SCS 1992). Excluding Mud Lake, the land to open water ratio deteriorated from 99:1 in 1953 to 70:30 by 1983.

Another problem in the project area is prolonged flooding of the marsh. Construction of La. Hwy. 27 to the west, and La. Hwy. 82 to the south has decreased avenues for drainage from the western and southern areas of the project. This has lead to prolonged periods of high water levels and which resulted in the deterioration of the vegetation (USDA-SCS 1994). Subsidence and sea level rise have also exacerbated the problem, resulting in a relative water level increase of 0.25 in/yr (0.64 cm/yr) from 1942 to 1988 (Penland et al. 1989). The East Mud Lake project addresses these problems by increasing the total number of drainage outlets for the area.

The project area has been divided into two nearly hydrologically separate Conservation Treatment Units (CTUs) that are managed independently (figure 1). CTU 1 contains Mud Lake and is managed passively. Structures and features in CTU 1 consist of vegetative plantings, earthen plugs, culverts with flapgates and variable-crest culverts. Variable crests allow the setting of an elevation at which water is allowed to flow over the crest stoplogs through the structure and out of the project area. In this way, an approximate desired water elevation can be maintained within the project area. On most structures there are flapgates on the outside part of the structure. They can be locked open allowing water to pass in and out or they can be allowed to operate or “flap” which allows water to exit but not enter the project area. Conversely, at structure 13 there are flapgates on the inside of the structure which can be used to prevent water from exiting the project area. The variable-crest culverts at stations 6, 7, and 8 are set at 6 in (15 cm) below marsh level with vertical slots open except when salinities exceed 15 ppt. The variable-crest culvert at station 13 is set at 6 in (15 cm) below marsh level (BML) with flapgates locked open except when salinities exceed 7 ppt.

CTU 2 is actively managed and has drawdown capabilities in order to encourage shallow water areas to revert to emergent vegetation. Two drawdown events were planned for the first five years of the project. Structures and features present in CTU 2 consist of vegetative plantings, variable crest culverts with flapgates, a gated culvert, and a variable-crest box structure (figure 1). Operational Phase I emphasizes curtailing marsh erosion and reclaiming emergent marsh by implementing a partial drawdown from February 15-July 15. All flapgates at variable-crest culverts 1, 3, 4, 5, 9a, and 11 are allowed to operate with all stoplogs removed. Stoplogs are set at 12 in (30.48 cm) above marsh level (AML) on the variable crest box structure at station 17. The screwgate at station 9 is opened and the flapgate is allowed to operate.

Operational Phase II, the maintenance phase, emphasizes stabilization of salinity and water levels while ensuring ingress and egress of fisheries species. During this phase of operation, flapgates at stations 3, 4, 5, 9a, 9b, and 11 are locked open. Stoplogs are set at 6 in (15 cm) below marsh level at stations 1, 3, 4, 9a, and 11 while at station 5, one bay is set at 6 in (15 cm) BML and one bay at 12 in (30.48 cm) BML. The screwgate at station 9b is opened and all stoplogs removed from station 17. To protect marsh vegetation during periods of high salinity, the ingress gates are closed when salinity inside the project area exceeds 15 ppt at stations 3 or 5.

Vegetation plantings were installed through a cooperative effort by the Louisiana Department of Natural Resources (LDNR), Soil and Water Conservation District, and Natural Resource Conservation Service (NRCS) from June 5 through July 8, 1995. A total of 7,200 *Spartina alterniflora* (smooth cordgrass) trade gallons were planted along the step levee (staircase shaped levee) and canal (straight levee) in CTU 2 (figure 1). The cut bank configuration of most of the Mud Lake shoreline limited plantings to 480 plants in areas adjacent to structures 17, 13, and the earthen plug west of structure 17 in CTU 1.

Construction was completed May 1, 1996. The project objectives are to prevent wetland degradation by reducing vegetative stress, thereby improving the abundance of emergent and submerged vegetation and to stabilize the shoreline of Mud Lake through vegetative plantings. Specific goals are to (1) decrease the rate of marsh loss, (2) increase vegetative cover along the shoreline of East Mud Lake, (3) increase percent cover of emergent vegetation in shallow open-water areas, (4) increase abundance of vegetation in presently vegetated portions of the project area, (5) reduce water-level fluctuations to within 6 in (15 cm) BML to 2 in (5.08 cm) AML and salinity levels to 15 ppt or less, (6) decrease the duration and frequency of flooding over emergent marsh, (7) decrease the mean salinity in CTU 2, and (8) increase vertical accretion in CTU 2. Maintaining fisheries abundance is not a specific goal as addressed in the project documentation. However, because of concerns regarding potential fishery impacts, it was included in the monitoring plan.

The area east of CTU 2, south of Oyster Bayou and Mud Bayou, (reference area 1) was selected as the best reference area for the evaluation of the water level, salinity, and fisheries monitoring elements (figure 1). The area north of Magnolia Road (reference area 2) is a suitable reference area for the evaluation of the vegetative, accretion, water-level, salinity, fisheries, and soil monitoring elements. The project area and both reference areas are classified as brackish marsh (Chabreck and Linscombe 1988) and contain mainly organic Bancker and Creole soils with ridges of Mermentau soils (USDA-NRCS 1995). All are directly influenced hydrologically by the CSC and are dominated by *Spartina patens* (marshhay cordgrass).

METHODS

A detailed description of the monitoring design can be found in Holbrook (1995).

Land to Water Ratio and Habitat mapping: At the NWRC, 1:12,000 scale color infrared aerial photography obtained on December 26, 1994 and November 27, 2000 was classified and photo-interpreted to measure land to open water ratios and to map habitat types in the project area preconstruction.

To determine land to open water ratios, the aerial photographs were scanned at 300 pixels per inch and georectified using ground control data collected with a global positioning system (GPS) capable of sub-meter accuracy. These individually georectified frames were then mosaicked to produce a single image of the project and reference areas. Using geographic information systems (GIS) technology, the photo mosaic was classified according to pixel value and analyzed to determine land to water ratios in the project and reference areas. All areas characterized by emergent vegetation were classified as land, while open water, aquatic beds, and mud flats were classified as water. An accuracy assessment comparing the GIS classification of 100 randomly chosen pixels to aerial photography determined an overall classification accuracy of 96%.

Using the National Wetlands Inventory (NWI) Classification System, the photography was photo interpreted by NWRC personnel and classified to the subclass level (Cowardin et al. 1992). The habitat delineations were transferred to 1:6,000 scale Mylar base maps, digitized, and checked for quality and accuracy.

The NWI classification system identifies habitat types by system, subsystem, class, and subclass. The estuarine system includes all tidal habitats in which waters consist of at least 0.5% ocean-derived salt and are diluted at least occasionally by freshwater runoff from the land. Palustrine habitats are nontidal wetlands dominated by trees, shrubs, persistent emergents, emergent mosses, or lichens, and all wetlands that occur in tidal areas where ocean-derived salinities are less than 0.5% (Cowardin et al. 1992). Urban habitats are those whose areal coverage consists of less than 30% vegetation or other cover. Upland scrub-shrub habitats consist of at least 30% scrub-shrub, and upland forested habitats consist of at least 3% forest (Anderson et al. 1976). When describing both upland and wetland habitats, the term "scrub-shrub" refers to woody vegetation less than 20 ft (6 m) in height. The term "forested" refers to woody vegetation taller than 20 feet. Where more than one class of vegetation exists, the uppermost layer of vegetation with areal coverage greater than 30% determines the NWI habitat type.

Vegetation plantings: The *S. alterniflora* plantings were divided into three land types due to different stress factors from boat wakes, wave energy, and herbivory. The canal plantings, located on a long, straight canal in CTU 2 are subject to herbivory from cattle year-round. The step levee plantings are located in CTU 2 on short canals where plants were installed at a farther distance from the shoreline. Lakeshore plantings are located on the shoreline of East Mud Lake in CTU 1 and subject to high wave energy due to the long north-south fetch across the lake. To document planting success, 5% of the plants along the step levee and canal, and 5% of the plants along the East Mud Lake shoreline were sampled. Nineteen plots along the step levee, seventeen plots along the canal, and 4 plots along the shoreline, consisting of 10 plants spaced 5 ft (1.5 m) apart, were selected and sampled. Parameters measured included, percent survival of planted vegetation, species composition of encroaching vegetation, and percent cover for each species present. Monitoring stations were placed every 1,000 ft (305 m). The 1-mo, 6-mo, 1-year, and 4-year postplanting sampling was conducted in July 1996, December 1996, August 1997, and June 2000, respectively. A Kruskal – Wallis test was used to compare percent survival and percent cover of *S. alterniflora* among the three planting locations (step levee, canal, and lake shoreline) for each sampling time. Chi – Square tests were considered significant at $p < 0.05$.

Existing vegetation: Sites to monitor existing vegetation were selected using a systematic transect pattern in which five transect lines were drawn in a northwest to southeast configuration from the Calcasieu Lake/West Cove shoreline in the project area and reference area 2. Five stations were chosen at equally spaced points along each transect line, for a total of 25 stations in the project area and 20 stations in reference area 2, to obtain an even distribution of stations throughout the marsh (figure 2). Percent cover, height of dominant species, and species composition were monitored in 1.0-m^2 vegetation plots. Emergent vegetation data were collected in July 1995 (preconstruction) and July 1997, June 1999, and July 2003 (postconstruction). Total percent cover and species richness data were not normally distributed and transformation did not improve normality. Therefore, Analysis of Variance (ANOVA) is not a valid test of the means. The total percent cover and species richness data were ranked. Data were divided into blocks and ranked for the two factors: year (1995, 1997, 1999, and 2003) and area (Project and Reference) (n=8). Friedman's two-way nonparametric ANOVA was then used to analyze differences. A method had been developed whereby ranked values could be analyzed with ANOVA in SAS JMP and the results could be converted to Chi-Squared values by multiplying the resulting Sum of Squares from the ANOVA by $12/(T*(T+1))$ where T = the number of treatments.

Our data did not meet the Friedman's analysis assumption of equal sample sizes. In 1995, the only pre-construction sampling, only 10 stations were sampled in the reference area. In order to compare year*area interactions, only 10 stations could be used for each year / area, so 10 stations were randomly chosen from the project area.

Additionally, one way comparisons of total cover and richness were done for each year within each area using the maximum number of stations possible.

Water quality: Data were collected using seven (7) YSI 6000 or YSI 6920 continuous recorders at five stations inside the project area and 2 stations in the reference areas (figure 3). Stations 14r, 15r and 17 were installed in February 1995. Stations 3, 7, and 9 were installed in June 1996. Station 106 was installed in April 1997. Water level (ft, NAVD), salinity (ppt), water temperature (^{o}C), and specific conductance (μS/cm) were recorded hourly at these stations. All continuous recorder data were shifted when necessary due to biofouling when error at time of retrieval exceeded 5%. Percent error due to biofouling was calculated at the time of retrieval by comparing dirty and clean discrete readings to those taken with a calibrated instrument. Missing data are usually due to instrument malfunction.

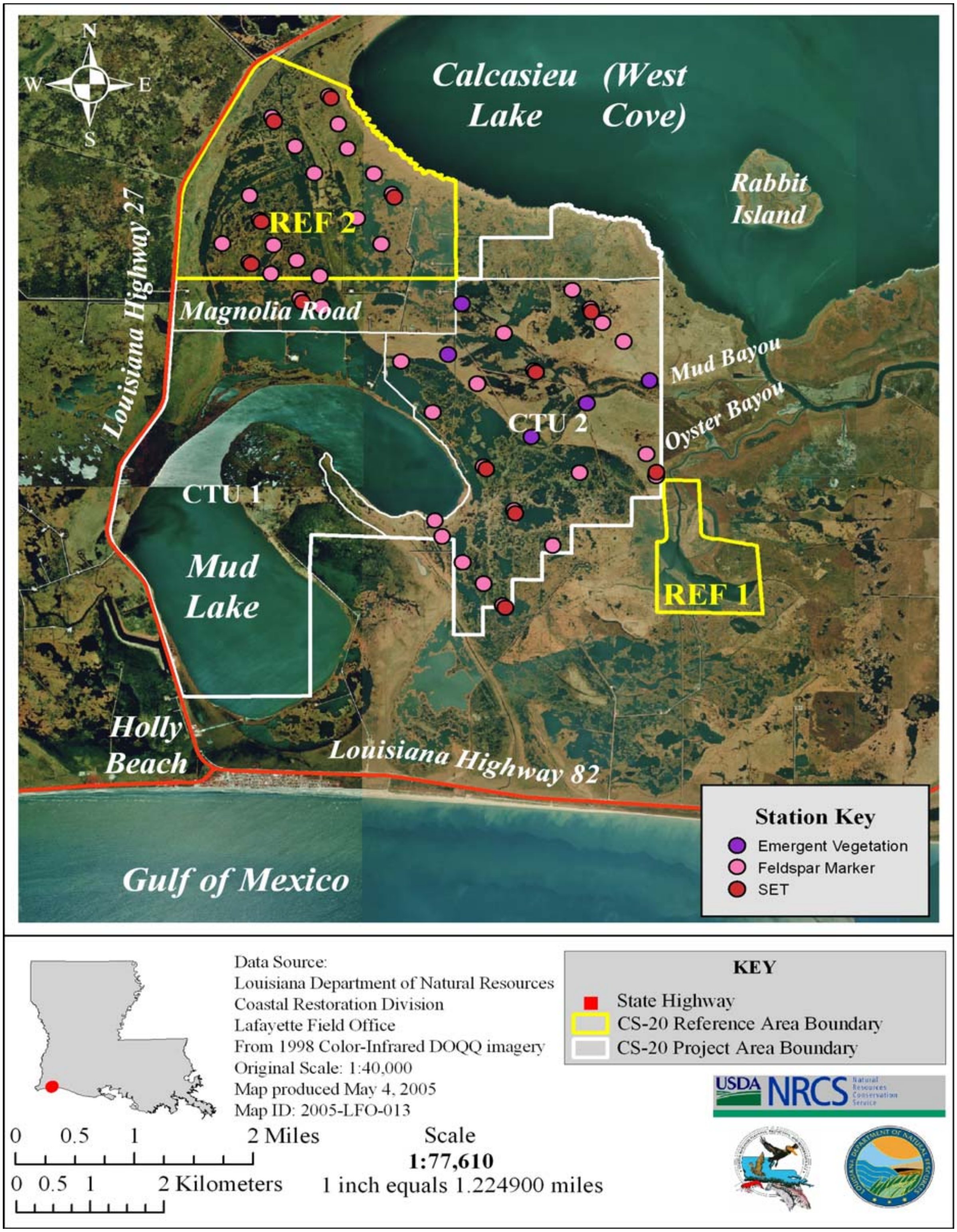


Figure 2. East Mud Lake (CS-20) project map depicting feldspar, emergent vegetation, and Surface Elevation Table (SET) stations.

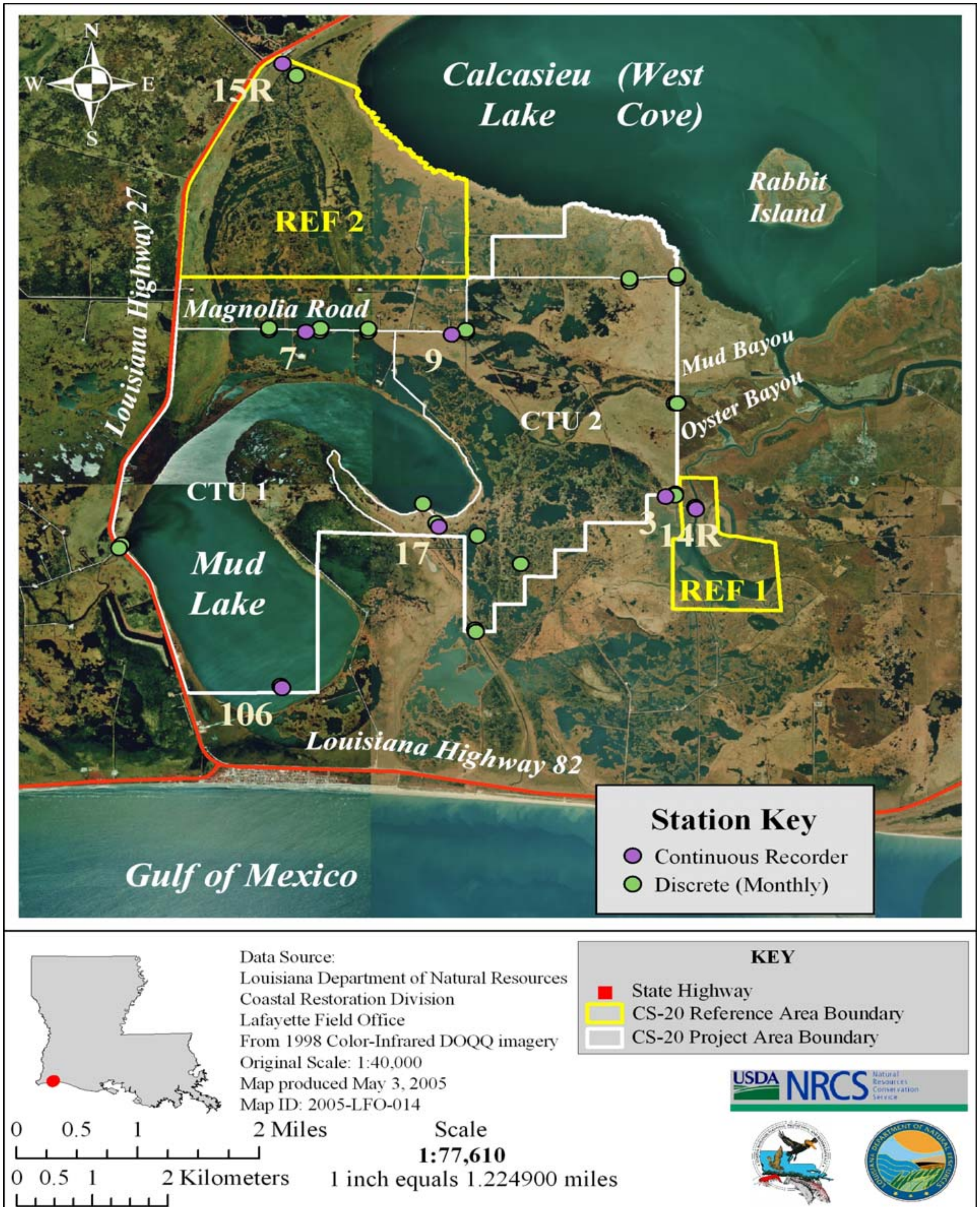


Figure 3. East Mud Lake (CS-20) project map depicting discrete monitoring stations, and continuous recorder stations.

Water depth and water salinity and temperature were measured monthly at 27 stations, 15 located inside the project area, and 12 either in the actual reference areas or taken on the outside of water control structures (figure 3). Monthly staff gauge readings were taken at 11 stations located inside the project area, and 10 in the reference areas. Some data are missing due to inaccessibility to sites at some sampling times.

The percent of hourly salinity measurements greater than or equal to15 ppt at each station during each year of operation was calculated to determine if the project was effective at maintaining salinities less than or equal to 15 ppt, and mean salinity for each year was calculated to evaluate the goal of decreasing mean salinity in CTU 2. Also calculated were the means of the differences between matched hourly readings from station 14r and 3 (difference = station 14r salinity – station 3 salinity; negative indicates sta. 3 salinity > sta. 14 salinity) during periods of different structure operations to determine the local effect flapgate position had on salinity. The yearly mean salinity was also calculated for each CTU and the combined reference areas.

The percent of hourly water level measurements lower, higher, or within the target zone of 2 inches above average marsh level (1.18 ft NAVD) and 6 inches below marsh level (0.51 ft NAVD) were calculated for all years and stations.

Soils: Soils from vegetation monitoring plots were analyzed for percent organic matter, and field moist bulk density. Cores were taken with a Swensen corer, refrigerated, and analyzed by personnel at the Louisiana State University (LSU) Agronomy Department where samples are first air dried and then oven dried at approximately 100 ^{o}C for 24-48 hours. Preconstruction soil samples were collected in July 1996, and postconstruction samples were collected in July 1999. Means and standard deviation for percent organic matter and field bulk density in the project and reference areas were calculated. Field moist bulk density was calculated as:

$$\left(\frac{\text{weight of oven dry sample - weight of empty tube}}{\text{volume of field moist sample}} \right)$$

Vertical accretion: Feldspar platforms were constructed August 1995 at 20 stations in CTU 2 in the project area and 19 stations in reference area 2 along the same transect lines as the vegetation stations to detect changes in vertical accretion (figure 2). In July 1996, two feldspar marker horizon plots were established at each of 14 stations in CTU 2 and 16 stations in reference area 2. Sites that were inaccessible in July were established in December 1996: 6 stations in CTU 2 and 3 stations in reference area 2. New feldspar plots were laid at all sites in December 1997 and the original plots were abandoned. Postconstruction data were collected December 1996, July 1997, December 1997, June 1998, June 2000, and July 2003. All sites were not visited during all sampling periods due to inaccessibility.

Feldspar was placed in 0.5 x 0.5 m plots marked with 2 PVC poles at opposing corners to enable location of the feldspar over time, and cores from randomly selected locations within each plot were taken with a cryogenic corer (Knauss and Cahoon 1990). Vertical accretion (sediment depth above the feldspar) was measured to the nearest millimeter with a vernier caliper at 1-7 locations within each core. A maximum of 3 cores per plot were taken at each sampling period, however, feldspar was not always clearly visible on any of the three cores. After the measurement was taken, the core material was returned to the sample hole to prevent sediment trapping.

Cumulative vertical accretion rates at each station were calculated for all sampling intervals, all beginning with June 1996 or December 1996 and standardized to mm/ year. Mean vertical accretion rates were compared with analysis of variance (ANOVA) using a mixed effects model, which tested the fixed effects of treatment (project and reference), sampling period, and the interaction of treatment and sampling period, over the random effect of station (SAS Institute, 1996). A repeated measures design was not appropriate because of missing data. When effects were significant at the alpha = 0.05 level, post-ANOVA comparisons were made with least square means tests.

<u>Surface elevation</u>: Surface elevation table stations (SETs) were established in August 1995 at 12 of the 40 feldspar stations to detect changes in marsh surface elevation due to subsidence and accretion/erosion combined (figure 2). Six SET stations were located in the project area and 6 in reference area 2. Stations in the Bancker soils include stations 27, 29, and 29A in the reference area, and stations 5, 7, and 8 in the project area. Stations located on Creole soil types include stations 31, 31A, and 35A in the reference area, and stations 15, 18, and 22 in CTU 2 of the project area. Stations 15 and 31A are in close associations with a ridge of the Mermentau soil type. Nine pin measurements were taken in four directions at each of the stations. Detailed procedures for the SET are documented in Steyer et al. (1995). Marsh surface elevation was measured pre-construction in December 1995, and postconstruction in July 1996, December 1996, July 1997, December 1997, June 1998, June 2000, and July 2003. Due to low water levels, only 10 of the 12 SET station sites were accessible for the first two measurements.

Mean rates of marsh surface elevation change were calculated for each station for each sampling period, standardized to reflect one year intervals and compared with ANOVA (SAS Institute, 1996). The main effects were treatment (project and reference) and sampling period, and the interaction effect was treatment / sampling period. Because of missing data, a repeated measures design was not appropriate. When effects were significant at the alpha = 0.05 level, post-ANOVA comparisons were made with least square means.

Additionally, elevation change data (cm) were used to compute cumulative SET data. All data points were plotted for each station (n=12 stations). A zero was inserted into the table for each station as the beginning point for the graph at the time of establishment of the SET. A regression line was forced through zero and the resulting slope was the rate. The graph was actually by days so the rate was in cm/day which was converted to cm/yr.

<u>Fisheries</u>: Fisheries monitoring was conducted to estimate abundance and species composition in the project and reference areas to determine whether the project affected fish abundance. Thirty samples each were collected from CTU 2 in the project area and reference area 2, concurrently, during each sampling period with a 1-m^2 throw trap with 1-m high walls constructed of 1.6 mm mesh nylon netting (Kushlan 1981). A 0.25 in (0.64-cm) diameter steel bar, bent into a square, was attached to the bottom of the net to make it sink rapidly in the water. A floating collar of plastic pipe 0.75 in (1.91-cm) diameter was attached to the top of the net to

keep the throw trap vertical in the water column after deployment. Additional samples were collected randomly using a 20-ft (6.1 m) minnow seine with 3/16 in (0.48 cm) mesh to compensate for the potential deficiency of the throw traps for determining species composition. A minimum of three seine pulls were conducted in the project area and both reference areas at each sampling event to determine whether throw traps adequately depict species composition. Mean density, relative abundance, and total biomass (dry weight in grams) of each species were recorded. A water sample was collected at each site and measurements taken for water temperature (^{o}C), salinity (ppt), dissolved oxygen (mg/l), water depth (cm) and distance to the marsh edge (m). At each site, presence or absence of SAV was noted. Sampling locations were randomly chosen from a grid pattern for each sampling trip. Personnel from LDNR/CRD conducted sampling in June 1995, October 1995, April 1996 (during drawdown), October 1996, and March 1997. National Marine Fisheries Service (NMFS) personnel and the LDNR/CRD monitoring manager conducted sampling in April 1997 (during drawdown), September 1997, April 2001, and November 2001. NMFS analyzed data from June and October 1995 and April 1996 and determined that throw trap sampling depicted species composition of the area at least as well as seine sampling, and seine sampling was discontinued.

Density and biomass means and standard errors for each fish and crustacean species were calculated for the project and reference area for each sampling period. Means and standard errors for all environmental variables collected were calculated for the project and reference area per sampling period. Although construction was not completed until after the April 1996 sampling time, access to the project area was disturbed by the ongoing construction and April 1996 was thus considered postconstruction. Two factor ANOVA's with interaction were used to compare mean animal densities and environmental variables between the project and reference areas for preconstruction sampling times to estimate the suitability of the reference area. The specific environmental variables tested were salinity, temperature, dissolved oxygen, depth, and distance to edge and the animal variables were total fishes, total crustaceans, transient fishes, transient crustaceans, resident fishes, and resident crustaceans. The same set of environmental and animal variables were then compared between preconstruction and postconstruction sampling times with a one-way ANOVA for each area separately (Appendix A). Prior to statistical analyses, Hartley's F-max test was used to determine if variances in the treatment cells were equal (Milliken and Johnson 1992). We performed a ln(x+1) transformation on the density, species richness, and biomass data, because cell means were positively related to standard deviations. In cases where cell means were positively related to variances (i.e., salinity, water temperature, dissolved oxygen concentration, water depth, distance to edge), a square root transformation was used prior to analyses. These transformations generally reduced the relationships between means and standard deviations or variances. However, F-max tests still indicated heterogeneity for some variables. Despite this failure to meet the assumption of homogeneity of variances in all cases, ANOVA tests were conducted on transformed data because the test is considered robust, and failure to correct heterogeneity does not preclude its use (Green 1979, Underwood 1981). An alpha level of 0.05 was used to determine statistical significance for all ANOVA tests.

<u>Drawdown and Maintenance Structure Operations</u>: Operational changes were carried out by Apache personnel according to permit specifications (table 1). The project permit allows a

Table 1. Operational changes for each of the structures at East Mud Lake (CS-20).

Structure number	Date and Operation Performed				
	5/2/96 (Phase I)	6/11/96	6/18/96	7/18/96(Phase II)	7/26/96
17	stoplogs 12" AML			stoplogs removed	
1	stoplogs removed			stoplogs 6" BML flapgates locked open	
3	stoplogs removed flapgates operating			stoplogs 6" BML flapgates locked open	
4	stoplogs removed flapgates operating			stoplogs 6" BML flapgates locked open	
5	stoplogs removed flapgates operating			stoplogs1 bay 6" BML, 1 bay 12" BML flapgates locked open	
9a	stoplogs removed flapgates operating			stoplogs 6" BML flapgates locked open	
11	stoplogs removed flapgates operating	flapgates locked open for 24hrs(plantingaccess)	flapgates locked open for 24hrs(plantingaccess)	stoplogs removed flapgates operating	stoplogs 6" BML flapgates locked open
13	stoplogs 6" BML flapgates locked open			stoplogs 6" BML flapgates operating	
6	stoplogs 6" BML			stoplogs 6" BML	
7	stoplogs 6" BML			closed	Stoplogs 6" and 12" BML
8	stoplogs 6" BML			stoplogs 6" BML	
9b	flapgates operating screwgate open			flapgates locked open screwgate open	

* Salinities exceeded 15 ppt in CTU 2.
** Salinities exceeded 15 ppt in CTU 1
‡ Vandalism ; AML=above marsh level, BML=below marsh level

Table 1, continued. Operational changes for each of the structures at East Mud Lake.

Structure number	Date and Operation Performed				
	8/3/96	3/12/97 (Phase I)	6/10/97	7/15/97 (Phase II)	8/26/97*
17		stoplogs 12" AML		stoplogs removed	
1		stoplogs removed		stoplogs 6" BML	
3	flapgates operating 24 hrs‡	stoplogs stuck 6" BML flapgates operating		stoplogs 6" BML flapgates locked open	stoplogs 6" BML flapgates operating
4			12 stoplogs removed 48 hrs‡	stoplogs 6" BML boards bolted ‡ flapgates open	
5		stoplogs removed flapgates operating		stoplogs1 bay 6" BML, 1 bay 12" BML flapgates locked open	stoplogs1 bay 6" BML, 1 bay 12" BML flapgates operating
9a		stoplogs removed flapgates operating		stoplogs 6" BML flapgates locked open	stoplogs 6" BML flapgates locked open
11		stoplogs removed flapgates operating		stoplogs 6" BML flapgates locked open	stoplogs 6" BML flapgates operating
13	stoplogs 6" BML flapgates locked open			stoplogs 6" BML flapgates locked open	
6		stoplogs 6" BML		stoplogs 6" BML	
7		stoplogs 6" BML		stoplogs1 bay 6" BML, 1 bay 12" BML	
8		stoplogs 6" BML		stoplogs 6" BML	
9b		flapgates operating screwgate open		flapgates operating screwgate open	

* Salinities exceeded 15 ppt in CTU 2.
** Salinities exceeded 15 ppt in CTU 1
‡ Vandalism ; AML=above marsh level, BML=below marsh level

Table 1, continued. Operational changes for each of the structures at East Mud Lake.

Structure number	Date and Operation Performed				
	9/5/97**	10/12/97	10/20/97	1/14/98	5/13/98*
17					
1					stoplogs 6" BML flapgates operating
3	flapgates operating 24 hrs‡			stoplogs 6" BML flapgates locked open	stoplogs 6" BML flapgates operating
4		2' hole dug in levee adjacent to structure‡	1 flapgate permanently removed from culvert ‡		stoplogs 6" BML flapgates operating plywood in open bay
5				stoplogs1 bay 6" BML, 1 bay 12" BML flapgates locked open	stoplogs 6" BML flapgates operating
9a				stoplogs 6" BML flapgates locked open	
11					stoplogs 6" BML flapgates operating
13				stoplogs 6" BML flapgates locked open	
6	stoplogs 6" AML				
7					
8	stoplogs 6" AML				
9b					

* Salinities exceeded 15 ppt in CTU 2.
** Salinities exceeded 15 ppt in CTU 1
‡ Vandalism **;** AML=above marsh level**,** BML=below marsh level

Table 1, continued. Operational changes for each of the structures at East Mud Lake.

Structure number	Date and Operation Performed				
	6/15/98*	9/2/98**	9/23/98***	9/30/98	10/5/98
17					
1					
3					
4					2 flaps open ‡
5					
9a	stoplogs 6" BML flapgates operating				
11					
13					
6		close slots			
7		close slots	remove stoplogs to exit high water	stoplogs1 bay 6" BML, 1 bay 12" BML	
8		close slots			
9b					

* Salinities exceeded 15 ppt in CTU 2.
** Salinities exceeded 15 ppt in CTU 1
*** Response to high water levels from Tropical Storm Frances
‡ Vandalism; AML=above marsh level, BML=below marsh level

Table 1., continued Operational changes for each of the structures at East Mud Lake (CS-20).

Structure number	Date and Operation Performed				
	2/20/99	5/7/99*	7/9/99	8/30/99	9/9/99
17	Bent tabs to allow stoplogs				
1	stoplogs 6" BML flapgates locked open	Flapgates operating			
3	stoplogs 6" BML flapgates locked open	Flapgates operating			
4	stoplogs 6" BML flapgates locked open	Flapgates operating			
5	stoplogs1 bay 6" BML, 1 bay 12" BML flapgates locked open	Flapgates operating			
9a	stoplogs 6" BML flapgates locked open				Flapgates operating
11	stoplogs 6" BML flapgates locked open	Flapgates operating	Vandalism; flap tied open‡		
13					
6					
7					
8					
9b				Flapgates operating	

* Salinities exceeded 15 ppt in CTU 2.
** Salinities exceeded 15 ppt in CTU 1
‡ Vandalism; AML=above marsh level, BML=below marsh level

Table 1., continued Operational changes for each of the structures at East Mud Lake (CS-20).

Structure number	Date and Operation Performed			
	9/23/99**	11/2/99	1/6/00	2/23/00
17				
1		Stoplogs at ML		stoplogs1 bay 6" BML, 1 bay 12" BML
3				
4				
5		Stoplogs at ML		stoplogs1 bay 6" BML, 1 bay 12" BML
9a		Stoplogs at ML		stoplogs 6" BML setting screwgate opened
11		Stoplogs at ML		stoplogs1 bay 6" BML, 1 bay 12" BML
13				
6	Closed flow from stoplogs			
7	Closed flow from stoplogs	stoplogs1 bay 6" BML, 1 bay 12" BML	Closed flow from stoplogs	
8	Closed flow from stoplogs			
9b				

* Salinities exceeded 15 ppt in CTU 2.
** Salinities exceeded 15 ppt in CTU 1
AML=above marsh level**,** BML=below marsh level

Table 1., continued Operational changes for each of the structures at East Mud Lake (CS-20).

Structure number	Date and Operation Performed				
	7/6/00	8/1/00	2/7/01	6/7/01	3/6/02
17					
1			stoplogs 6" BML flapgates locked open	stoplogs 6" BML Flapgates operating	stoplogs 6" BML flapgates locked open
3			stoplogs 6" BML flapgates locked open	stoplogs 6" BML flapgates operating	stoplogs 6" BML flapgates locked open
4			stoplogs 6" BML flapgates locked open	stoplogs 6" BML Flapgates operating	stoplogs 6" BML flapgates locked open
5			stoplogs1 bay 6" BML, 1 bay 12" BML flapgates locked open	stoplogs1 bay 6" BML, 1 bay 12" BML flapgates operating	stoplogs1 bay 6" BML, 1 bay 12" BML flapgates locked open
9a			stoplogs 6" BML flapgates locked open	stoplogs 6" BML Flapgates operating	stoplogs 6" BML flapgates locked open
11			stoplogs 6" BML flapgates locked open	stoplogs 6" BML Flapgates operating	stoplogs 6" BML flapgates locked open
13		Water flow restored	stoplogs 6" BML flapgates locked open		
6					
7					
8					
9b					

* Salinities exceeded 15 ppt in CTU 2.
** Salinities exceeded 15 ppt in CTU 1
AML=above marsh level, BML=below marsh level

Table 1., continued Operational changes for each of the structures at East Mud Lake (CS-20).

Structure number	Date and Operation Performed	
	6/10/03	12/31/03(end of period covered in report)
17		
1	stoplogs 6" BML Flapgates operating	stoplogs 6" BML Flapgates operating
3	stoplogs 6" BML Flapgates operating	stoplogs 6" BML Flapgates operating
4	stoplogs 6" BML Flapgates operating	stoplogs 6" BML Flapgates operating
5	stoplogs1 bay 6" BML, 1 bay 12" BML flapgates operating	stoplogs1 bay 6" BML, 1 bay 12" BML flapgates operating
9a	stoplogs 6" BML Flapgates operating	stoplogs 6" BML Flapgates operating
11	stoplogs 6" BML Flapgates operating	stoplogs 6" BML Flapgates operating
13		
6		
7		
8		
9b		

* Salinities exceeded 15 ppt in CTU 2.
** Salinities exceeded 15 ppt in CTU 1
AML=above marsh level, BML=below marsh level

drawdown twice in the first 5 years following end of construction. Low water conditions occurred in spring 1996, optimizing conditions for drawdown. Gulf low water levels resulting from lack of southerly winds were as influential upon low water levels in the marsh at this time as lack of rainfall. Upon completion of construction, the first Phase I drawdown was initiated on May 5, 1996. The drawdown was terminated July 17, 1996, as stop logs were set in place and flaps were locked opened. However, water levels did not return to normal until October 1996 due to extended low water levels outside the project area caused by the ongoing major drought.

A second drawdown was initiated March 3, 1997, when weather conditions favorable to lower water levels predominated. During this time, the parish experienced mild drought conditions from May through August. The second drawdown was terminated July 15, 1997.

Repeated vandalism occurred throughout the summer at structure 4 as unlawful attempts were made to keep flapgates open. The vandalism included removal of stoplogs in July, excavation of a 2 ft trench in the levee adjacent to the structure, and removal of a flapgate from one of the five bays in October 1997. Apache personnel attempted repairs in May 1998.

During 1998, flapgates remained locked open from January 14 to May 13, but high salinities forced the unlocking of flapgates at structures 1, 3, 4, 5, and 11 in CTU 2. At this time, Apache personnel attempted to close the bay with the missing flapgate at structure 4 with a plywood board to prevent high salinities from entering the project area. The plywood was in place until January 2000 when the flap was replaced by LDNR's Coastal Engineering Division. Unfortunately, by 1999 it was evident that structure 4 also began sinking on one side. In 1999, LDNR / CED attempted to stabilize the structure with rock reinforcement. Since then, the stoplogs in at least one bay on the sinking side have been lower than the maintenance phase height of six inches below marsh level (BML) (figure 4). Since 7 Februaruy 2001, the sinking of the structure has also changed the position of the bulkheads, preventing the flapgates from being locked open when necessary. The flapgates on structure 4 were again locked open briefly in June 2003. More repairs would be needed to lock them open in the future. A design for a conventional structure to replace structure 4 was initiated in 2002 but was discarded in favor of a unique, automated control structure that uses continuous recorders to monitor water salinity and water level and automatically operate the structure accordingly. Additional funds were solicited from the CWPPRA Task Force in October 2004 and the project went out to bid in January 2005. There were no successful bidders, and another, more conventional structure design is currently being considered.

Further operations of the flapgates on the other structures followed the permit guidelines which allow for unlocking the flapgates when inside salinities are 15 ppt or greater, and temporary removal of stoplogs to drain high water.

Figure 4 East Mud Lake (CS-20) structure 4 showing sinkage of the southern end.

All structures are currently functioning as designed with the exception of structure 4, mentioned previously, and structure 13. Structure 13 was designed to allow lower salinity water into the project area from the northwest and control water release out of East Mud Lake into First Bayou. It has been silted in to the top of the stoplogs since August 1999. First Bayou itself, which leads to the structure has also silted in due to low flow. When water does flow in First Bayou it can enter East Mud Lake through structure 13. The flapgates on the inside (East Mud Lake side) have not been able to close normally since August 1999, preventing the use of the structure to stop flow out of the lake.

RESULTS

Land to Water Ratio and Habitat mapping: The overall habitat composition of the project and reference areas has not changed significantly since 1978 according to the broad habitat categories used by Chabreck and Linscombe (1968, 1978, 1988, 1997). After a small area of intermediate vegetation present in 1968 was not seen again in 1978, the whole area has remained a brackish marsh through at least 1997. The 1956, 1978, and 1988 habitat analyses also reinforce this assertion (figures 5, 6, 7). In 1994 and 2000 a different and more detailed analyses was available. Habitats in the project and reference areas represent two NWI habitat systems: the estuarine system and the palustrine system (tables 2, 3; figures 8, 9). In 1994, classification of photography to the NWI class level yielded 11 distinct habitat classes in the project and reference areas, for the purpose of mapping change. The habitat classes included 3 upland, 1 urban, 1 wetland scrub-shrub, 1 mud flat, 2 marsh, 1 submerged aquatic, and 2 open water categories. The 2000 classification added floating aquatic, forested wetlands – fresh, and upland barren components. Land habitats in both the project and reference areas were dominated by salt marsh in both 1994 and 2000. During this time, the major habitat increases in CTU 2 were in salt marsh, wetland scrub-shrub and upland scrub-shrub of 113.5 acres (45.95 ha), 22.7 acres (9.19 ha), and 6.4 acres (2.6 ha), respectively. The main habitat area decrease was a 4.9 acre (2.0 ha) piece of agriculture range habitat that was converted to upland scrub shrub. In CTU 1, saltmarsh area decreased by 86.6 acres (35.1 ha), and wetland scrub-shrub increased by 28.9 acres (11.7 ha). In the reference areas the largest habitat change was a 17 acre (6.9 ha) increase in wetland scrub-shrub in reference area 2. CTU 1 had a net decrease in land area of 51 acres (20.6 ha)(mostly saltmarsh on the peninsula), whereas CTU 2 experienced a 131.6 acre (53.28 ha) net increase in land area. Reference area 1 lost a net 2.5 acres (1.0 ha) to open water and reference area 2 had a net conversion of land to water of 17.2 acres (6.96ha).

Although the overall habitat type composition is relatively consistent over time, the rate of loss / gain of emergent marsh has been variable. For the period of 1956 to 1978, the average per year marsh change was a loss, with the greatest in CTU 2 (36.73 acres [14.87 ha]), followed by REF 2, CTU 1, and REF 1 (1.27 acres [0.51 ha])(table 4; figures 4 and 5). Between 1978 and 1988 the average loss per year decreased in most areas, especially in CTU 2 and REF 2 (table 4; figures 6 and 7). Because of the difference in the data and method of analyses no valid loss / gain calculations could be made for the time period of 1988 to 1994. Between 1994 and 2000, the per year rates of marsh loss in CTU 1, REF 1, and REF 2 were similar to the 1978 to 1988 rates, but in CTU 2, there was a 22.7 acre (9.19 ha) per year gain from 1994 to 2000, up from a 5.2 acre (2.1 ha) per year loss from 1978 to 1988 (table 4; figures 6, 7 and 10).

Vegetative Plantings: Overall percent survival was 100% at 1 mo, decreased to 96% at 6 mo, 62% at 12 mo, and percent survival was only 35% at 48 mo (figure 11). There were no differences in percent survival among land types during the 1-mo and 6-mo periods, but percent survival differed among the land types at 12 mo (χ^2_{df2}= 17.15, P = 0.0002) and at 48 mo (χ^2_{df2}= 7.643, P = 0.02). Percent survival remained above 90% in the canal plantings, but declined to 45.6% in the step levee and to 15% in the lake at 12 mo postplanting (figure 11). Four years after planting, the canal group survival decreased to 55.3%, step levee survival was 51%, and no shoreline plants remained alive. Percent cover differed among the land types at 1-mo (χ^2_{df2} = 6

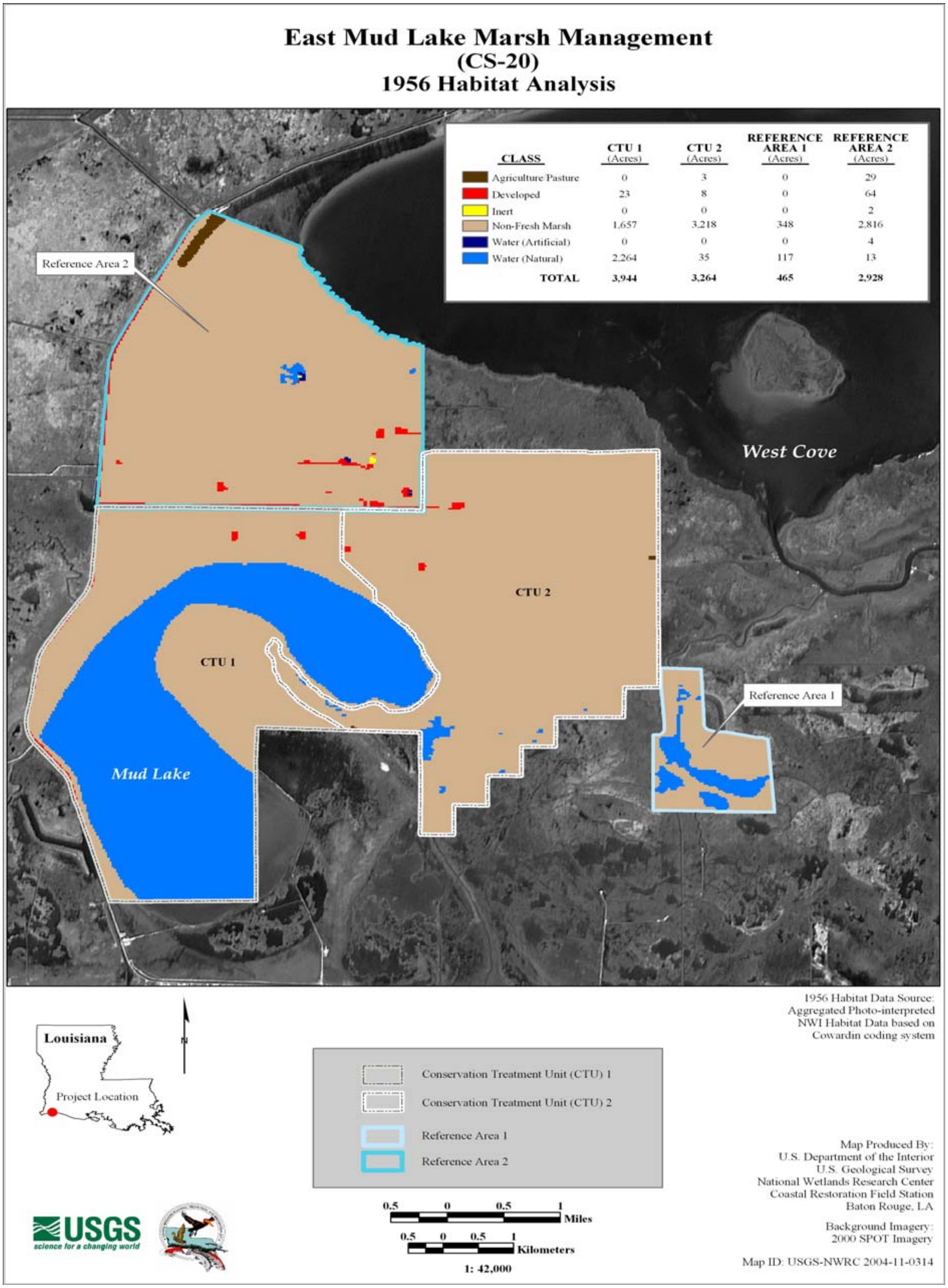


Figure 5. Habitat analysis for East Mud Lake (CS-20) in 1956.

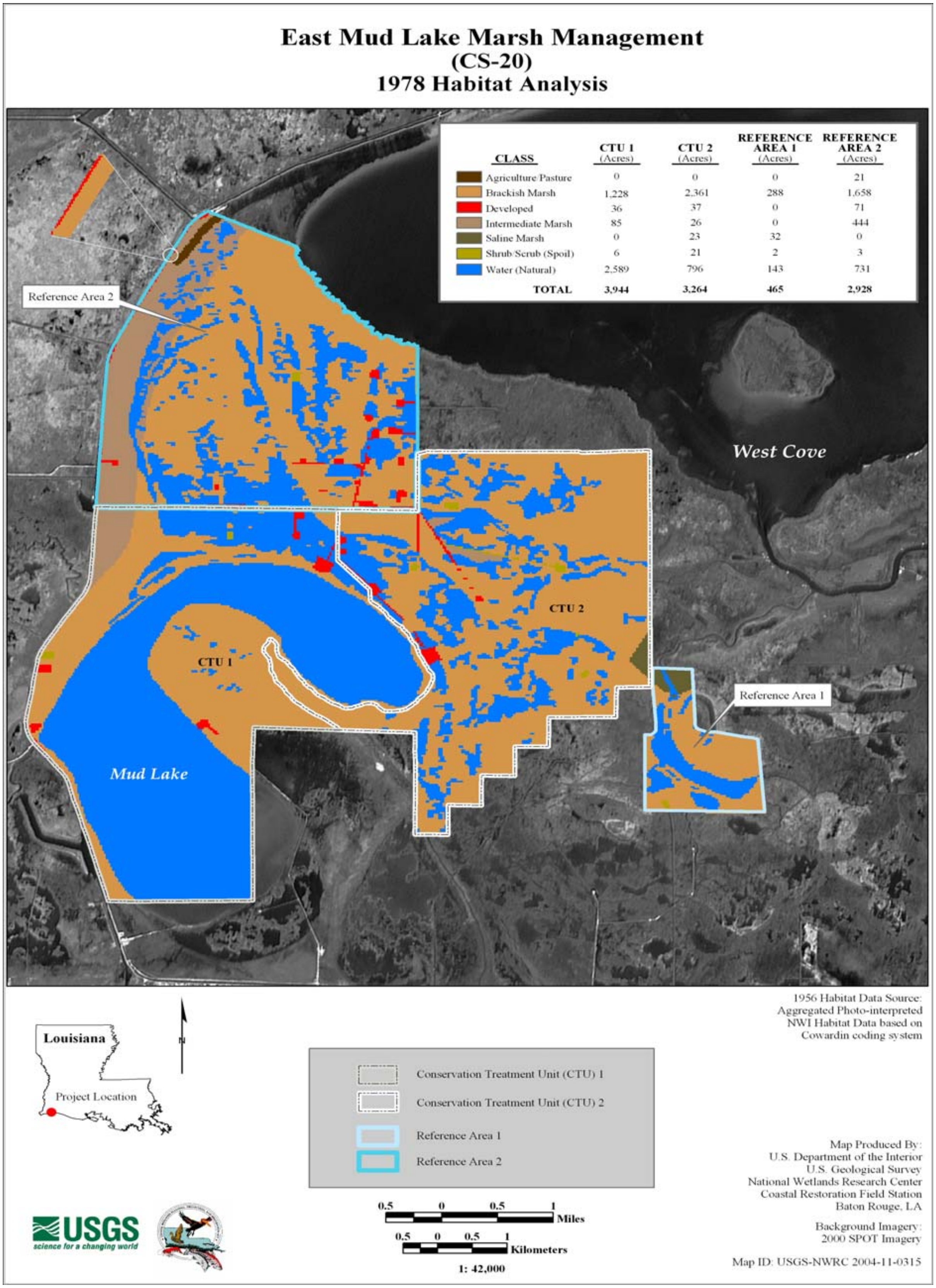


Figure 6. Habitat analysis for East Mud Lake (CS-20) in 1978.

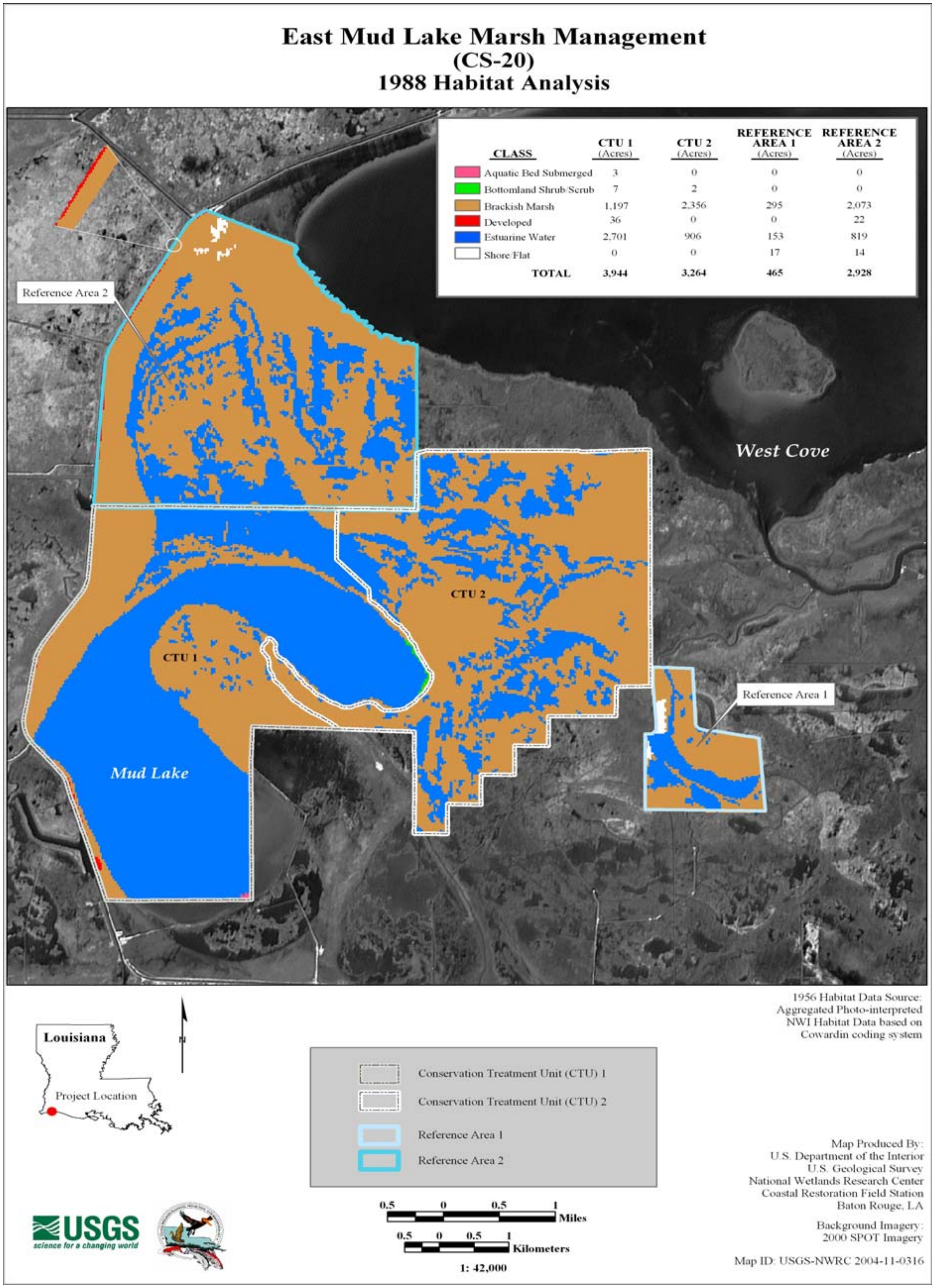
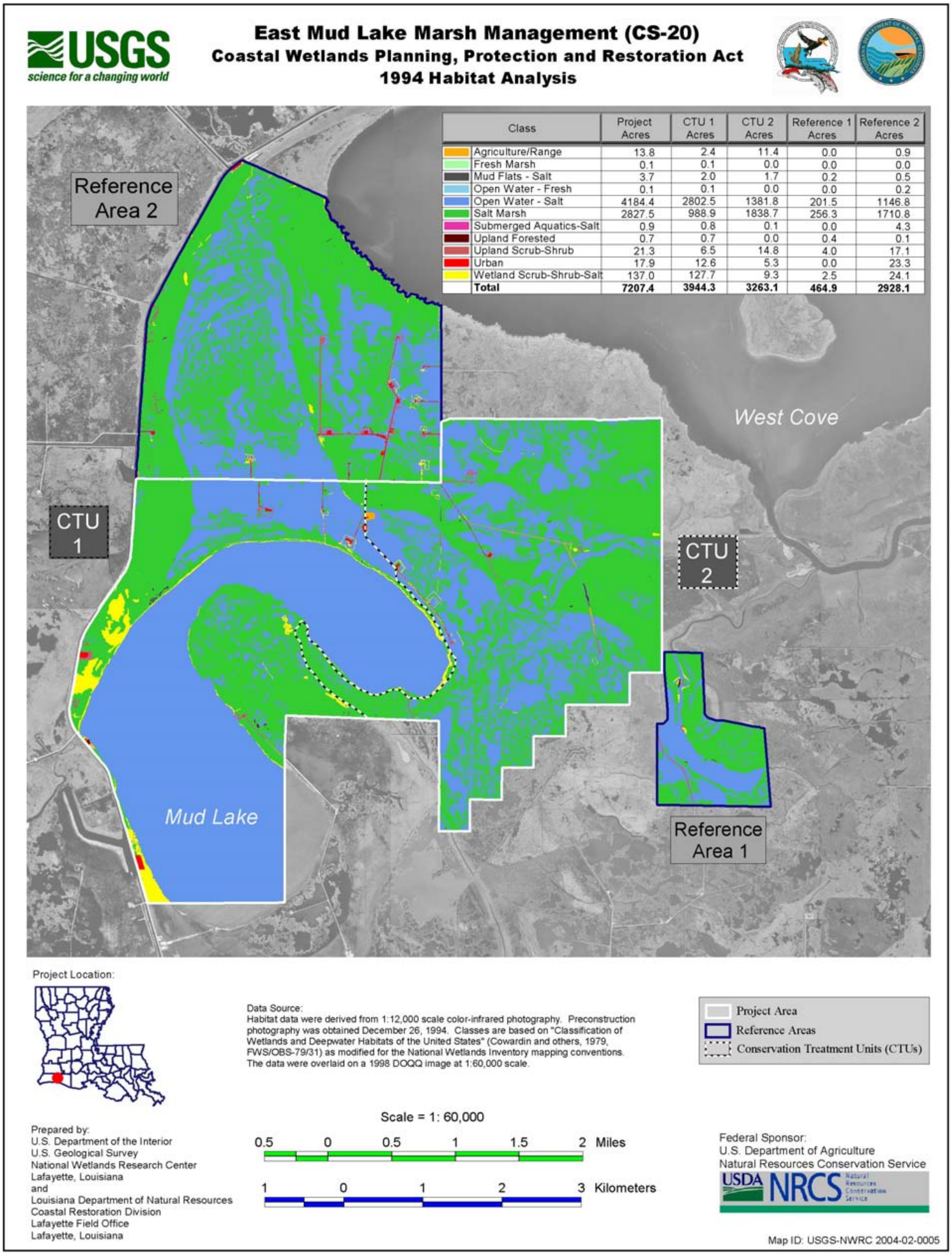
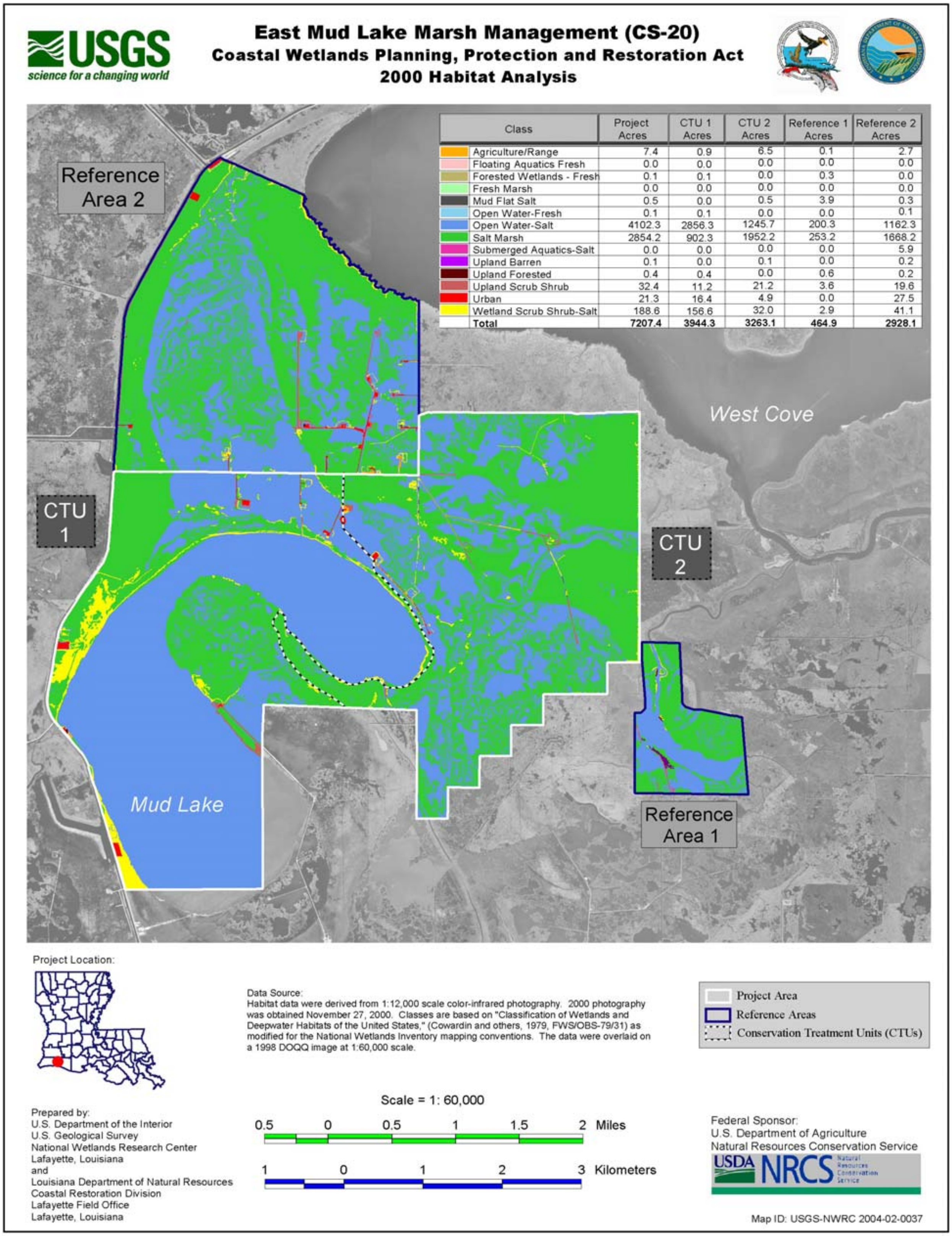


Figure 7. Habitat analysis for East Mud Lake (CS-20) in 1988.



Class	Project Acres	CTU 1 Acres	CTU 2 Acres	Reference 1 Acres	Reference 2 Acres
Agriculture/Range	13.8	2.4	11.4	0.0	0.9
Fresh Marsh	0.1	0.1	0.0	0.0	0.0
Mud Flats - Salt	3.7	2.0	1.7	0.2	0.5
Open Water - Fresh	0.1	0.1	0.0	0.0	0.2
Open Water - Salt	4184.4	2802.5	1381.8	201.5	1146.8
Salt Marsh	2827.5	988.9	1838.7	256.3	1710.8
Submerged Aquatics-Salt	0.9	0.8	0.1	0.0	4.3
Upland Forested	0.7	0.7	0.0	0.4	0.1
Upland Scrub-Shrub	21.3	6.5	14.8	4.0	17.1
Urban	17.9	12.6	5.3	0.0	23.3
Wetland Scrub-Shrub-Salt	137.0	127.7	9.3	2.5	24.1
Total	**7207.4**	**3944.3**	**3263.1**	**464.9**	**2928.1**

Figure 8. Habitat analysis for East Mud Lake (CS-20) in 1994



Class	Project Acres	CTU 1 Acres	CTU 2 Acres	Reference 1 Acres	Reference 2 Acres
Agriculture/Range	7.4	0.9	6.5	0.1	2.7
Floating Aquatics Fresh	0.0	0.0	0.0	0.0	0.0
Forested Wetlands - Fresh	0.1	0.1	0.0	0.3	0.0
Fresh Marsh	0.0	0.0	0.0	0.0	0.0
Mud Flat Salt	0.5	0.0	0.5	3.9	0.3
Open Water-Fresh	0.1	0.1	0.0	0.0	0.1
Open Water-Salt	4102.3	2856.3	1245.7	200.3	1162.3
Salt Marsh	2854.2	902.3	1952.2	253.2	1668.2
Submerged Aquatics-Salt	0.0	0.0	0.0	0.0	5.9
Upland Barren	0.1	0.0	0.1	0.0	0.2
Upland Forested	0.4	0.4	0.0	0.6	0.2
Upland Scrub Shrub	32.4	11.2	21.2	3.6	19.6
Urban	21.3	16.4	4.9	0.0	27.5
Wetland Scrub Shrub-Salt	188.6	156.6	32.0	2.9	41.1
Total	**7207.4**	**3944.3**	**3263.1**	**464.9**	**2928.1**

Figure 9. Habitat analysis for East Mud Lake (CS-20) in 2000.

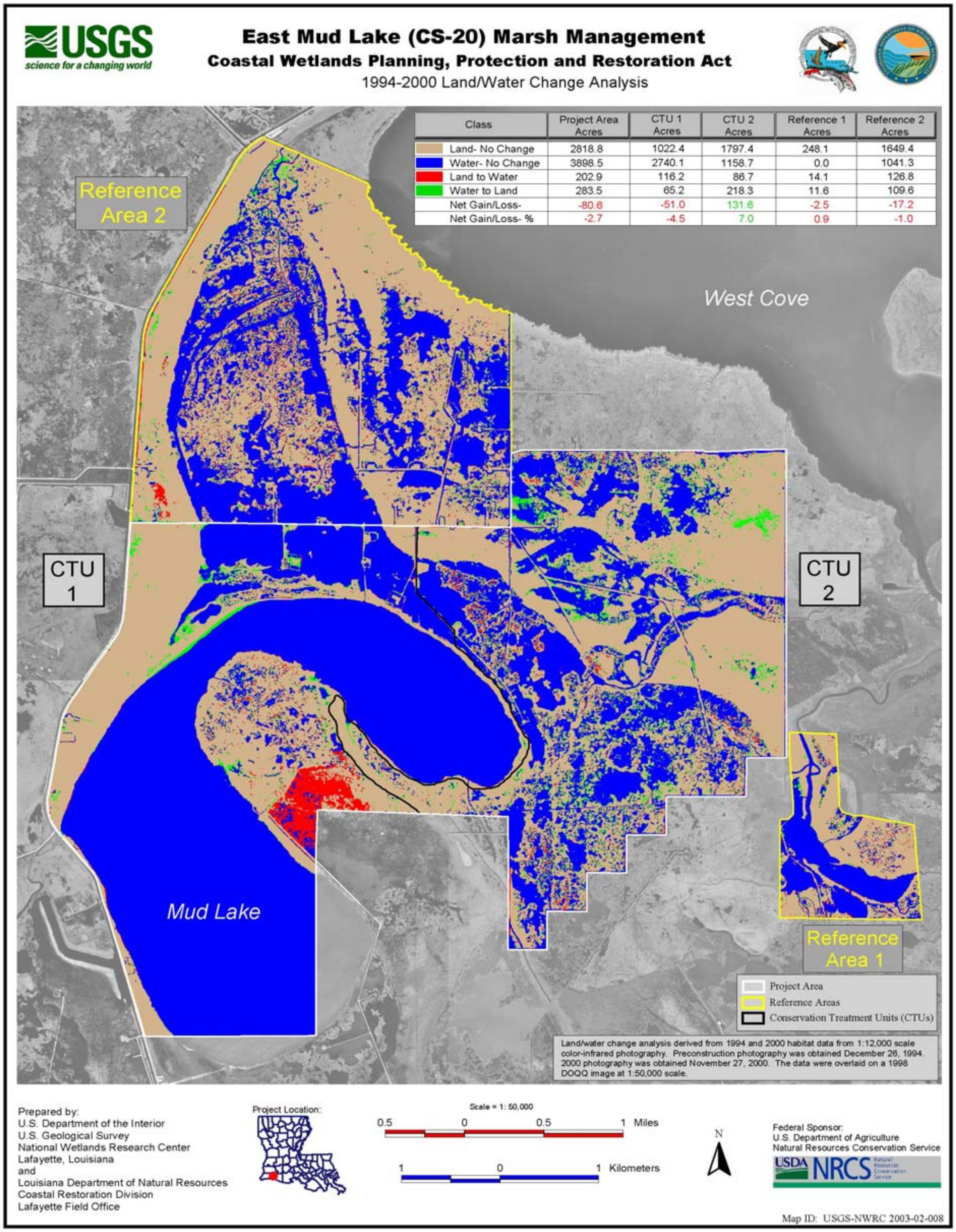


Figure 10. Land water change analysis from 1994 to 2000 for East Mud Lake (CS-20).

Table 2. Acreage (hectares) of habitat types derived from photointerpretation of the 1994 aerial photography in the East Mud Lake (CS-20) project and reference areas.

Habitat Class	Project Area		Reference Areas	
	CTU 1	CTU 2	1	2
Open Water - Fresh	0.1(0.04)	0.0(0.0)	0.0(0.0)	0.2(0.08)
Open Water - Salt	2902.5(1175.1)	1381.9(559.5)	201.5(81.6)	1146.8(464.3)
Submerged Aquatics - Salt	0.8(0.3)	0.1(0.04)	0.0(0.0)	4.3(1.7)
Fresh Marsh	0.1(0.04)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Salt Marsh	988.9(400.4)	1838.7(744.4)	256.3(103.8)	1710.8(692.6)
Mud Flats - Salt	2.0(0.81)	1.7(0.69)	0.2(0.08)	0.5(0.20)
Wetland Scrub-Shrub - Salt	127.7(51.7)	9.3(3.8)	2.5(1.0)	24.1(9.78)
Upland Scrub-Shrub	6.5(2.6)	14.8(5.99)	4.0(1.6)	17.1(6.92)
Upland Forested	0.7(0.3)	0.0(0.0)	0.4(0.2)	0.1(0.04)
Agricultural/Range	2.4(0.97)	11.4(4.62)	0.0(0.0)	0.9(0.4)
Urban	12.6(5.10)	5.3(2.1)	0.0(0.0)	23.3(9.43)
TOTAL	3944.8(1597.1)	8263.1(3345.4)	464.9(188.2)	2928.1(1185.5)

Table 3. Acreage (hectares) of habitat types derived from photointerpretation of the 2000 aerial photography in the East Mud Lake (CS-20) project and reference areas.

Habitat Class	Project Area		Reference Areas	
	CTU 1	CTU 2	1	2
Open Water - Fresh	0.1(0.04)	0.0(0.0)	0.0(0.0)	0.1(0.04)
Open Water - Salt	2856.3(1156.4)	1245.7(504.33)	200.3(81.09)	1162.3(470.57)
Floating Aquatics - Fresh	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Submerged Aquatics - Salt	0.0(0.0)	0.0(0.0)	0.0(0.0)	5.9(2.4)
Fresh Marsh	0.0(0.0)	0.0(0.0)	0.0(0.0)	0.0(0.0)
Salt Marsh	902.3(365.3)	1952.2(790.36)	253.2(102.5)	1668.2(675.38)
Mud Flats - Salt	0.0(0.0)	0.5(0.2)	3.9(1.6)	0.3(0.1)
Forested Wetlands - Fresh	0.1(0.04)	0.0(0.0)	0.3(0.1)	0.0(0.0)
Wetland Scrub-Shrub - Salt	156.6(63.40)	32.0(12.9)	2.9(1.2)	41.1(16.6)
Upland Scrub-Shrub	11.2(4.53)	21.2(8.58)	3.6(1.5)	19.6(7.94)
Upland Forested	0.4(0.2)	0.0(0.0)	0.6(0.2)	0.2(0.08)
Upland Barren	0.0(0.0)	0.1(0.04)	0.0(0.0)	0.2(0.08)
Agricultural/Range	0.9(0.4)	6.5(2.6)	0.1(0.04)	2.7(1.1)
Urban	16.4(6.64)	4.9(2.0)	0.0(0.0)	27.5(11.1)
TOTAL	3944.3(1596.9)	3263.1(1321.1)	464.9(188.2)	2928.1(1185.5)

Table 4. Land loss (-)/gain of natural emergent marshland only using habitat mapping numbers; land is only marsh or wetland scrub-shrub. Other land classes were associated with oil field activity. Note: 1956, 1978, and 1988 are of one type of analysis1994 and 2000 are of a slightly different type of analysis. Therefore, land loss calculations during the period of 1988 to 1994 would not be valid.

Year	CTU 1	CTU 2	REF 1	REF 2
	marsh land (acres/hectares)	marsh land (acres/hectares)	marsh land (acres/hectares)	marsh land (acres/hectares)
1956	1657(670.9)	3218(1303)	348(141)	2816(1140)
1978	1313(531.6)	2410(975.7)	320(130)	2105(852.2)
Loss(-)/gain per yr (1956-1978)	**-15.64(-6.332)**	**-36.73(-14.87)**	**-1.27(-0.51)**	**-32.32(-13.09)**
1988	1204(487.4)	2358(954.7)	295(119)	2073(839.3)
Loss(-)/gain per yr (1978-1988)	**-10.90(-4.413)**	**-5.20(-2.11)**	**-2.50(-1.01)**	**-3.20(-1.30)**
1994	1116.7(452.11)	1848.0(748.18)	258.8(104.8)	1734.9(702.39)
2000	1058.9(428.70)	1984.2(803.32)	256.1(103.7)	1709.3(692.02)
Loss(-)/gain per yr (1994-2000)	**-9.63(-3.90)**	**22.70(9.190)**	**-0.45(-0.18)**	**-4.27(-1.73)**

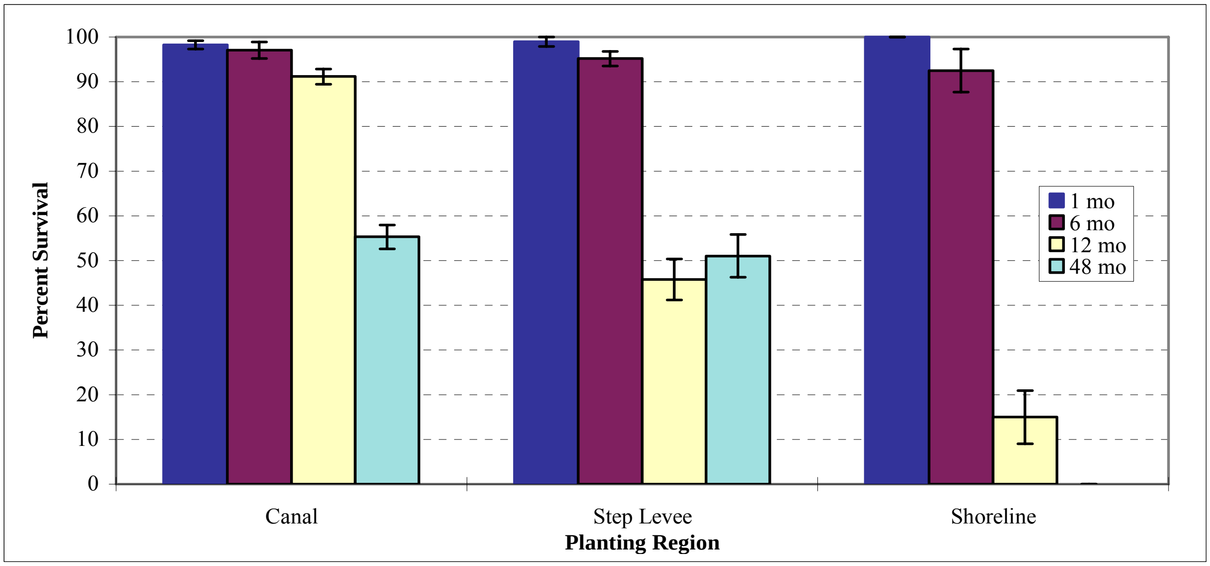


Figure 11. Average percent survival of *Spartina alterniflora* plantings in the East Mud Lake (CS-20) project area.

.09, P = 0.047), at 6-mo (χ^2_{df2} =7.47, P= 0.02), at 12 mo (χ^2_{df2} =16.83, P= 0.0002), and at 48 mo (χ^2_{df2} =8.046, P= 0.02) (figure 12). Cover increased over time in the canal and the step levee to a maximum of 73% and 33% respectively, at 12 mo. The lakeshore plantings increased marginally by 6 mo, but decreased to almost 0% by 12 mo (figure 12). The canal and step levee plants decreased in percent cover to 29.3% and 23.3%, respectively, after 48 mo. Native species colonizing the step levee and shoreline included *Distichlis spicata* (saltgrass), *S. patens*, *Heliotropium currassivicum* (seaside heliotrope), *Lycium carolinianum* (salt matrimony-vine) and *Salicornia bigelovii* (glasswort).

Existing vegetation: Our conservative analysis of the data did not determine any statistically significant differences in total percent cover or species richness among years or between areas (figures 13 and 14). The year*area interaction term was not significant and within area comparisons among years were also not significant. Despite the lack of statistically significant differences in cover and species richness we report the means for cover, species richness, and dominant species composition (figures 13, 14, and 15). The total percent cover in the project area declined from 89% in 1995 to 66% in 1997 and was approximately 60% in the two subsequent samples. The reference area cover appears to have been lower in 1999 than in other years. Species richness increased in both areas to a maximum in 1999 and then returned to the 1997 level by 2003 in both areas. Change in the species number and composition was greater in the project area. Dominant species composition changed over time, especially in the project area (figure 15, table 5). In 1995, each area was dominated by *S. patens*. By 1997, in the project area, *S. patens* made up only about 50% of the cover in the average sample plot. *Amaranthus australis* and *D. spicata* made up the majority of the other 50% along with a small increase in *S. alterniflora*. *D. spicata* actually grew in on top of dead *S. patens*. The reference area was still mostly *S. patens*, but *A. australis* and *D. spicata* appeared for the first time. In 1999, the reference area had become split almost evenly between *S. patens* and *D. spicata*, whereas, the project area continued to be dominated by *S. patens* but now with the virtual absence of *S. alterniflora* and a seemingly permanent *D. spicata* presence. In 2003, the reference area was still about half *S. patens*, and half other species with *D. spicata* the most abundant of them. *S. alterniflora* cover increased in the project area and reference area samples. Some of the *S. alterniflora* expansion was due to plantings not part of the project plan (figure 16). The reference area continued to be dominated by *S. patens*, but with a small increase in cover percent by other species.

There was also new vegetation growth which was not detected by our monitoring methods. Expansion of *S. alterniflora* and *P. vaginatum* at the marsh edge outside of our sample plots was first noticed in 1997 following the drawdown and drought of 1996. With long term monitoring we expect to use these types of descriptive graphics to suggest trends and supplement statistical analyses.

Precipitation Synopsis: Because of the potential impact of precipitation on marsh management projects, this section provides a brief summary of rainfall patterns for the 1995 to 2003 period of study.

There was above normal rainfall and normal moisture for 1995 according to the Palmer Drought Index (figure 17a) (LOSC 1995). Monthly rainfall amounts appear to be alternately greater or

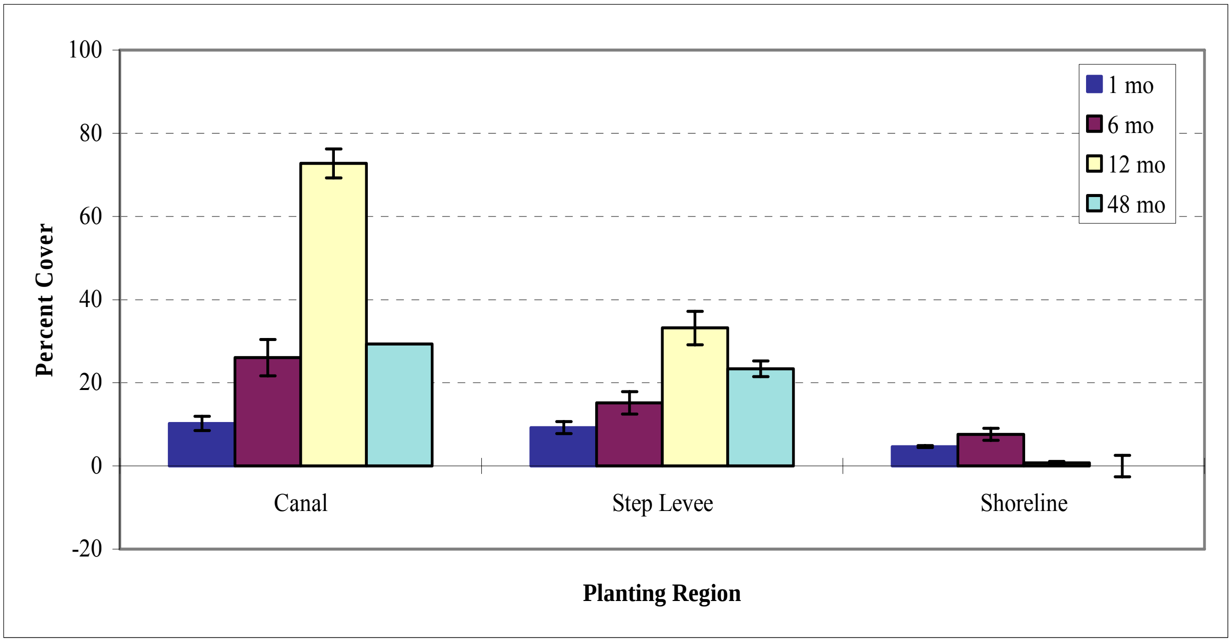


Figure 12. Average percent cover of *Spartina alterniflora* plantings in the East Mud Lake (CS-20) project area.

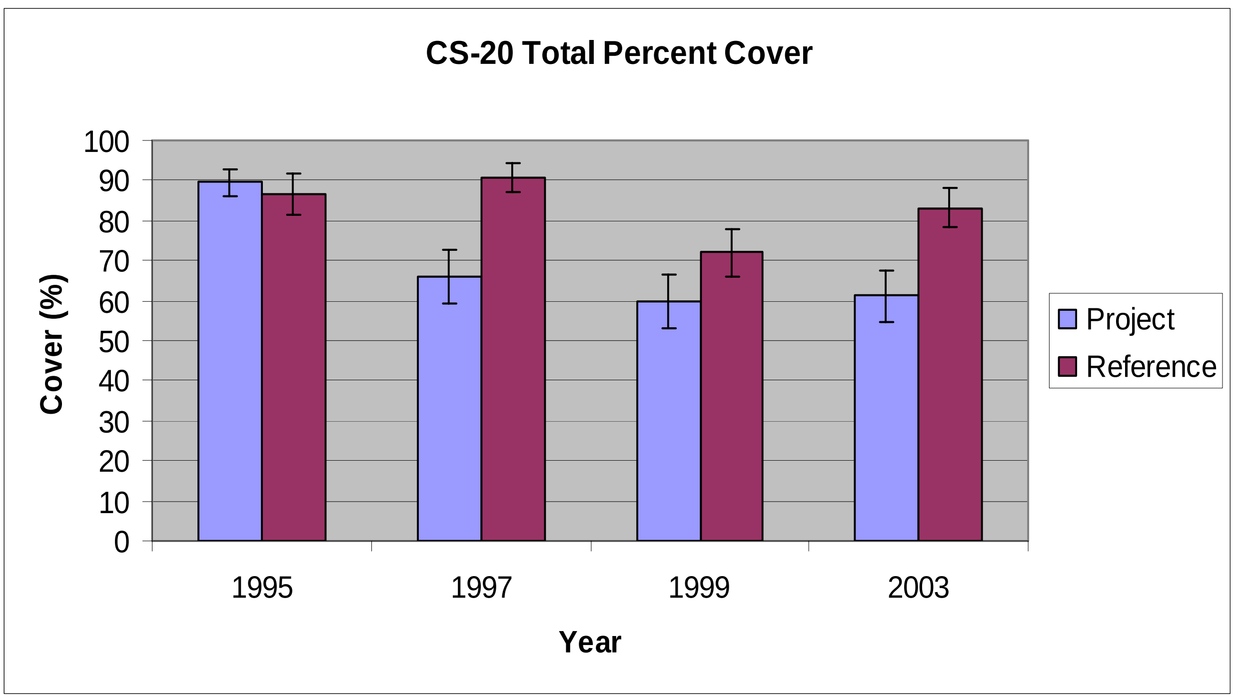


Figure 13. Emergent vegetation total percent cover among areas and years sampled.

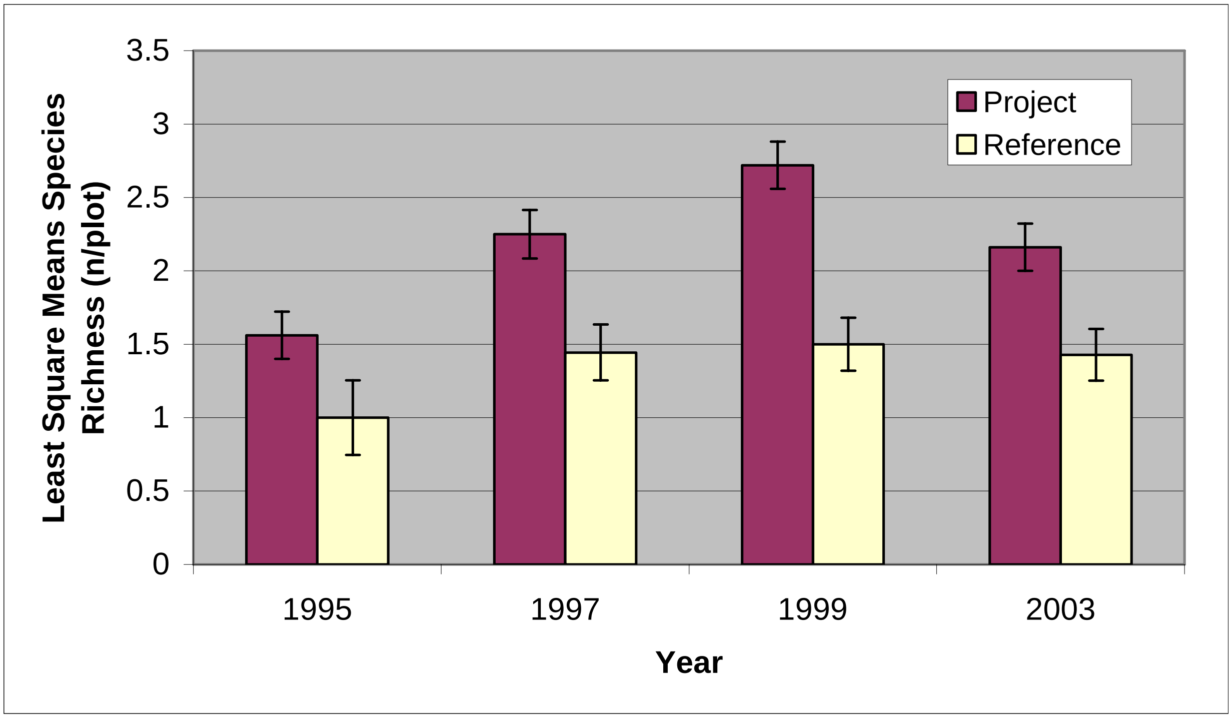


Figure 14. Emergent vegetation species richness among areas and years sampled.

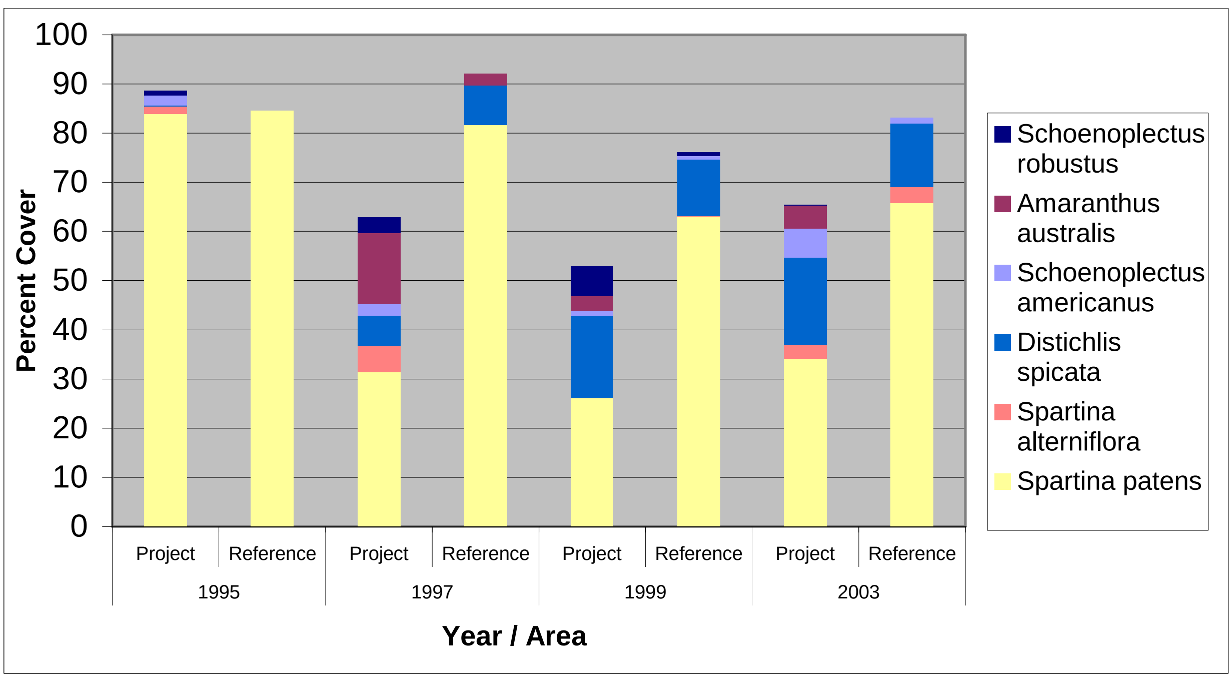


Figure 15. Mean percent cover of dominant emergent vegetation species at East Mud Lake (CS-20) project and reference areas from data collected at 25 stations preconstruction (June 1995) and postconstruction (June 1997, 1999, and 2003)

Table 5. Mean percent cover and standard error (SE) of emergent vegetative species in the East Mud Lake (CS-20) project and reference areas from data collected at 25 monitoring stations preconstruction (1995) and postconstruction (1997, 1999, 2003).

	Project Area								Reference Area							
	1995		1997		1999		2003		1995		1997		1999		2003	
Species	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**
Amaranthus australis (Gray) Sauer			14.47	(4.20)	3.13	(2.01)	4.60	(2.51)			2.33	(2.22)				
Atriplex cristata Humb. & Bonpl. Ex Willd.			1.25	(1.25)												
Borrichia frutescens (L.) DC.					1.20	(1.20)									0.48	(0.48)
Cyperus odoratus L.			4.40	(2.20)							2.22	(2.22)				
Distichlis spicata (L.) Greene	0.20	(0.20)	6.25	(4.17)	16.60	(4.02)	17.80	(5.05)			8.00	(5.52)	11.50	(4.22)	12.90	(6.70)
Erechtites hieraciifolia (L.) Raf. *ex.*DC.			0.01	(0.01)												
Heliotropium curassavicum L.			0.21	(0.21)												
Ipomoea sagittata Poir.			1.25	(1.25)												
Iva frutescens L.	0.04	(0.03)			0.05	(0.04)									1.19	(1.19)

Table 5. (continued)

	Project Area								Reference Area							
	1995		1997		1999		2003		1995		1997		1999		2003	
Species	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**	**S.E.**	**Mean**		**Mean**	**S.E.**	**Mean**	**S.E.**
Paspalum vaginatum Swartz.	0.02	(0.02)	0.42	(0.42)	5.44	(3.25)										
Phragmites australis (Cav.) Trin. ex Steud.							4.00	(4.00)								
Ruppia maritima L.			0.02	(0.02)	0.02	(0.02)										
Schoenoplectus americanus Pers.	2.02	(2.00)	2.29	(2.29)	1.00	(1.00)	5.88	(2.45)					0.75	(0.75)	1.19	(1.19)
Schoenoplectus robustus Pursh	1.00	(0.71)	3.13	(2.01)	6.00	(3.21)	0.20	(0.20)					0.75	(0.75)		
Solidago sempervirens L.			0.21	(0.21)												
Spartina alterniflora Loisel.	1.40	(0.98)	5.38	(4.26)	0.04	(0.04)	2.80	(1.33)					0.01	(0.01)	3.33	(2.52)
Spartina cynosuroides (L.) Roth	1.40	(0.98)	0.17	(0.17)	0.60	(0.60)										
Spartina patens (Ait.) Muhl.	84.00	(4.40)	31.35	(7.99)	26.16	(6.65)	34.12	(8.03)	84.60	(4.98)	81.72	(6.40)	63.10	(7.18)	65.71	(8.16)
Spartina spartinae (Trin.) Hitchc.	3.00	(3.00)														
Symphiotrichum spp.	0.02	(0.02)	2.92	(2.35)	1.40	(1.21)	1.04	(0.71)							0.10	(0.10)
Typha L.					0.60	(0.60)										

Figure 16. Expansion of *S. alterniflora* from nonproject plantings installed near pvc pipe.

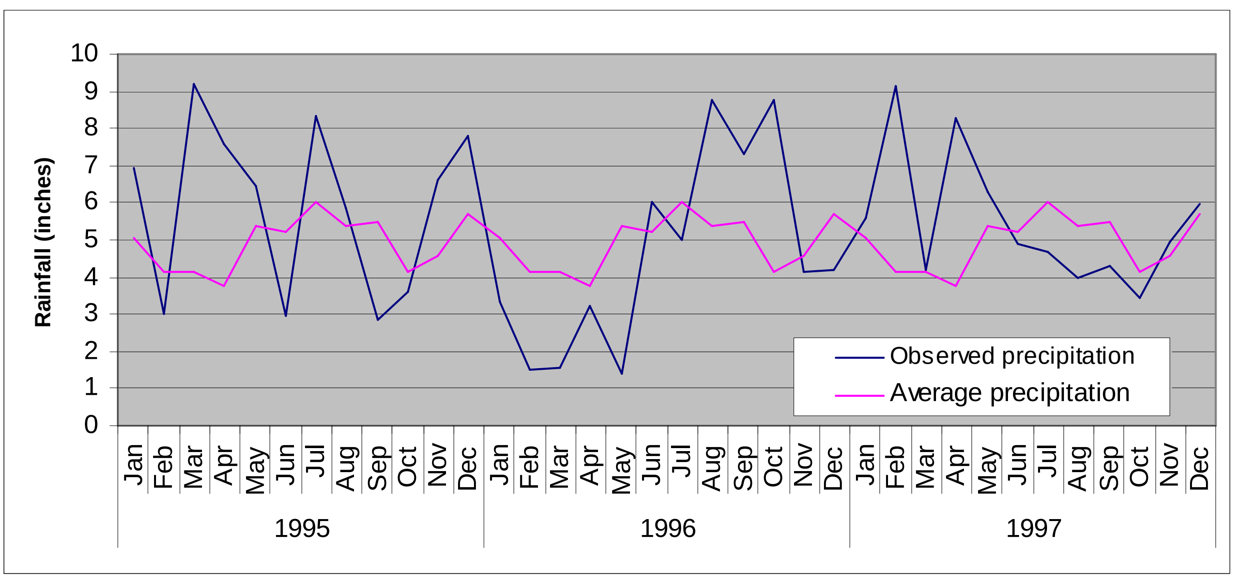


Figure 17a. Monthly and average precipitation for the Southwest division of Louisiana in 1995, 1996 and 1997.

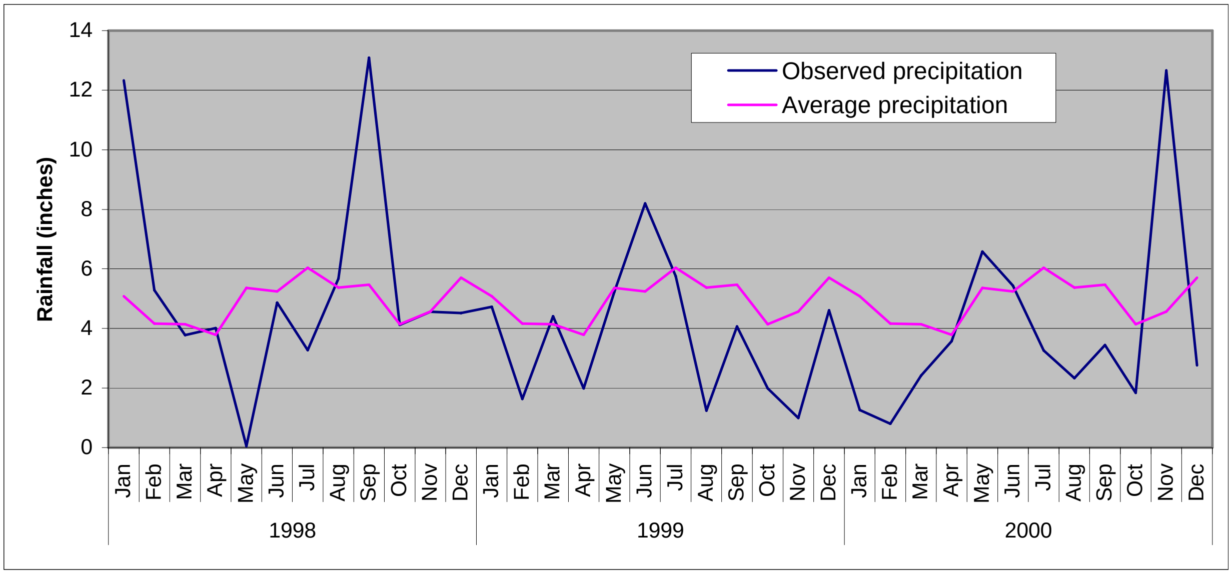


Figure 17b. Monthly and average precipitation for the Southwest division of Louisiana in 1998, 1999 and 2000.

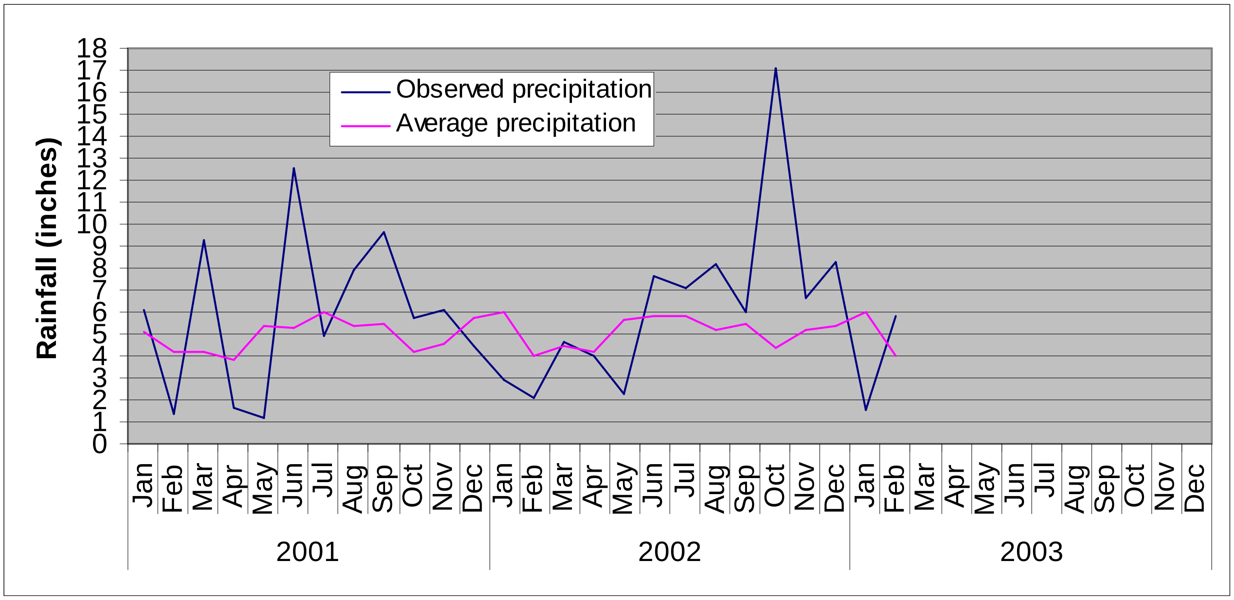


Figure 17c. Monthly and average precipitation for the Southwest division of Louisiana in 2001, 2002 and 2003.

less than the average.

In 1996, precipitation was very different from the average. There was decreased rainfall in the early part of the year followed by greater than average precipitation in the latter half (figure 17a) (LOSC 1996). Rainfall was below normal in January (66% of normal) and February (36% of normal) and the southwest region began a mild drought by February. The region had a cumulative deficit for the year of at least 10 inches by May (26% of normal) when the region officially began a moderate drought. This period ranks as the 5th driest January to May rainfall total of this century. The rain gauge in Hackberry, LA which is very close to the project area was the driest station in the state for April and May. Except for a wet June, below normal precipitation continued until in August 1996, the area experienced one of the ten wettest Augusts in 100 years, bringing about a change from drought to near normal.

From fall 1996 into the summer of 1997 above normal precipitation persisted in the southwest region (figure 17a) (LOSC 1997). During the late summer and early fall of 1997, there were some departures below the normal from about 1 to 2 inches but the rest of the year had normal to above normal rainfall. During the ten month period between August 1996 and May 1997, five months had over 100% of the normal rainfall and three months had over 200% of the normal rainfall.

In 1998, rainfall was normal or above average every month until May when it was over 5 inches below normal (figure 17b) (LOSC 1998). June precipitation was only 0.37 inches below normal but the region was declared to be in a moderate drought because high temperatures and cloudless sunny skies had dried the soil with record evaporation rates. By July 1998, the southwest region was experiencing a severe drought according to the Palmer Drought Index. In August, rains from Tropical Storm Charley helped to bring back near normal precipitation for the month, but the area remained in a severe drought. September 1998 was the wettest September in more than 100 years, mostly due to Tropical Storm Frances which contributed to the almost 8 inch above normal rainfall in the southwest region and ended the drought for 1998.

In the early part of 1999, it took only two months of below normal rainfall to lead to a moderate drought in the area by April (figure 17b) (LOSC 1999). Above normal rainfall in June alleviated drought conditions briefly, but by November 1999, the area had a cumulative precipitation deficit of about 12 inches returning the area to drought conditions.

Except for above normal precipitation in May 2000, the area remained in a drought until rainfall in November 2000 of at least 12 inches, which was 277% of the normal amount (figure 17b) (LOSC 2000). Until October 2002, the area remained at about normal moisture levels with cycles of above normal (up to 150%) and below normal (down to 60%) rainfall (figure 17b,c) (LOSC 2001, 2002). In October 2002, Hurricane Lili caused rainfall of 359% of normal. For the rest of the year and into 2003, moisture levels remained normal or just above normal (LOSC 2003).

Salinity: Stations 14R, 15R, and 17 are the only stations with hourly hydrologic data from the preconstruction period (figures 18a, 21a, and 24a). The data sets for stations 14R, 15R, and 17 begin in January 1995, June 1995, and June 1996 respectively. Project station 17 was within the target range of ≤ 15 ppt. for nearly 100 % of the readings recorded in the preconstruction period of January 1995 to May 1996 (figure 24a, table 6). For the year immediately preceding project construction (June 1995 – May 1996), salinity measurements at reference stations 14R and 15R were ≤ 15 ppt only 36% and 50% of the total number of measurements, respectively.

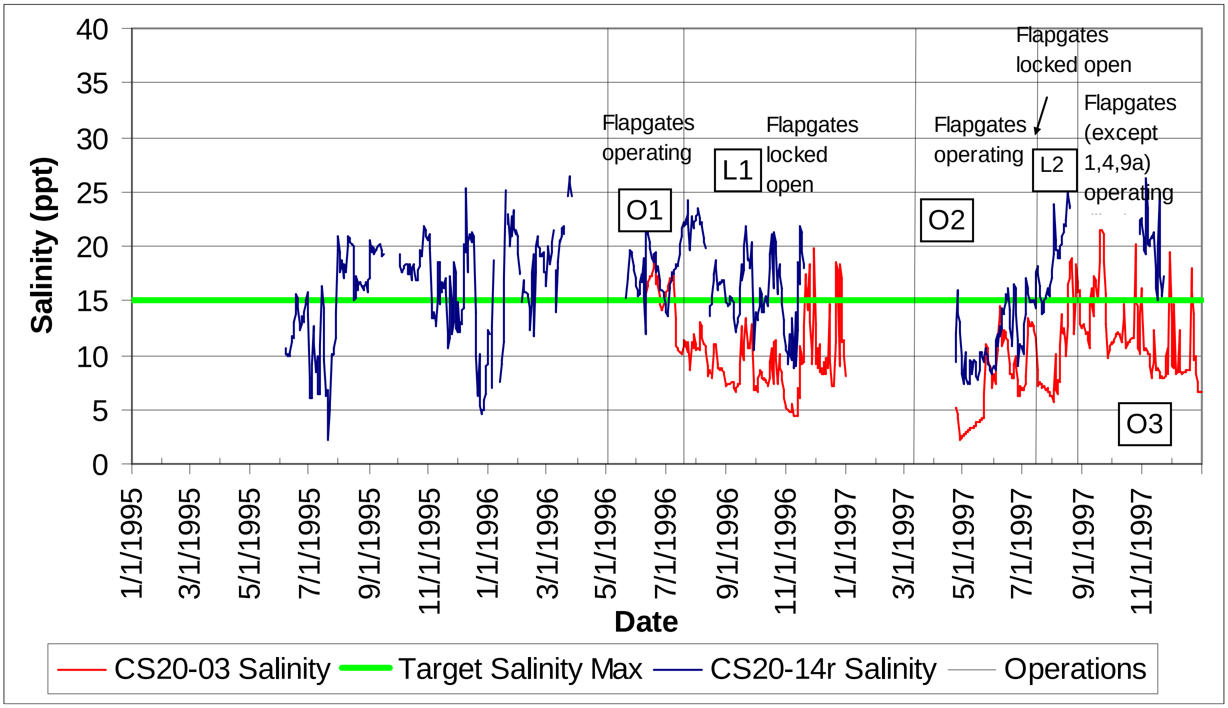


Figure 18a. Water salinity at station 3 and 14R from 1995 – 1997.

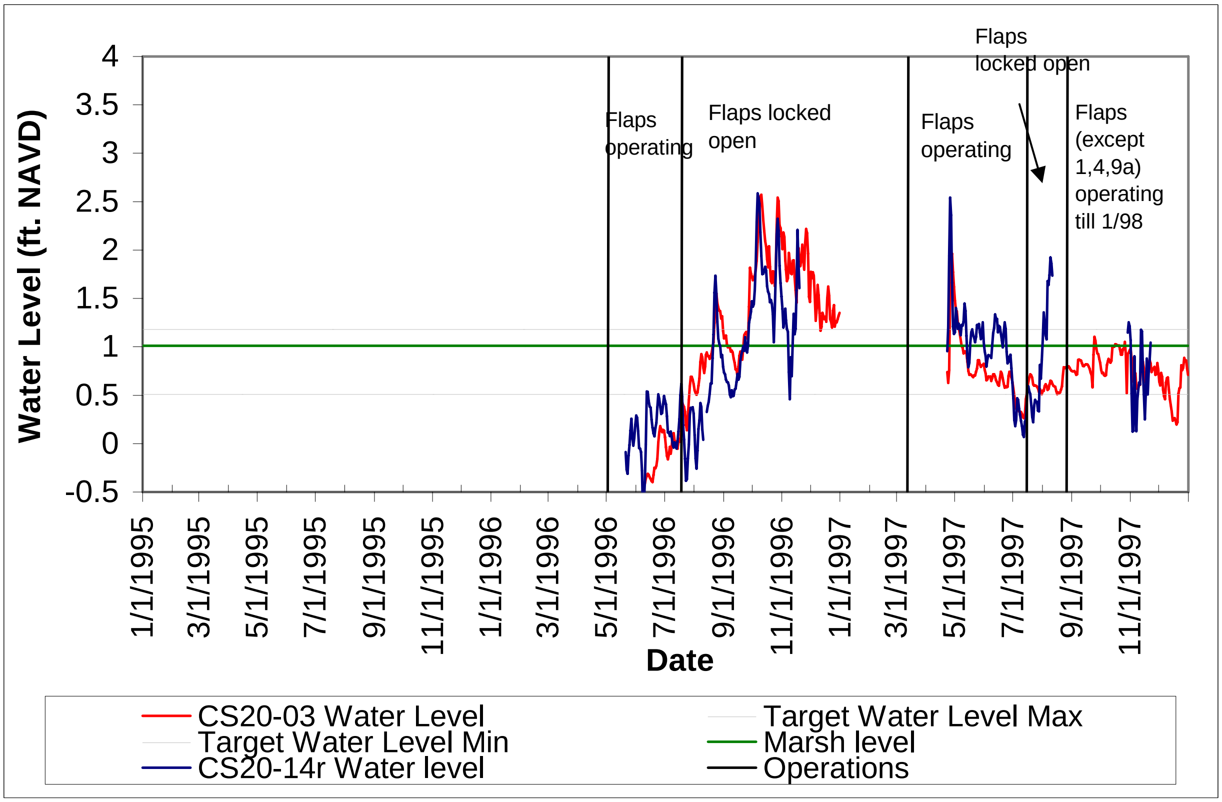


Figure 18b. Water level at station 3 and 14R from 1995 – 1997.

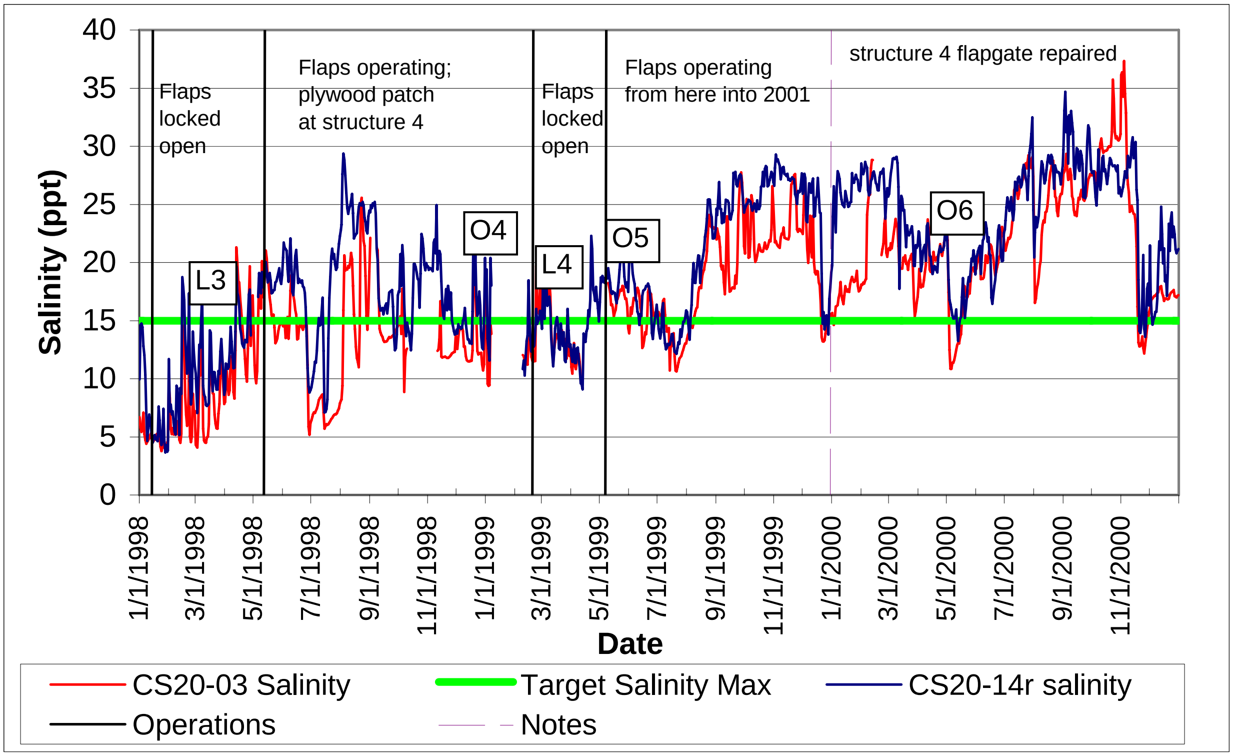


Figure 19a. Water salinity at stations 3 and 14R from 1998 – 2000.

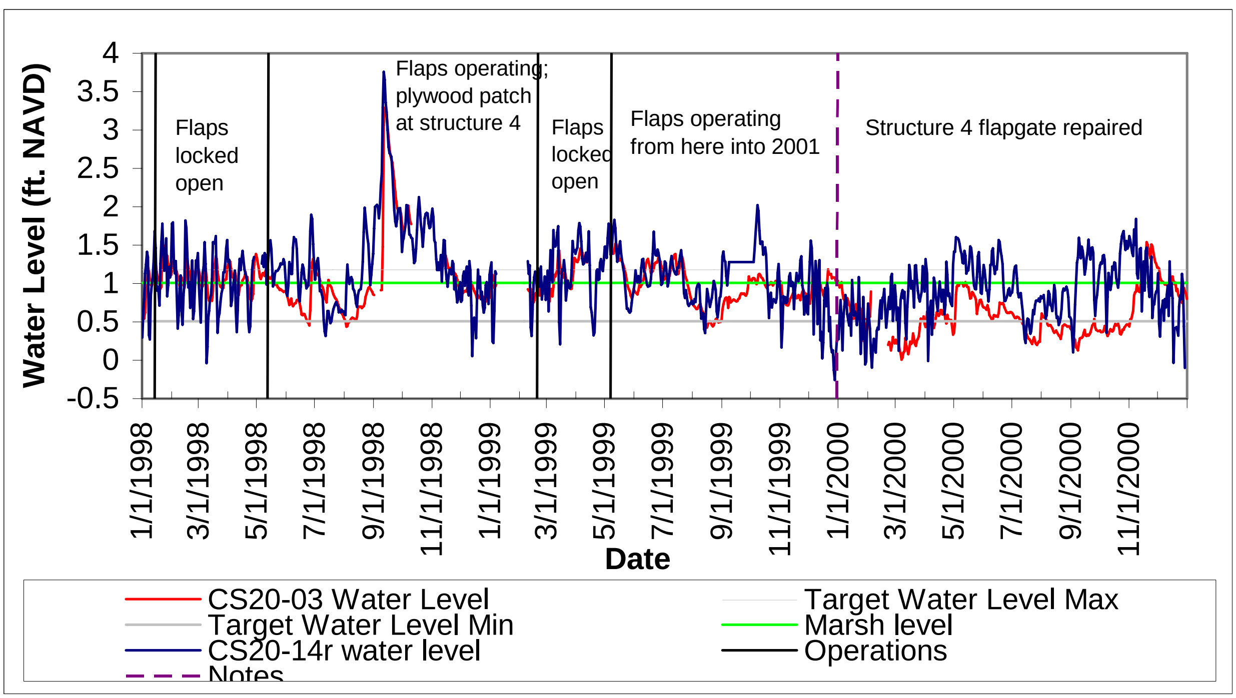


Figure 19b. Water level at stations 3 and 14R from 1998 – 2000.

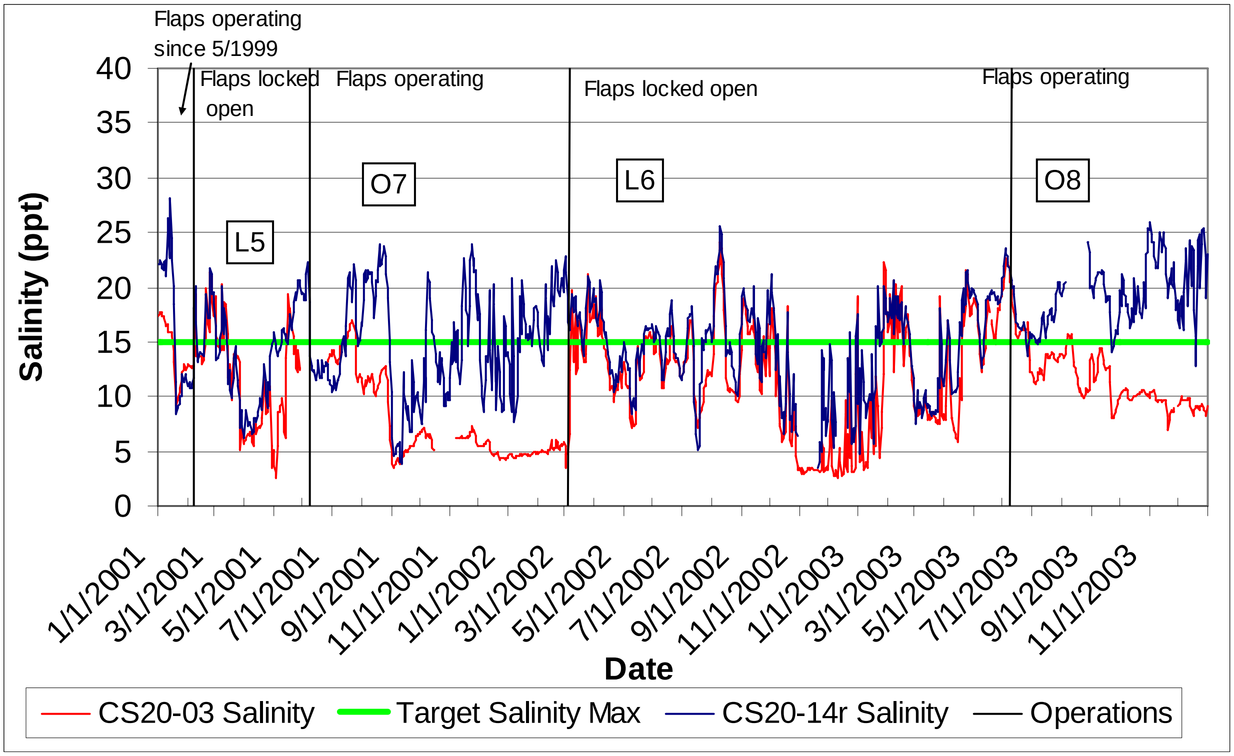


Figure 20a. Water salinity for stations 3 and 14R from 2001 to 2003.

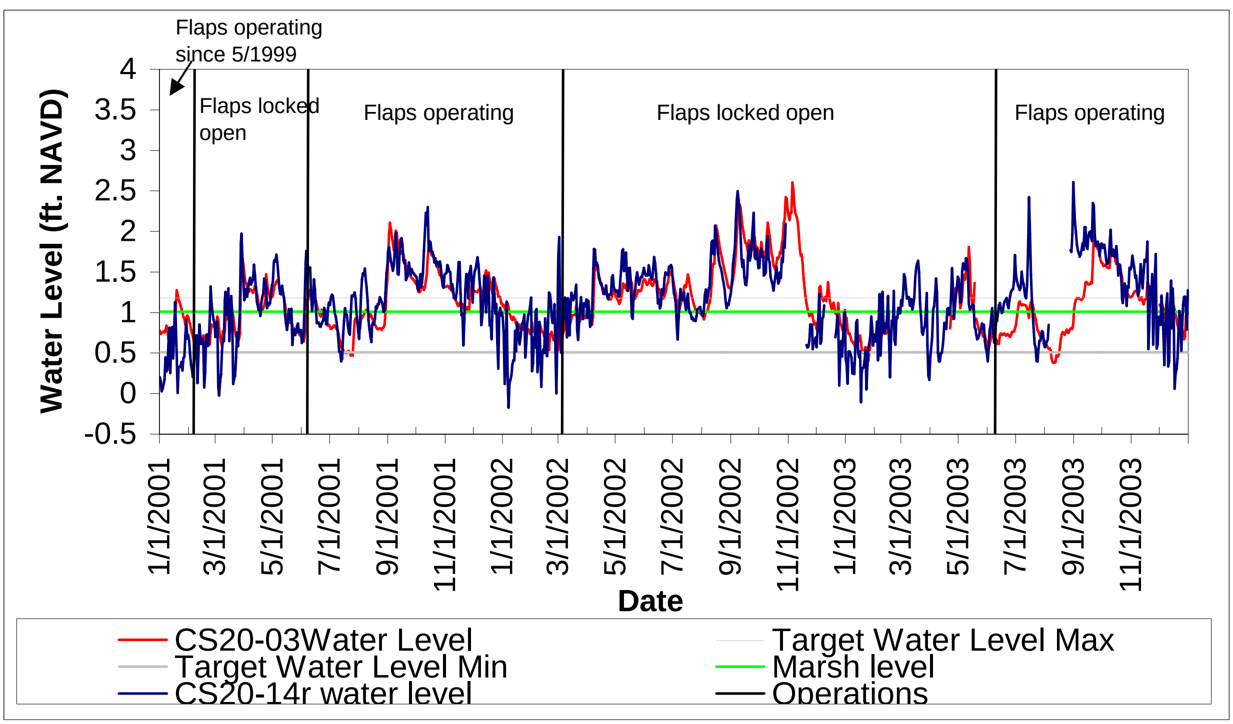


Figure 20b. Water level for stations 3 and 14R from 2001 to 2003.

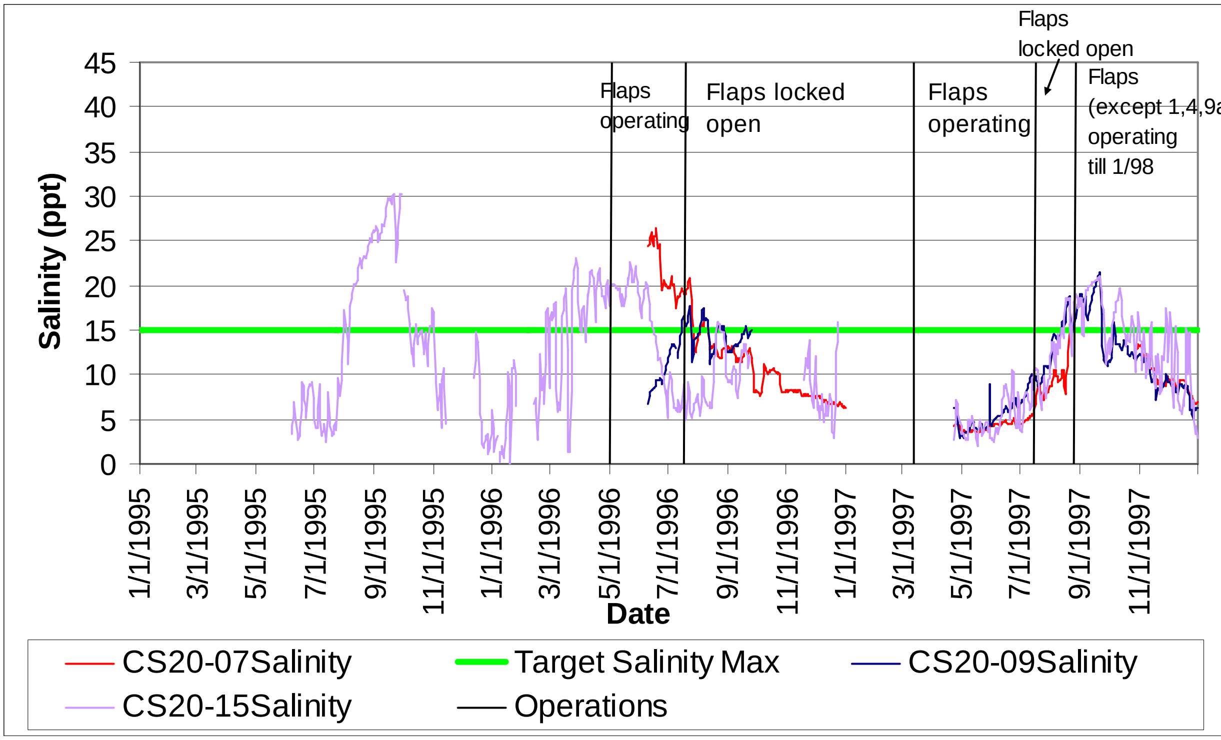


Figure 21a. Water salinity at stations 7, 9, and 15R from 1995 to 1997.

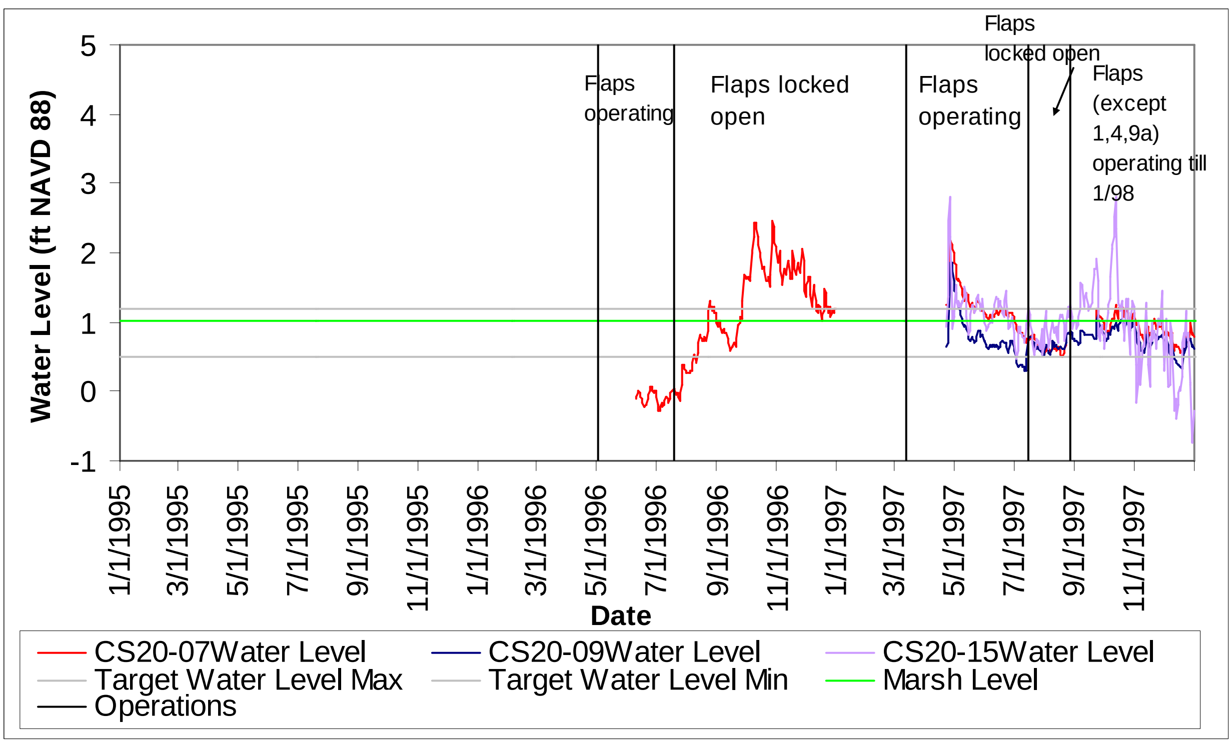


Figure 21b. Water level at stations 7, 9, and 15R from 1995 to 1997.

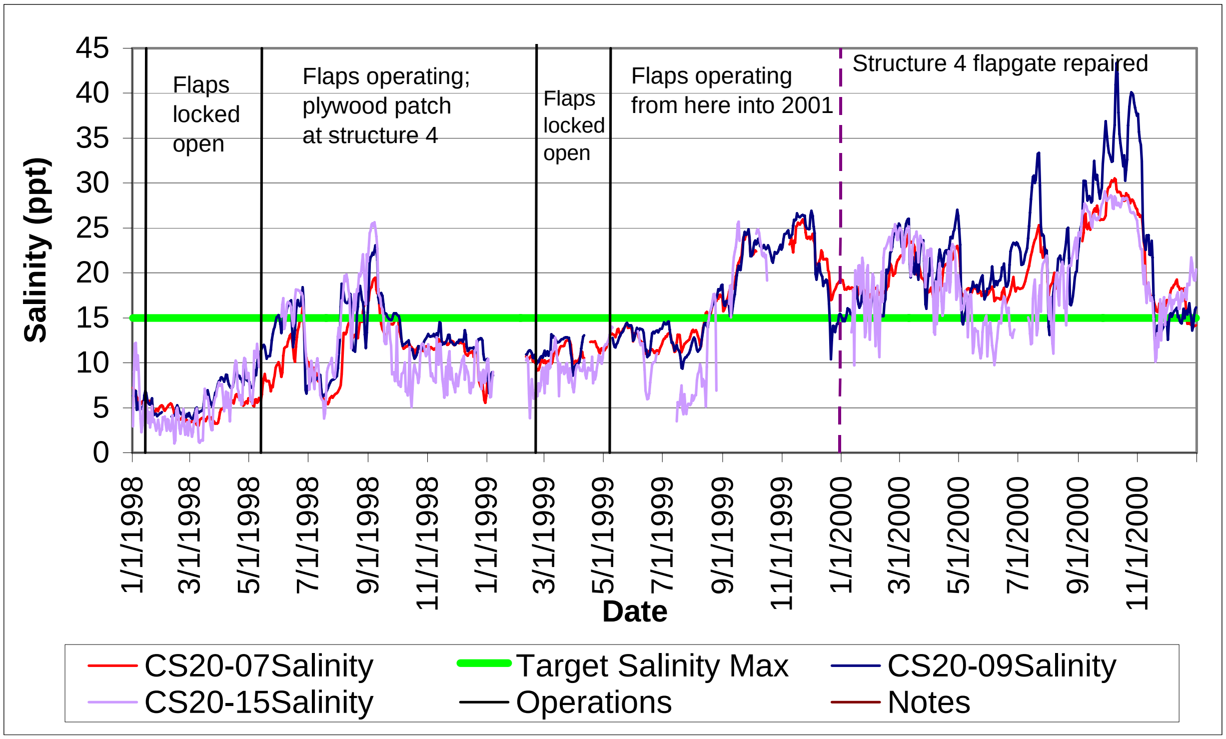


Figure 22a. Water salinity for stations 7, 9, and 15R from 1998 to 2000.

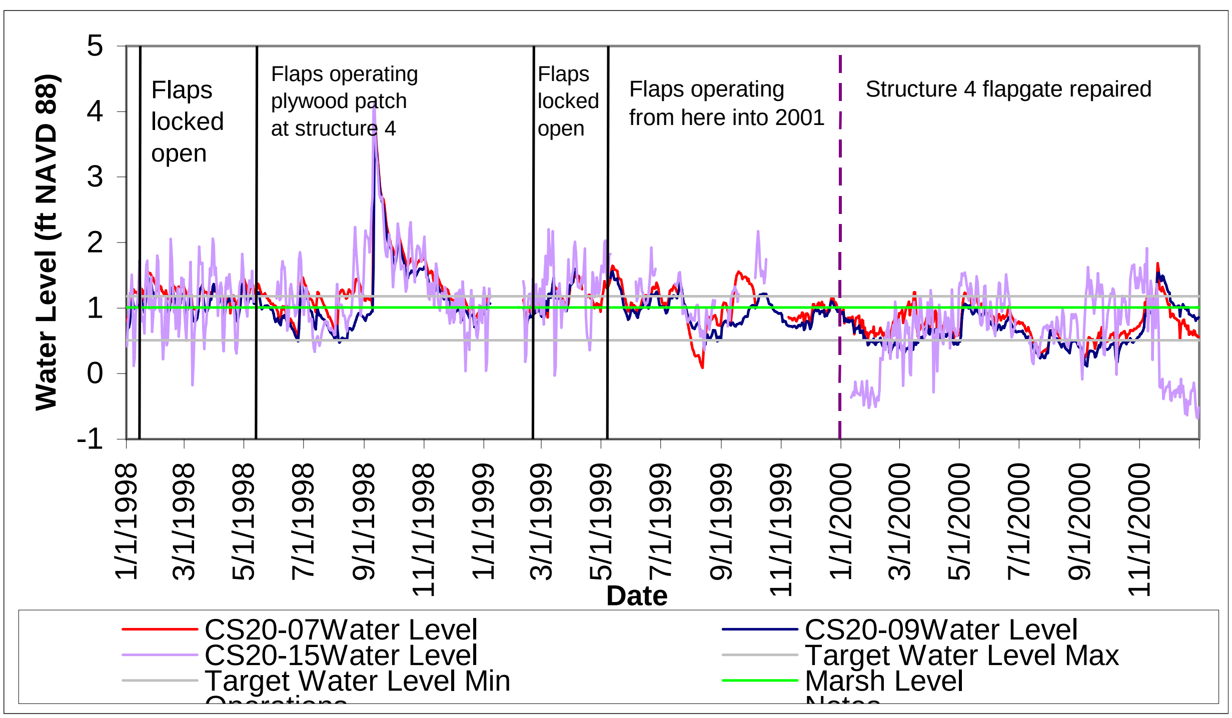


Figure 22b. Water level for stations 7, 9, and 15R from 1998 to 2000.

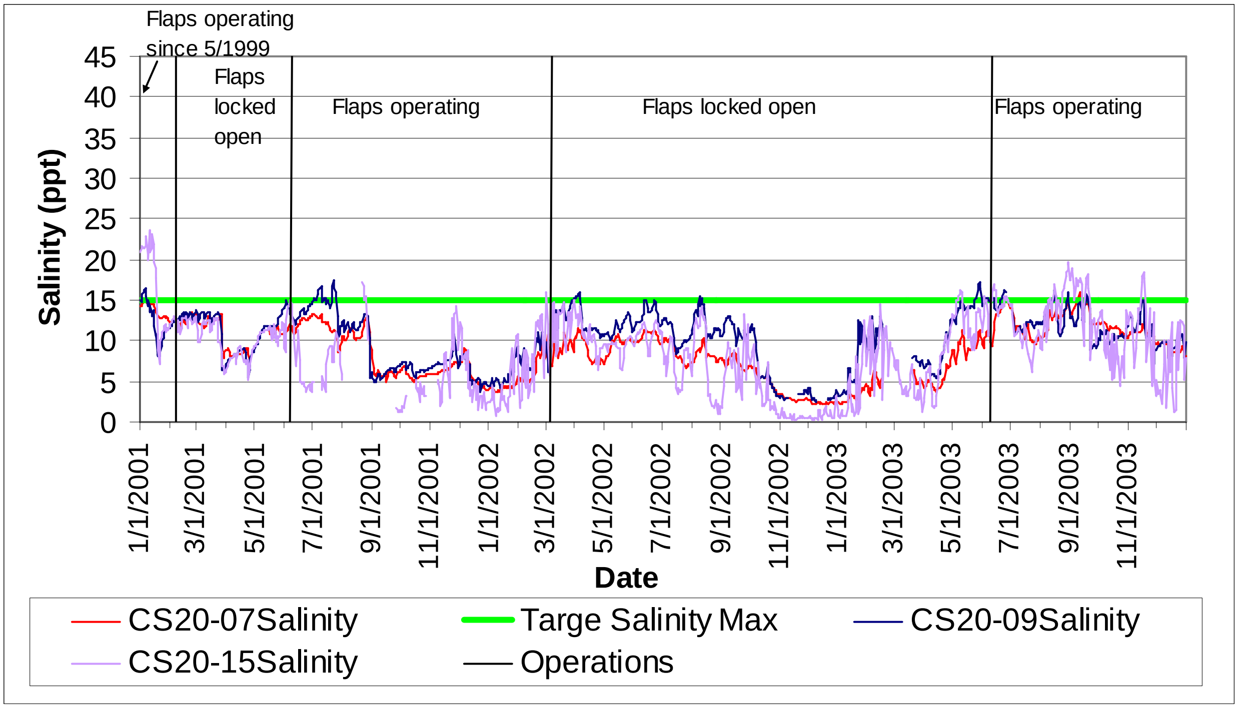


Figure 23a. Water salinity for stations 7, 9, and 15R from 2001 to 2003.

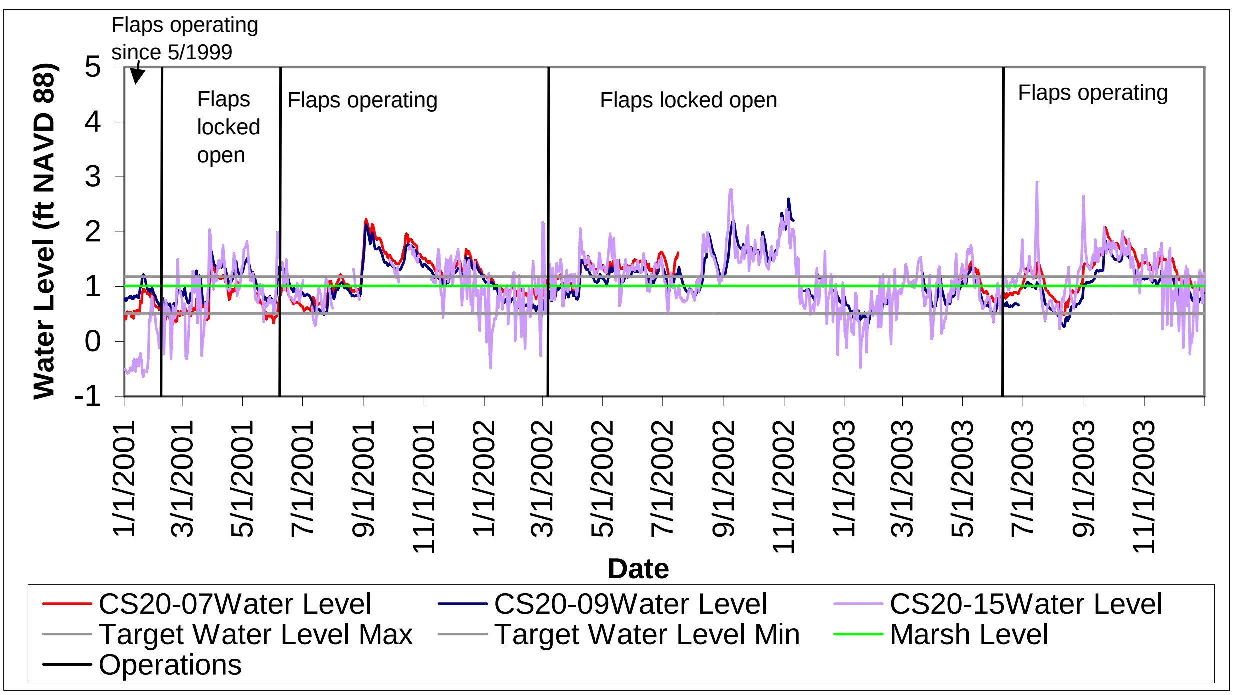


Figure 23b. Water level for stations 7, 9, and 15R from 2001 to 2003.

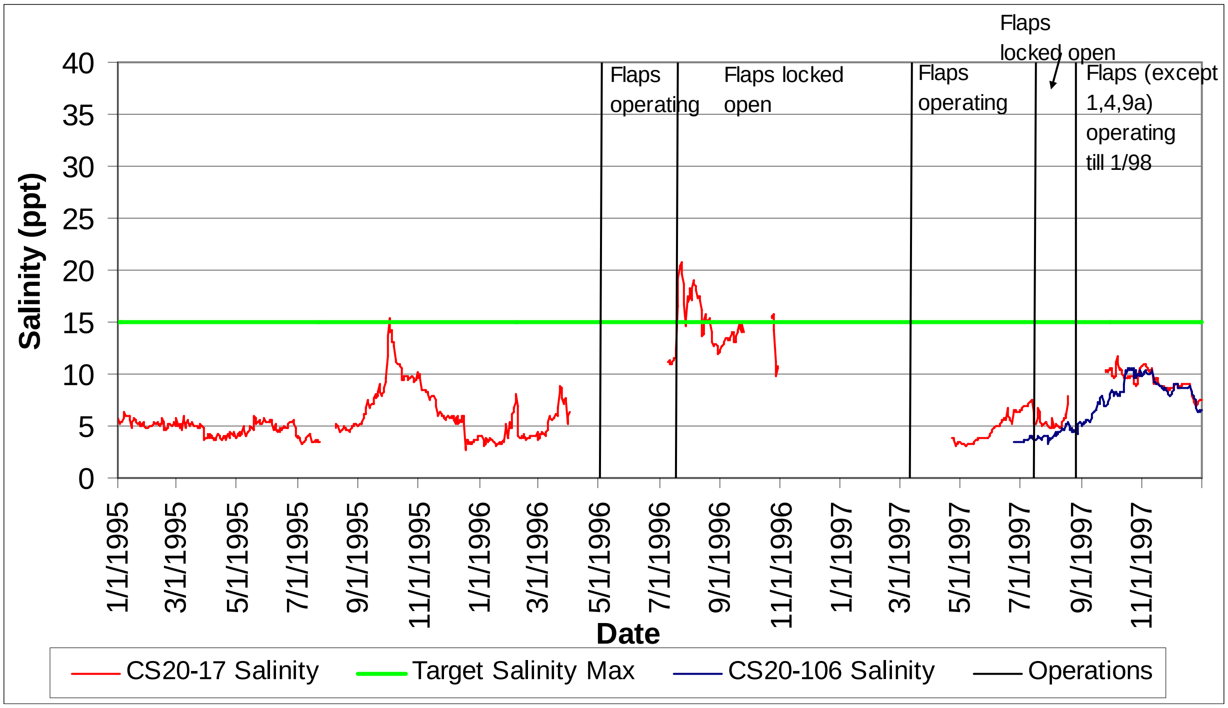


Figure 24a. Water salinity for stations 17 and 106 from 1995 to 1997.

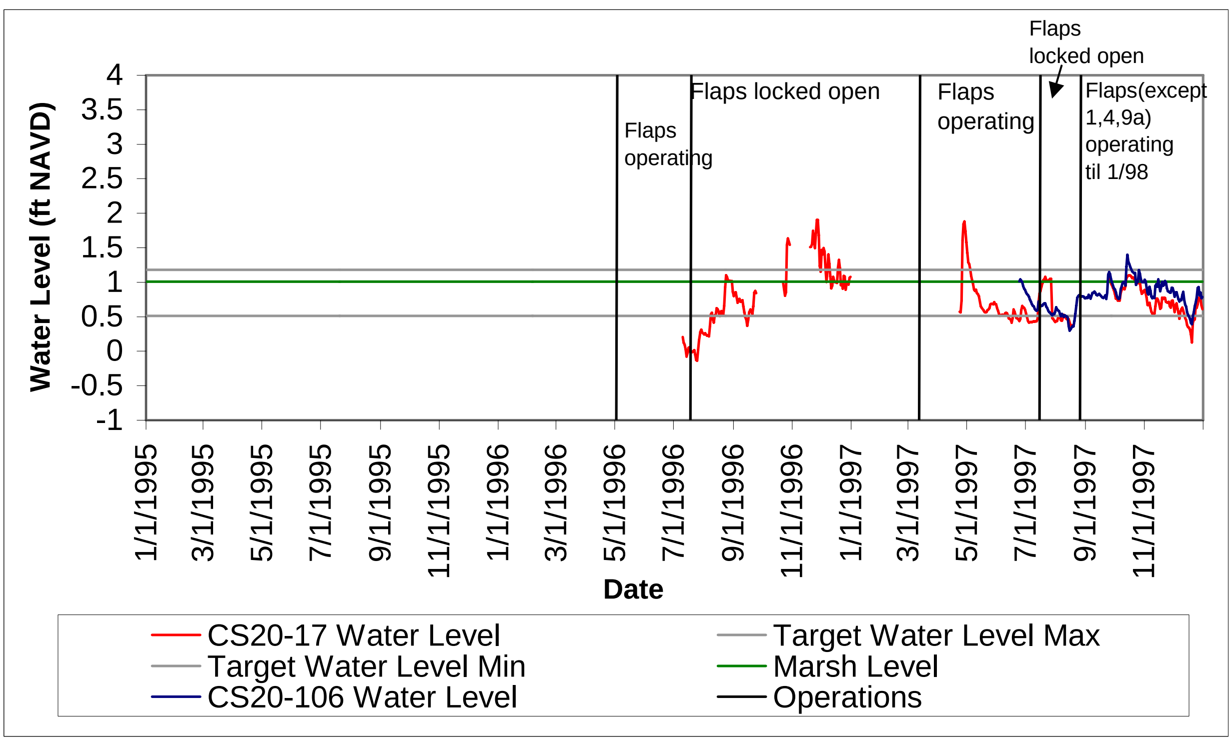


Figure 24b. Water level for stations 17 and 106 from 1995 to 1997.

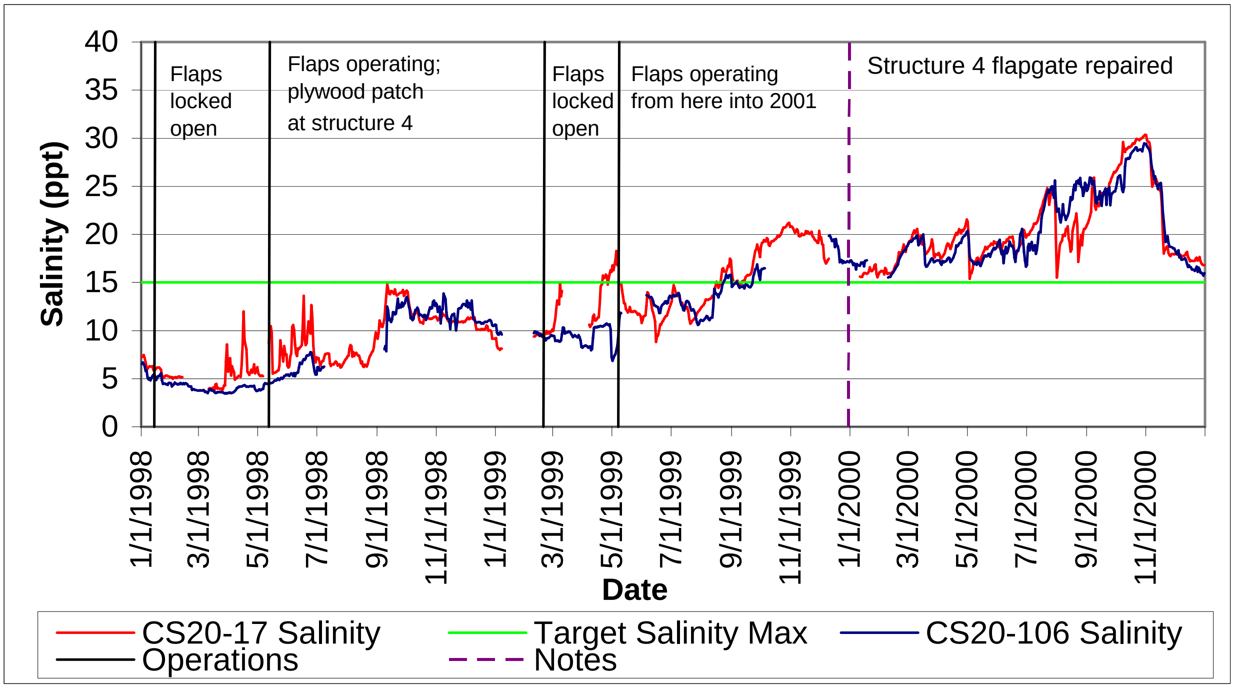


Figure 25a. Water salinity for stations 17 and 106 for 1998 to 2000.

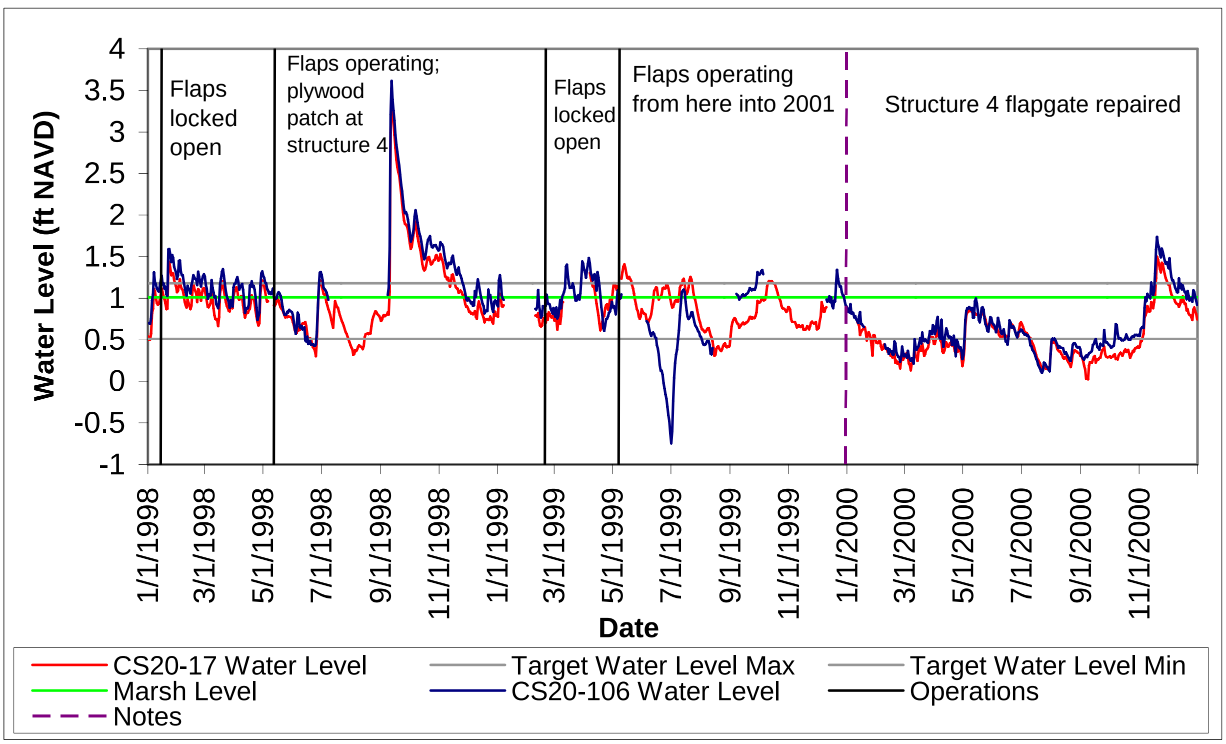


Figure 25b. Water level for stations 17 and 106 for 1998 to 2000.

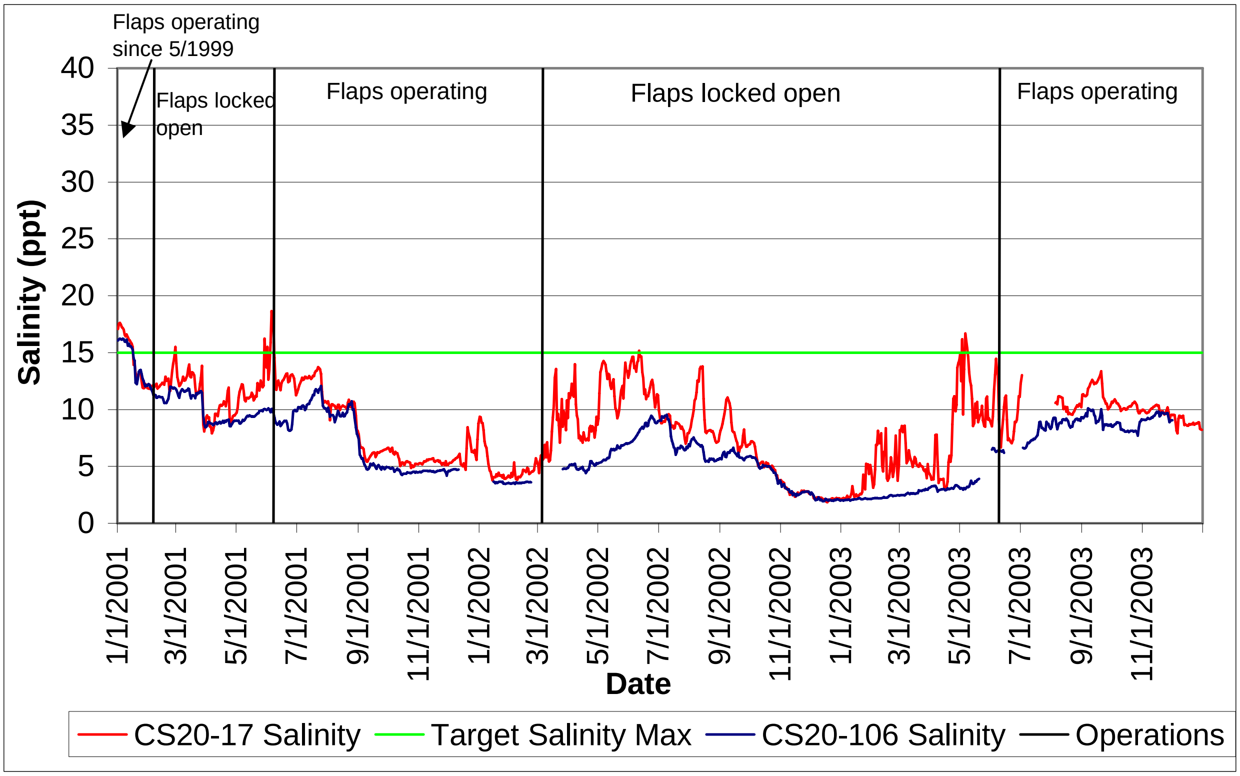


Figure 26a. Water salinity at stations 17 and 106 from 2001 to 2003.

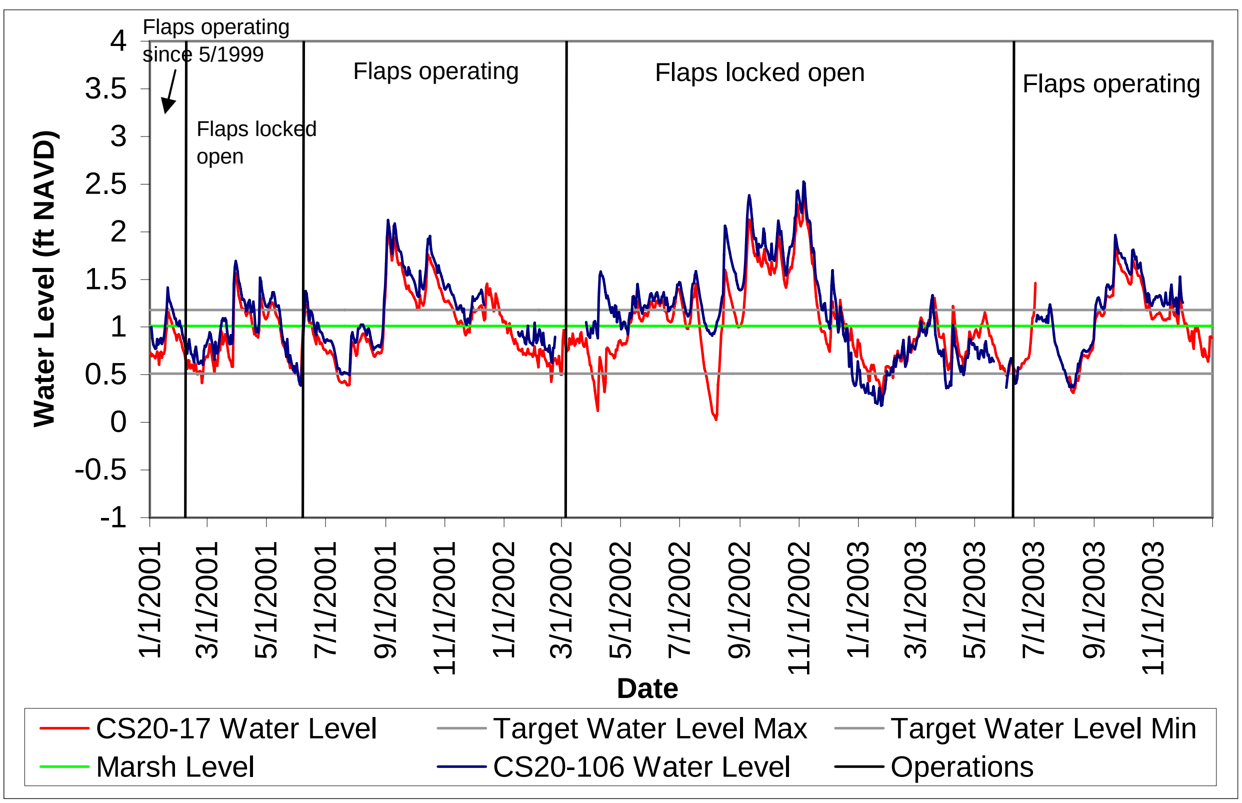


Figure 26b. Water level at stations 17 and 106 from 2001 to 2003.

After construction (May 1996), project stations in CTU 2 had salinities within the target range for at least 70% of the total number of hourly measurements each period until the period of June 1999 to May 2000 (table 6). During the same period, the percentage of target range salinity readings at reference station 14R did not get above 57% for any interval. A notable, but brief departure above the target salinity range at CTU 2 stations 3 and 9 occurred in August and September 1998 during tropical storms Charley and Frances (figures 19a, 22a). Some stations, especially in CTU 1, had salinities in the target range for up to 100% of the readings in the period between June 1996 and June 1999 (table 6). For the same time period of June 1996 through May 1999, reference station 15R had salinities within the target range for at least 79% of the measurements. Beginning with a sharp rise in salinity in August 1999 and ending around December 2000, a major drought kept salinities high for over a year at all hydrologic monitoring stations. Except for a few brief time periods of target range salinity, due to some rain relief in May (123% of normal rainfall), measurements were above normal and in November were as high as 37 ppt, 39 ppt, and 45 ppt, at stations 14r, 3, and 9 respectively (figures 19a, 22a). Salinities declined quickly to 14 ppt by November 18 at station 3 and similarly in other parts of the project area and the reference area presumably because of rainfall of at least 12 inches which was 277% of the normal amount for November. After February 2001, salinities at stations 7, 9, 15r, 17, and 106 remained in the target range almost continuously until the end of the period of study (figures 23a, 26a). Salinities at station 3 were relatively stable and less than 15 ppt except when the structure flapgates were locked open (figure 20a). During that time salinities at station 3 and 14r fluctuated together, although station 3 salinity was usually lower. Station 14r was more variable and stayed above 15 ppt for longer periods. After May 2003, salinities recorded at station 14r were nearly always greater than 15 ppt (figure 20a).

The majority of the mean differences of paired salinity measurements from stations 3 and 14r during the time periods with operating flapgates at structure / station 3 were greater than those during times when the flapgates were locked open (table 7). The first two intervals of locked open flapgates had much higher mean differences than the other intervals of locked open flapgates. The mean differences during flapgate locked open periods ranged from -0.3 ppt (negative indicates when station 3 salinity was greater than station 14r salinity) to 9 ppt. The mean differences during flapgate operating periods ranged from 2.4 ppt to 8 ppt. The two most recent flapgate operating periods had mean difference values of nearly 8 ppt. The two most recent flapgate locked open periods had mean difference values of almost 2 ppt. The mean values were not related to the number of observations (table 7).

The yearly means of the recorder salinity measurements in the two CTU's and the reference areas combined were similar among years and areas (table 8). Differences in the area yearly means were rarely more than a few ppt in any given year. Higher mean salinity (over 15 ppt) was limited to 1999 and 2000 and was evident in all areas.

<u>Water Level</u>: Water level was generally less variable at project stations than reference stations even when the control structure flapgates were locked open, allowing maximum water exchange (figures 18b, 19b, 20b, 21b, 22b, and 23b). The project area water level generally remained within target range for a greater percentage of the total measurements recorded than the reference area (table 9). During some periods, such as June 1997 to May 1998 the difference was great, (83% vs. 47%) and other times, such as June 2000 to May 2001, it was very similar (56% vs.

50%). Departures from the target water level range were more often to higher levels than lower levels for both the project and reference areas with one exception (table 9). During the 1999 – 2000 drought, the percentage of low water readings were higher than those of the high water readings for the project and reference areas.

Table 6. Percent of hourly salinity measurements less than or equal to the target salinity range maximum of 15 ppt at each continuous recorder station at East Mud Lake (CS-20) for 1-year intervals during preconstruction and postconstruction periods.

Area	Station	Preconstruction		Postconstruction							
		6/94-5/95	6/95-5/96	6/96-5/97	6/97-5/98	6/98-5/99	6/99-5/00	6/00-5/01	6/01-5/02	6/02-5/03	6/03-12/03
		n %	n %	n %	n %	n %	n %	n %	n %	n %	n %
CTU-2	3			5828 **86%**	7199 **83%**	6313 **70%**	8572 **18%**	8698 **32%**	7586 **86%**	8715 **72%**	5040 **84%**
REF	14R		5748 **36%**	4923 **41%**	5832 **57%**	7955 **34%**	8707 **12%**	8608 **26%**	8705 **50%**	7858 **54%**	4587 **7%**
CTU-1	7			5824 **79%**	7114 **99.6%**	7800 **93%**	7961 **22%**	7710 **44%**	8755 **100%**	8012 **100%**	5135 **98%**
CTU-2	9			922 **100%**	8480 **88%**	7241 **79%**	8782 **26%**	8757 **47%**	8756 **93%**	7485 **95%**	4980 **87%**
REF	15R		7276 **50%**	4456 **90%**	8249 **79%**	7347 **79%**	5321 **40%**	8353 **49%**	6779 **96%**	8670 **97%**	5135 **74%**
CTU-2	17	3608 **100%**	6936 **99.7%**	2908 **74%**	7049 **100%**	7194 **95%**	8018 **26%**	8758 **36%**	8758 **99%**	8757 **98%**	4318 **99.5%**
CTU-1	106				8144 **100%**	5962 **99.9%**	6557 **36%**	8757 **37%**	7151 **100%**	8479 **100%**	3924 **100%**

Table 7. The mean, minimum, and maximum differences between salinity (ppt) measurements at stations 3 and 14r (Difference = station 14r salinity– station 3 salinity) during times when flapgates were either locked open or operating at structure 3.

Period	# of observations	Mean of salinity differences (ppt)	Minimum salinity difference (ppt)	Maximum salinity difference (ppt)
Locked Open 1	11328	8.1	2.4	17.7
Locked Open 2	2016	9.8	2.7	22.5
Locked Open 3	5712	1.7	-5.9	15.5
Locked Open 4	3648	-0.3	-6.9	7.8
Locked Open 5	5760	1.9	-7.4	15.5
Locked Open 6	22128	2.0	-10.16	18.8
Operating 1	3744	2.9	-7.3	14.4
Operating 2	6000	4.0	-4.2	15.2
Operating 3	6768	8.0	-4.3	20.0
Operating 4	13584	4.2	-5.0	23.1
Operating 5	11424	2.6	-7.5	12.2
Operating 6	19392	2.4	-13.3	17.7
Operating 7	13056	7.9	-6.1	21.1
Operating 8	9840	7.9	-9.6	19.0

Table 8 Yearly mean salinity for both CTU 1 and CTU 2 in the project area and the yearly mean salinity for the two reference areas combined.

Year	Area		
	CTU 1	CTU 2	REF
1995		5.8	14.4
*1996	12.5	10.7	14.5
1997	7.0	9.2	12.2
1998	8.3	10.3	12.6
+1999	13.8	16.2	16.4
‡ 2000	20.5	21.4	22.0
2001	9.3	10.2	12.3
2002	6.2	9.0	10.6
2003	7.8	10.6	13.4

* drought and drawdown year
+drought and structure vandalism
‡drought

Table 9. Percent of water level measurements that were greater than, less than or in the target zone of 2 inches AML to 6 inches BML using the average marsh elevation of 1 ft. NAVD.

Area	Station		Postconstruction															
			6/96-5/97		6/97-5/98		6/98-5/99		6/99-5/00		6/00-5/01		6/01-5/02		6/02-5/03		6/03-12/03	
			n	%	n	%	n	%	n	%	n	%	n	%	n	%	n	%
CTU-2	3	Target	5828	**35%**	8720	**83%**	6313	**70%**	8393	**74%**	8758	**56%**	8757	**57%**	8715	**54%**	5039	**64%**
		Low		20%		7%		3%		18%		30%		3%		2%		4%
		High		45%		10%		27%		8%		15%		41%		44%		32%
REF	14R	Target	4923	**33%**	5648	**47%**	7959	**40%**	8746	**49%**	8496	**50%**	8710	**38%**	7860	**39%**	4551	**31%**
		Low		33%		18%		8%		17%		19%		9%		12%		8%
		High		34%		35%		53%		34%		32%		53%		49%		61%
CTU-1	7	Target	5824	**24%**	7979	**67%**	7800	**50%**	7961	**77%**	7710	**70%**	8756	**49%**	2078	**29%**	5135	**45%**
		Low		25%		1%		0%		5%		23%		1%		0%		1%
		High		51%		33%		50%		17%		7%		50%		71%		54%
CTU-2	9	Target	922	**74%**	8479	**73%**	7142	**64%**	8782	**77%**	8757	**59%**	8756	**59%**	7485	**54%**	4980	**71%**
		Low		0%		17%		1%		17%		26%		2%		4%		7%
		High		26%		10%		35%		6%		16%		40%		41%		22%
REF	15R	Target	922	**39%**	8249	**48%**	7347	**34%**	5337	**43%**	8288	**39%**	6779	**42%**	8723	**41%**	5135	**36%**
		Low		0%		16%		9%		29%		36%		14%		15%		12%
		High		61%		36%		57%		28%		25%		44%		44%		52%
CTU-1,2	17	Target	3928	**56%**	7700	**78%**	7194	**64%**	8018	**64%**	8758	**57%**	8758	**66%**	8757	**58%**	4342	**62%**
		Low		25%		17%		8%		32%		34%		8%		7%		9%
		High		20%		4%		28%		4%		9%		26%		35%		29%
CTU-1	106	Target			8144	**80%**	5962	**53%**	5957	**59%**	8757	**55%**	7151	**54%**	8478	**42%**	3924	**36%**
		Low				4%		4%		37%		27%		3%		12%		10%
		High				16%		43%		4%		19%		43%		46%		55%

There were 5 major flooding events when the water level at most project stations was higher than the average marsh elevation of 1 ft NAVD for about 3 or more months. The approximate midpoints for these events were November 1996, October 1998, October 2001, August 2002, and October 2003 (figures 18b, 19b, 20b, 21b, 22b, 23b, 24b, 25b, and 26b). The 1996 flooding event was due to heavy rainfall, Tropical Storms Frances and Charley caused extremely high water in 1998, and high rainfall caused flooding in 2001. Above normal rain, and storm surge and rain associated with Tropical Storm Fay and Hurricane Lili apparently flooded the area for about 8 months in 2002, and presumably increased precipitation raised the water level in 2003. Project stations in general had lower and less variable water levels than reference areas during these events (figures 18b, 19b, 20b, 21b, 22b, 23b). Water level at the project stations returned to normal at about the same time as it did at the reference area stations.

<u>Soils</u>: Preconstruction, mean bulk density was 0.43 (± S.D. = 0.18) gm/cm^3 in the reference area and 0.40 (± S.D. = 0.07) gm/cm^3 in the project area. Mean organic matter was 42.7 (± S.D. = 14.31) % was in the reference area and 39.7 (± S.D. = 13.94) % in the project area. After construction, by 1999, project area organic matter had decreased to 31.24 (± S.D. = 13.32) % and bulk density decreased to 0.21 (± S.D. = 0.11) gm/cm^3. The reference area also experienced a decrease in organic matter to 36.45 (± S.D. = 19.47) % and in bulk density to 0.16 (± S.D. = 0.09) gm/cm^3.

<u>Accretion</u>: Accretion data are limited to the postconstruction period. Mean accretion rates in the reference area were significantly greater than those in the project area for the first four sampling intervals, July 1996 to Dec 1996, July and December 1996 to July 1997, July and December 1996 to December 1997, and December 1997 to June 2000 (figure 27). Accretion rates in the reference area decreased from a range of about 7 to 12 mm/yr prior to December 1997 to between 4 and 6 mm/yr in the last two sampling intervals ending on June 2000 and July 2003. In the project area, accretion rates were stable across the first three sampling times, varying between just under 2 mm/yr up to about 3 mm/yr. The rate increased to 6 mm / yr for the December 1997 to June 1998 period and then decreased to 4 mm / yr during the last period ending July 2003.

<u>Surface Elevation</u>: During the preconstruction sampling interval (December 1995 – June 1996), both the project and reference areas had negative mean marsh surface elevation change rates of about 3 cm/yr (figure 28). In the first four postconstruction sampling intervals, elevation change rates were not as great. The rates were variable and included gains and losses in elevation for both project and reference areas. The elevation change rates in the project and reference areas were nearly the same for the June 1998 – June 2000 and June 2000 – July 2003 sampling intervals. Statistically, neither the areas ($F=0.02$, $p=0.8804$) or the interval*area interactions ($F=1.04$, $p=0.3996$) were significantly different, but the interval ($F=5.93$, $p<0.0001$) factor was significant. The soil type effect was not statistically significant ($F=1.14$, $p=0.3634$)

Long term marsh surface elevation change rates for each station, as determined by linear regression using 8 data points, indicate that both the project and reference areas have stations that have had similar elevation gain and loss during the period of December 1996 to July 2003 (figure 29 and Appendix). Project station CS20-07 had the highest rate of surface elevation loss (-0.55 cm / yr), and 5 of 6 project stations had a long term elevation loss. However, the reference area had the station with the second highest rate of negative surface elevation change (-0.47 cm / yr), and 4 of 6 of the reference area stations had long term negative elevation rates. It should be noted also that the elevation change rate for station CS20-8 was calculated from only the last 6 data points and not the complete 8 used for all other stations. Considering the elevation loss for most stations early on in sampling, the rate shown for station CS20-8 relative to the other stations, is probably artificially high in the positive range.

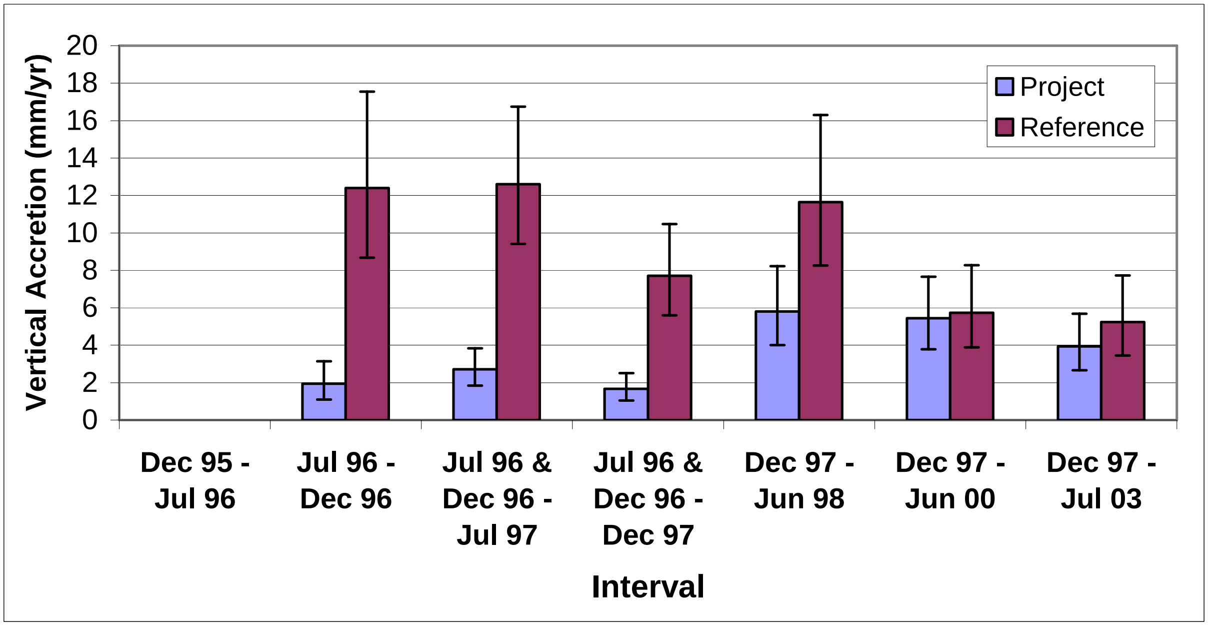


Figure 27. Mean vertical accretion in the East Mud Lake (CS-20) project and reference areas. During the first interval, data was collected from SET sites but accretion measurement sites were not yet installed.

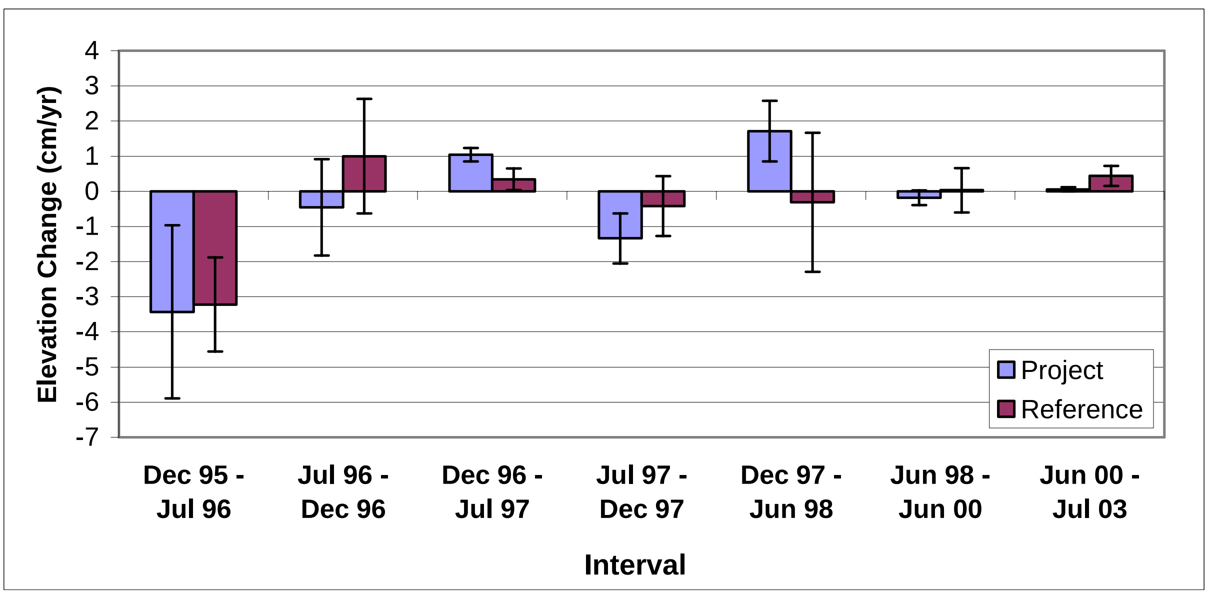


Figure 28. Mean marsh surface elevation change in the East Mud Lake (CS-20) project and reference areas.

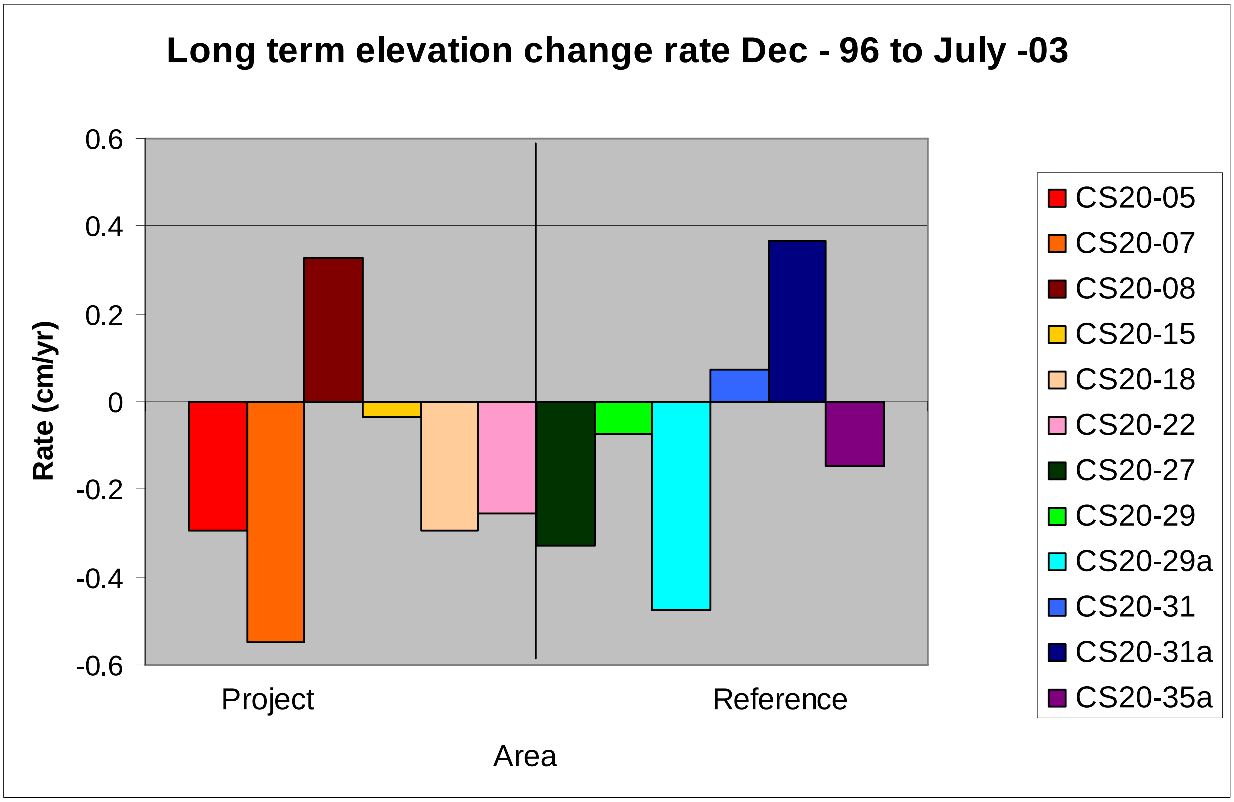


Figure 29. Long term marsh surface elevation change rates, determined by linear regression, for project and reference area sampling stations from December 1996 to July 2003.

Fisheries: In order to accurately describe the most important differences in fisheries species abundances, resident and transient species are treated separately. Resident species spend most of their life cycle within the estuary, whereas transient species spawn in nearshore or offshore waters and use shallow estuarine habitats as nursery areas.

The most abundant resident fish species included *Poecilia latipinna* (sailfin molly), *Gambusia affinis* (western mosquitofish), *Menidia beryllina* (inland silversides), and *Cyprinodon variegatus* (sheepshead minnow), while *Brevoortia patronus* (gulf menhaden) and *Anchoa mitchilli* (bay anchovy) were two of the most abundant transient fish species. The most abundant resident decapod taxa include *Palaemonetes intermedius* (brackish grass shrimp), *P. pugio (*daggerblade grass shrimp), and *Palaemonetes* sp., while *Penaeus setiferus* (white shrimp), *P. aztecus* (brown shrimp), and *Callinectes sapidus* (blue crab) represent most abundant transient decapod species.

Environmental data collected on both project and reference areas before project construction (June 1995 and October 1995) showed significant interaction effects between area and sampling times for all variables except dissolved oxygen. This interaction essentially means that the difference between the two areas was not consistent across sampling times, and precludes any meaningful interpretation of the main effects (sampling time and area) alone. A graphic illustration of interaction is indicated by the crossing or nonparallel lines representing the means in each area across sampling times. Dissolved oxygen was significantly higher in October 1995 than June 1995 for both areas.

During the post-construction period, data for some environmental variables were not collected or had inadequate replicate samples for certain sampling times (Appendix). However, all environmental variables were temporally variable and changed similarly over time in both project and reference areas. There was no apparent differential response to project construction was seen between the areas. Supporting environmental data over all sampling periods are presented in the Appendix.

Density and biomass of fisheries variables showed the same relationships and patterns of statistical significance across sampling times and areas, indicating individual sizes were probably quite similar. Consequently, we are presenting only results on density analysis.

Transient fish density was significantly greater in the reference area than the project area (figure 30). Transient crustaceans density was significantly greater in the reference area and resident crustacean density was significantly greater in the project area, but no differences were found among sampling times (figures 31 and 33). For fish species, a significant area*sampling time interaction during the preconstruction period was found for resident fish (figure 32). A test of overall fisheries species richness showed no differences between areas or sampling times.

After construction, mean densities were only different from pre-construction for some crustacean variables. In the project area, transient crustacean density was higher post-construction (figure 31). In the reference area, resident and transient crustacean densities were significantly higher post-construction than preconstruction. Overall, transient fish and crustacean species densities were greater in the reference area, whereas resident fish and crustacean species densities were greater in the project area. There were no differences in overall fisheries species richness.

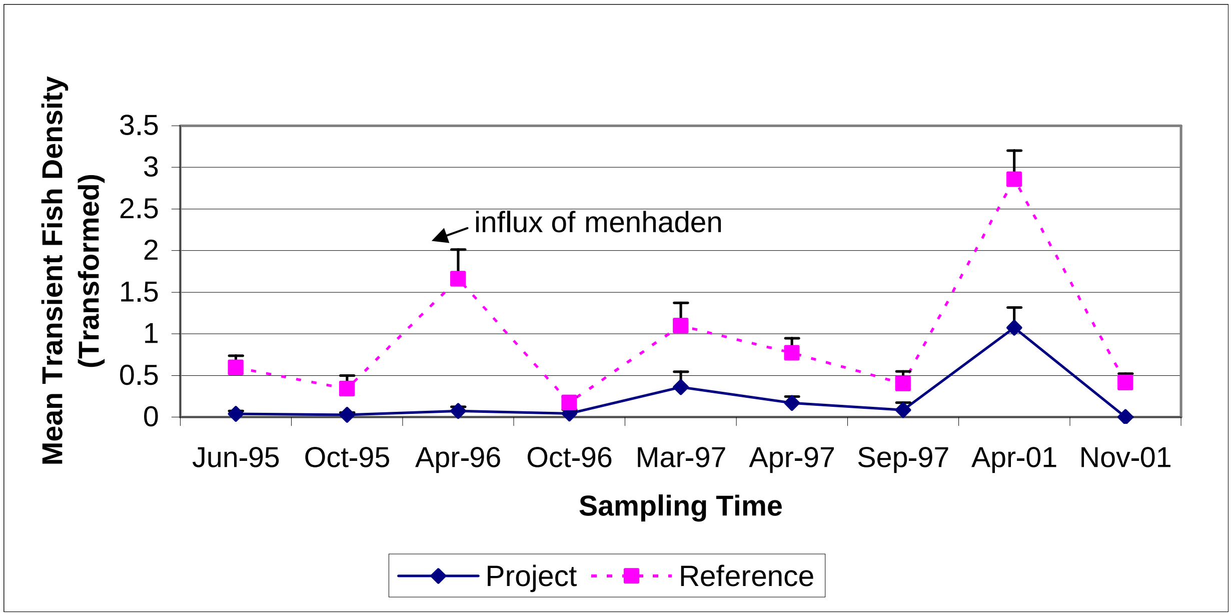


Figure 30. Transformed mean density per square meter of transient fish species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

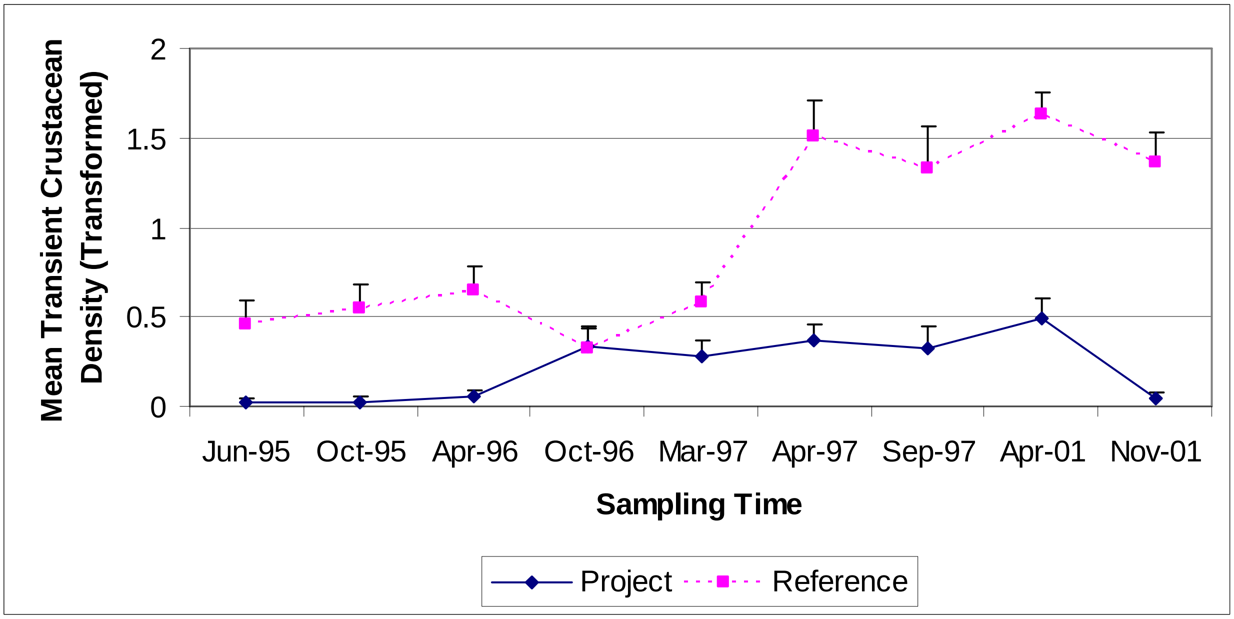


Figure 31. Transformed mean density per square meter of transient crustacean species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001

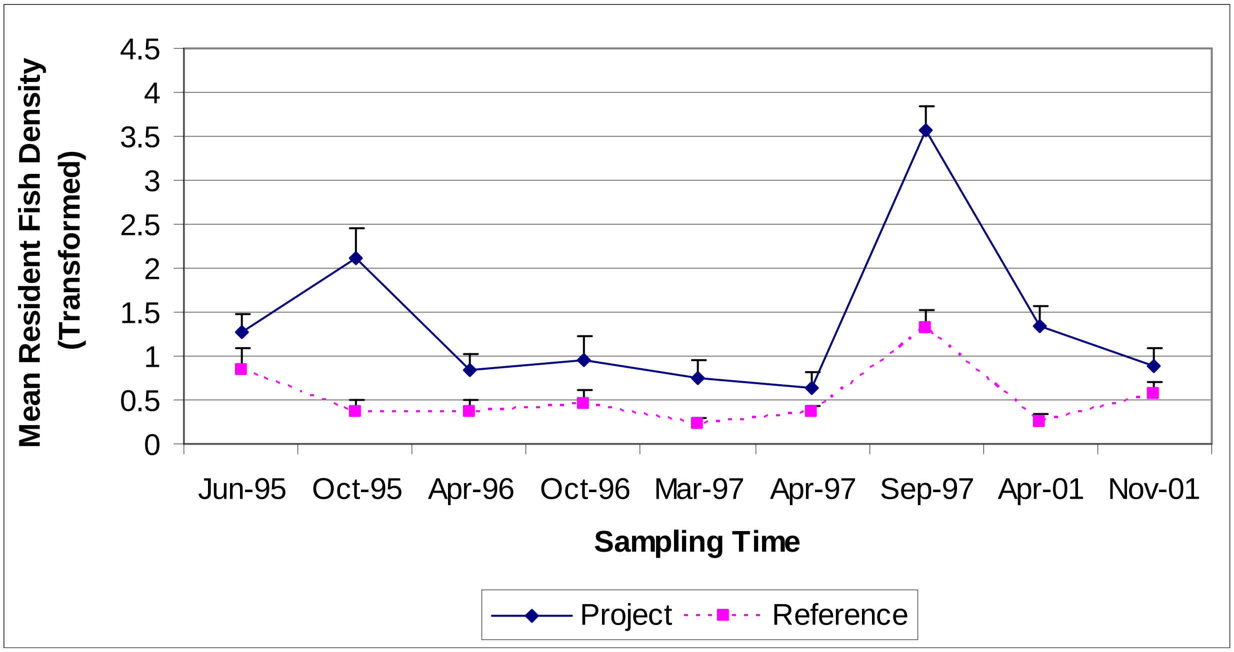


Figure 32. Transformed mean density per square meter of resident fish species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

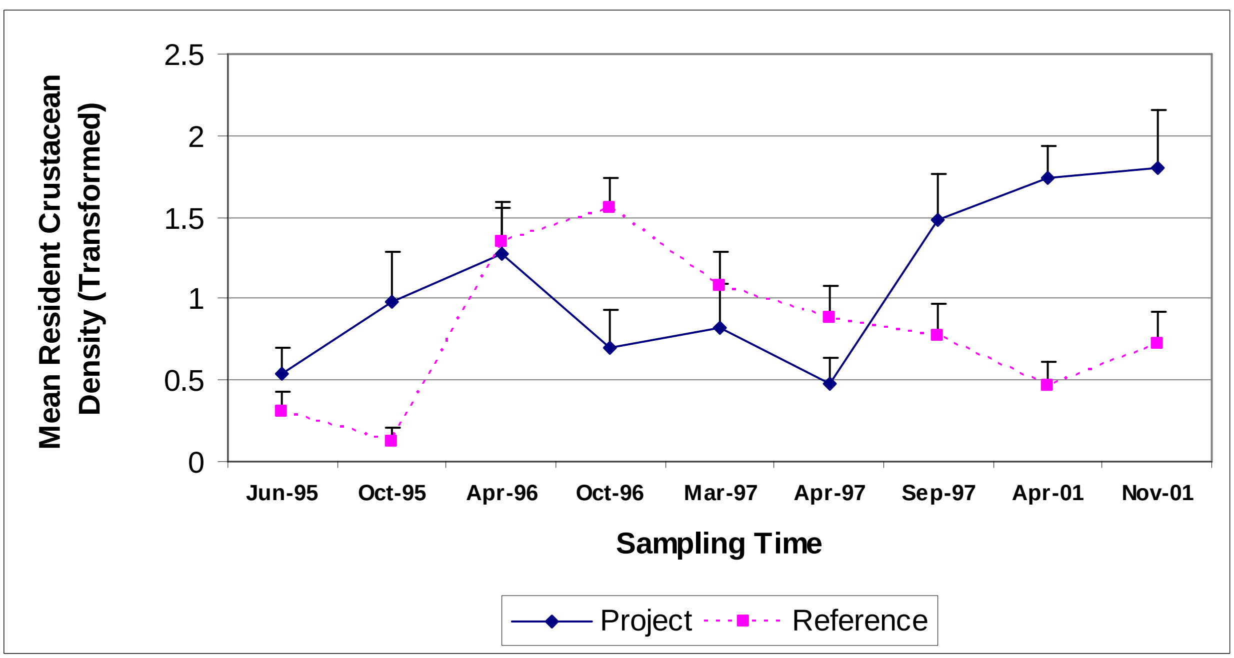


Figure 33. Transformed mean density per square meter of resident crustacean species collected in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

DISCUSSION

In general, the rate of marsh loss decreased in all project and reference areas over time. However, the only area to have a net gain was the actively managed CTU 2, between 1994 and 2000. Some of the gain was in areas that had vegetative plantings that were not a part of the original project plan, but other areas of gain had no such plantings. There was loss and gain in areas of solid marsh and in more degraded areas. In CTU 2, most loss appears to have been in the more fragmented, lower elevation marsh. Although the project and reference areas both experienced decreases in marsh loss rate, the greater net gain found in CTU 2 could be due in part to expansion of vegetation due to drawdowns intended for that purpose in 1996 and 1997. In CTU 1, the marsh loss was largely restricted to one area on the peninsula in East Mud Lake. From examination of 1998 DOQQ photography, it appears that the loss on the peninsula happened or at least began by 1998, but there was no obvious cause for this loss.

Vegetative cover along the shoreline of East Mud Lake was not increased by vegetative plantings; however, about 50% of plantings along the canal and step levee areas remained four years after planting, and maintained over 20% cover. The original plan to install all plantings on the lakeshore was modified because of unexpected difficulty securing suitable planting substrate. Only a small portion of the plants were put on the lake shoreline. The 1994 – 2000 land water change analysis shows a water to land gain on the northwest shoreline of the lake directly across from the peninsula tip; however, the vegetative plantings that were installed in that area cannot be definitively credited for the new land. According to our planting monitoring data, the shoreline plots we sampled survived well for six months, but never increased in cover. At the time of our last sampling in 2000, there were no surviving plants and 0% cover. The water to marsh change could be due to protection of the shoreline made possible by the short fetch in that narrow part of the lake coupled with favorable winds that ultimately allowed deposition of resuspended sediment. The existing vegetation could have then colonized the new, higher elevation substrate. The new land could also be the result of the expansion of existing vegetation into previously unvegetated mudflat that had not been detected by earlier aerial photography.

The goal to increase coverage of emergent vegetation in shallow, unvegetated, open water areas was achieved, but the amount is difficult to quantify. The drawdown phase of the project was intended to allow germination of marsh vegetation seeds and expansive tillering. Because our formal emergent vegetation sampling only incorporated existing vegetated areas, the only way to attempt to evaluate this goal was through analysis of aerial photography and through observations during field trips. Land / water analysis 1994 – 2000 did show a land gain in CTU 2 and we believe it is due mainly to expansion of *P. vaginatum* and *S. alterniflora* at the marsh water interface. Evidence of this new vegetation became apparent during vegetation sampling after the drawdown and drought in 1996.

The abundance of vegetation in presently vegetated portions of the project area has not increased since project construction. The one preconstruction vegetation data set for 1995 documented mean vegetation cover of almost 90% for the project and reference areas. To increase cover would have been unlikely, therefore postconstruction monitoring data was essentially used to assess the continuation of the current high vegetation cover. Although the conservative statistical tests conducted did not find significant differences among sampling times, the project area total cover appeared to have suffered an initial decrease in cover in project area between 1995 sampling and 1997. This time period included the time of the 1996 drought and drawdown which resulted in extreme drying of the marsh soil which can cause an increase in soil salinity and water soluble metals and a decrease in pH (Lehto and Murphy 1988, Sigua and Hudnall 1988). The subsequent high rainfall caused flooding stress with a three month period of water level over the target range. With water level as high as 1.5 ft over the marsh surface and salinities between 5 ppt and 10 ppt, this event may have further aggravated damaged root systems by causing possibly anoxic conditions in the soil, which when coupled with saline water, can result in root oxygen deficiencies, decreased nutrient uptake, and a buildup of sulfides in the soil (Mendelssohn and McKee 1989). Although the reference area also experienced effects from the drought, including marsh elevation decrease, percent total vegetation cover was not appreciably changed. Both areas, but especially the project area, experienced species composition changes after the 1995 sample that persisted to 2003. The percent cover of species other than the dominant *S. patens* increased, especially those able to exploit disturbance such as *A. australis*. *D. spicata*, better able to tolerate the high soil salinity caused by the 1996 drought, increased in cover in 1997 and eventually became the second most dominant species after *S. patens*. Other species composition changes, such as the increase of *P. vaginatum* at marsh edges, were likely the beneficial result of the drawdowns in 1996 and 1997.

High salinity in late 1999 and early 2000 did not seem to have a long term detrimental effect on vegetation. Total vegetation cover increased in the reference area and remained about the same in the project area from 1999 to 2003. The apparent lack of effect on vegetation and marsh elevation of the 1999 – 2000 drought is likely due to the water level in the project area during this time. Although water level did drop below the target range of 1.0 ft NAVD to about 0 ft NAVD at one point, there was nothing like the extended period of water level below 0 ft NAVD in 1996 to cause extensive subsurface soil desiccation.

Because of the limited preconstruction data set, it would be difficult to determine if there was a reduction of salinity from preconstruction levels to within ranges for brackish vegetation. In fact, the one project station (CS20-17) with preconstruction data recorded salinities within the target range for nearly 100% of its readings in the year before project construction. We have instead attempted to determine if salinity and water level were maintained within the target ranges after project construction. Except for during the 1999 – 2000 drought, the salinity at project stations was at or below 15 ppt for a very great percentage of the total number of measurements. Fluctuations in salinity were less at project station 3 than reference station 14r during flapgate operation at least for the two most recent periods of operation. The flapgate operation clearly prevented high salinity inputs during these two periods. However, because some of the structures involved in the operations were in place prior to project construction we cannot determine the effect from only the structures installed or modified as part of the project.

Short term fluctuations in water level were much less at project stations than at reference stations but the overall longer term trend in water level change was similar. The water level target range was not maintained as consistently as the target salinity. Water level values not within the target zone of 2 inches above average marsh level to 6 inches below marsh level were usually high rather than low. It should also be noted that marsh elevation in sections of CTU 2 are lower than the average marsh elevation of 1 ft. NAVD. Therefore, the marshes in some of these areas are actually flooded for an even longer time. A reexamination of stoplog levels may be beneficial, but any changes should not be implemented without consideration of the current effectiveness in draining the area after extreme high water events and preventing flooding from rapid inflow during these events.

The project was designed to decrease the duration and frequency of flooding over marsh. Again, without adequate preconstruction data as a baseline, it cannot be determined if there has been a decrease since project construction. It is clear, however, that high water was effectively drained when it was possible (i.e. when the outside water level dropped below that of the inside). Heavy rainfall and storms appear to have been the major causes of extended flooding and could not be prevented from flooding the project area; however, gravity drainage with the present structures was adequate to reduce the water level.

One of the goals of the project regarding salinity was to decrease mean salinity in CTU 2. The lack of extensive preconstruction data in CTU 2 prevented a valid analysis of before and after construction effects on mean salinity. We therefore evaluated the current ability of the structures and their operations to maintain a favorable mean salinity relative to the outside reference areas. Mean salinity for an area may not be the best parameter to evaluate the effect of the project on salinity. However, combined with the other analyses it may help to summarize long term changes. In and around the project area, water level and salinity control appears to be largely a function of environmental factors, especially precipitation. There was no clear trend toward higher or lower mean salinity values over time. High salinity starting around August 1999 and peaking in October – November 2000 was likely due to drought conditions, as water levels were low during the same time period. Although soil salinity was probably very high and plant stress was definitely much greater during the drought of 1996, the increase in water salinity was relatively small and inconsistent. Salinities increased dramatically, and remained elevated for longer durations during the 1999 – 2000 drought. The 1996 drought occurred primarily in the cooler weather of the spring, whereas the 1999 – 2000 drought included the summer of 2000. High evaporation and evapotranspiration apparently created hypersaline conditions at stations 3 and 9 of up to 37 ppt and 43 ppt, respectively (LOSC 1999, 2000). Alternatively, salinities in the unimpounded reference area station 14R were not greater than 35 ppt. In 1996, water levels remained extremely low into August, but rainfall in the area increased to above normal by June and may have prevented the extreme water salinity concentrations recorded in 2000.

Salinities at project and reference stations before construction were presumably already somewhat different as a result of the previously impounded state of the area prohibiting free exchange with water from the Calcasieu Ship Channel. At least in the area near station 17, salinities in the project area were lower than at the two reference stations 14R and 15R. We saw that in general, the reference areas had the highest mean salinities over the years followed by CTU 2 and CTU 1. Each yearly mean was generally different from the other groups in that same year by only a few ppt. This lack of dramatic differences should not obscure the effect of structure operations that are evident at station 3 after the 1999-2000 drought from 2001 through 2003 (figure 19a). During the period of open 6, the maximum difference is not much different from the maximum difference during operating 7 or operating 8 which precede and follow respectively. However, you must consider the duration of the maximum difference event.

During the locked open period, there is usually a lag time before the station 3 salinity increases until is nearly the same as station 14R again (figure 19a). In contrast, during the operating intervals, station 3 salinity remains lower than station 14R salinity for much longer periods, and therefore the the prevention of high salinity is more effective.

Vertical accretion can be increased by increasing suspended sediment deposition and/or increasing surface organic matter accumulation and below ground vegetation production. We measured vegetation cover, which we also used as a proxy for above ground production. With the project area at almost 90% mean vegetation cover in 1995 (pre-construction), it appeared that it would have been difficult to increase vegetation production much, especially by only controlling water level and salinity. Alternatively, with the new and refurbished structures that the project added, greater water flow from outside the project area and thus potentially more suspended material was made possible.

Vertical accretion was not appreciably increased in CTU 2 during the post-construction period. As with some of the other goals, without pre-construction data, we cannot determine if any of the rates measured after construction were greater, equal, or less than pre-construction rates. Although there appears to have been an accretion increase in the project area between July 1997 and December 1997, the most recent measurement (December 1997 – July 2003) was not much different from one of the three earliest measurements.

The rate of vertical accretion in both areas may be low because of low vegetation production. Vegetation cover in all samples in the reference area, and in the project area in 1995, was relatively high; however, the use of cover as a proxy for production may become inappropriate when cover is nearly 100%. At this point, no increase in cover can be detected, but production may or may not be at the maximum. Both areas may be suffering from less than expected organic accumulation because of suboptimal vegetation production. Although the percent cover of vegetation is relatively high, we don't know exactly what production rates are currently, or were, in past years.

The reduction in the accretion rate in the reference area accretion rate by June 2000 is puzzling. It may indicate that the source or availability of material from resuspended lake bottom sediments or material made available from erosion in other locations has decreased for both areas. The reference area would be affected more because it is generally more hydrologically open to receive such input. Without any suspended sediment data or water flow information, further investigation of suspended sediment input change is not possible. Reduction in accretion from organic matter accumulation was also considered. From 1996 to 1999, the percent organic material and the bulk density decreased in the project and reference areas. The percent organic matter decreases as a result of less dead plant parts accumulating, caused by decreased plant production, or increased export of the organic matter. The bulk density can decrease due to a decrease in mineral input or the export of less refractory organic material. There was no appreciable decrease in vegetation cover (i.e. production proxy) in the reference area over this time to explain the soil organic matter percentage decrease. Also, during the same period the project area experienced a greater decrease in cover, especially in *S.patens* (approximately 50%). *D. spicata* became a more important component of the vegetation after 1996. Estimates for *S. patens* production in Louisiana range as high as 4159 $gm^{-2}\ yr^{-1}$, whereas *D. spicata* production was reported at only 1967 gm^{-2} yr^{-1} (Hopkinson et al. 1980). Accretion from organic matter accumulation should have decreased considering the vegetation production limitation and the decrease in soil organic matter. Instead, accretion in the project area at least remained the same and may have increased slightly. Ultimately, we have no satisfactory explanation for the change in accretion rates leading to equivalent rates for the project and reference areas.

The ultimate goal of increasing vertical accretion, of course, is to maintain or increase marsh elevation. Our results do not support the achievement of this goal either. Analysis by sampling period of marsh elevation change rates varied by the sampling interval and standard error was large, but the large initial elevation loss is clearly evident. The exceptional average decrease in elevation from December 1995 to July 1996 in both the project and reference areas is the result of soil compaction resulting from the drought of February through July 1996. Initial subsidence of organic soils is estimated to result in a reduction of thickness of the organic materials above the water table by about 50%, accompanied by permanent open cracks that do not close when the soil is hydrated. Shrinkage then continues at a fairly uniform rate as biochemical oxidation of organic materials continues (Murphy 1988). Interestingly, despite the decrease in average reference area accretion and slight increase in average project area accretion, some recent marsh elevation changes have been positive in the project and reference areas. The accretion amounts measured were not great enough alone to have changed the marsh elevations. We suspect that much of the elevation gains found at some stations is due to marsh substrate swelling with the reintroduction of water. The amount of interstitial water in marsh soils can affect the marsh surface elevation on a much shorter time scale than that of the SET sample schedule. This behavior of intertidal marsh can make it difficult to discern the true trajectory of marsh surface elevation change.

Long term elevation change rates as determined by regression analysis indicated that in the project and reference areas, more SET stations are experiencing long term surface elevation loss than stasis or gain. This analysis also indicated that the East Mud Lake Project has not reduced marsh elevation loss rates below those of the reference area and may in fact be higher. Because the elevation loss rates are still within the range of historical rates of change for the Calcasieu Lake area (0 – 0.6 cm/yr) and are similar to most of the reference stations (Coast 2050), the project cannot be deemed effective for increasing accretion or slowing marsh elevation decreases. However, this regression analysis has its limitations. It was greatly affected by the unusually large elevation decline due to the drought of 1996 and subsequent soil compaction; and the following recovery due to swelling of the marsh substrate. Except for the most recent measurements, the data points in the regression reflect a severe and discrete event, and not the more usual and consistent processes that affect marsh elevation. A regression analysis not including the drought and recovery period would be markedly different. The actual measurements at some stations point to elevation recovery even though the regression slopes are negative. Project station 7 average marsh elevation determined by SET sampling, declined from 1.08 ft NAVD, in December 1995, to 0.87 ft. NAVD, in July 1996, immediately after the drought. Marsh elevations in June 2000 and July 2003 were 1.02 ft NAVD and 1.03 ft. NAVD respectively. The elevation decreased by 0.21 ft after the drought, but then subsequently increased by 0.16 ft. Examining only snapshot data taken every few years in a dynamic environment to make long term predictions is risky also. While it is true that the recent sampling indicates that surface elevation seems to have recovered significantly at many stations, the surface elevation just prior or just after the measurements were taken is unknown. We don't know if in fact it indicates a trend or just coincidence with peaks of marsh elevation movement. With either evaluation, the initial dramatic decline and the rapid elevation increase (at some stations) has confounded the true long term elevation changes. For a more accurate trajectory of the future marsh elevation, more SET samples, with shorter interval times, are needed.

Maintaining the abundance of fisheries species in the project area, although not an official monitoring element, was deemed important to document. The major part of the preconstruction fisheries data analysis was to determine the suitability of the reference area for fisheries sampling. Several variables had statistically significant interaction effects between area (Project and Reference) and sampling times. This indicates that the two areas may have been functionally different with respect to variability of environmental variables. This is expected since the project area historically has been at least somewhat impounded. Still, the environmental variables appear to be similar enough not to dismiss the suitability of the reference area on that basis alone. When the preconstruction distributions of animals in both areas are considered along with the high temporal variability in both fisheries and environmental variables, it is difficult to dismiss the reference area as inappropriate. Only two true preconstruction samples were collected; more intense preconstruction sampling would have been necessary to more accurately determine the suitability of the reference area.

Resident fishes and crustaceans were generally more abundant in the project area and transient fishes and crustaceans were generally more abundant in the reference area before and after project construction. This likely indicates a previous and present access restriction for transient species to the project area, and a more suitable habitat for resident species in the project area. Fisheries species densities were temporally variable in both areas, and despite a trend toward higher crustacean densities after project construction in both areas, the project did not have a significant effect on total fisheries species densities. Although transient crustacean densities did increase significantly postconstruction in the project area, there was a much greater significant postconstruction increase in the reference area in total, transient, and resident crustacean densities, which means that even if the project effects contributed to an increase in animal numbers it was overshadowed by other (likely natural) causes. The high transient fish density in the reference area in April 1996 was due to large catches of gulf menhaden. Menhaden form large schools and therefore sampling can yield very large or very small catches. The very low numbers of menhaden collected in the project area during the same sampling trip could be the result of missing schools of the fish, but the low numbers may also be indicative of a lack of access to the project area for the transient menhaden during this year of extreme drought.

CONCLUSION

Weather patterns dominated control of water level and salinities inside and outside of project area. Although operation of water control structures, such as allowing flapgates to operate, definitely attenuates the high salinities that occur outside the project area, the effect of the original impoundment of the area is also evident. During normal weather conditions structure operation is effective at muting high salinity in the project area, but even when operated correctly, the high salinity seen during the 1999 – 2000 drought could not be controlled by the structures. Indeed, the highest salinities recorded during the drought were at CTU 2 station recorders when the structure flapgates were in operation. The maintenance of selected project structures has been an ongoing challenge. The ability to determine project effects on water level and salinity are likely confounded by the operational status of structures such as 13 in CTU 1 and 4 in CTU 2.

Although the 1999-2000 drought resulted in much higher water salinity than the 1996 drought, there was not a detrimental effect on vegetation cover as with the 1996 drought and subsequent flooding event. The drought was the major factor. The area has been inundated for nearly as long at other times without the same adverse affects on elevation and vegetation. Extreme drying of marsh soils in 1996 due to drought (and drawdown), had a significant impact on the elevation of the marsh in the East Mud Lake Project area and the reference area, at least in the short term. The 1996 drying event and subsequent prolonged flooding later in the year also caused a decrease in vegetation cover in the project area. The combined stress of dried soils and probably high soil salinity did the most damage. High water salinity, like that in the 1999 – 2000 drought, does not seem to be the greatest problem long term. Also, other than during surges from tropical systems, the salinities were overwhelmingly within the target range.

A positive aspect of the drought experience is that it seems to show that lowering the water level did allow expansion of vegetation from the marsh edge. Another drawdown, conducted during more normal environmental conditions may be beneficial and should be considered. The new vegetation extending from the marsh edge can increase the amount of valuable emergent marsh.

Increasing the land to water ratio by encouraging vegetation growth on the marsh edge is a worthwhile effort and a goal of the project, but it will only last if the marsh elevation is maintained. Overall, the marsh surface elevation decline is not as great as the regression analysis seems to show nor as small as the most recent measurements show. Some things are confirmable however. The marsh in the project and reference areas is slowly sinking and the project thus far has not been effective at reducing the elevation loss. More SET sampling, at a higher frequency, during average climatic conditions will be necessary to provide enough data to accurately describe the marsh elevation change. Increasing accretion is the only technique the project can employ to counteract the effect of subsidence on marsh elevation. It appears that neither the project nor reference areas vertical accretion rates are great enough to completely counter the effects of subsidence over time. The project area probably receives less input from resuspended lake sediments than the reference area; however, recently it appears that the accretion rates of the two areas are similar so it is doubtful that the lack of suspended material input is the only factor. More precise estimates of production could help to determine the importance of organic matter accumulation in accretion in the project and reference areas. In some marshes, fertilization or prescribed burning has been shown to increase plant production, and dredge spoil has been used effectively to raise substrate elevations. The use of alternative techniques such as these should be considered along with the more conventional approaches to marsh management. More soil sampling and analyses may also help to determine the nutrient content of the soil and the source of the accumulated material, and help us to better understand the accretion processes in this area.

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APPENDIX

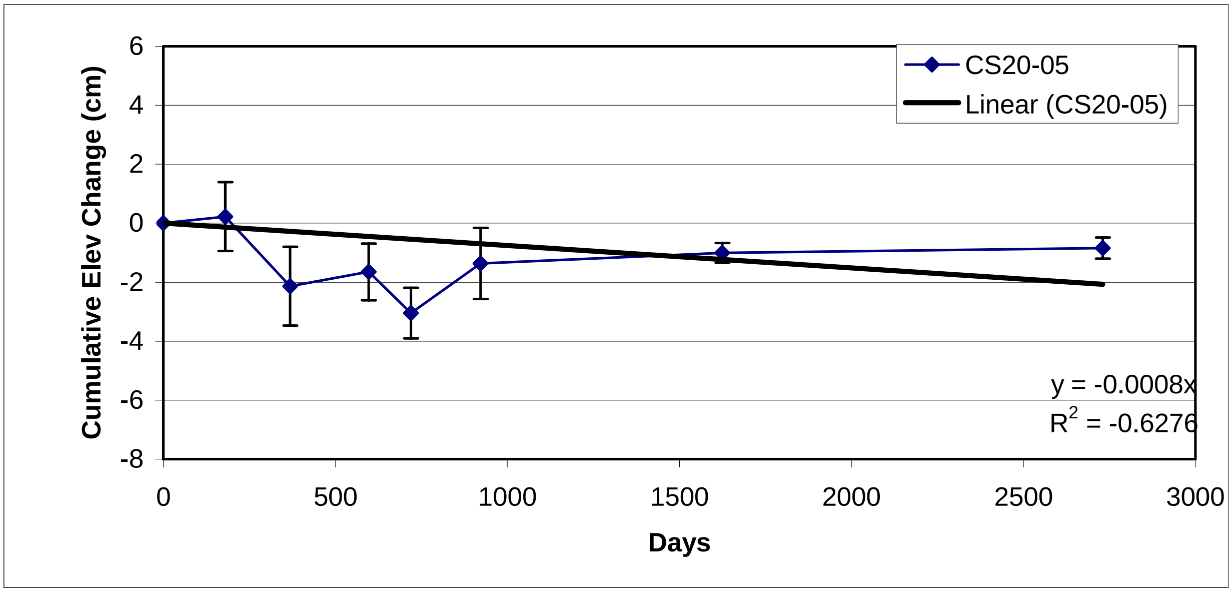
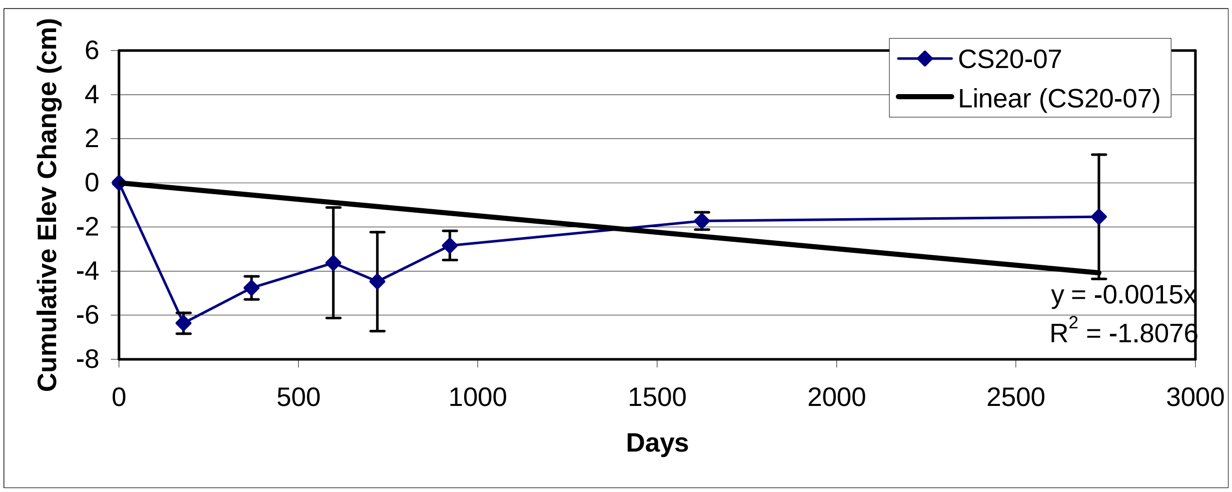


Figure A-1. Regression of cumulative elevation change for station CS20-05.



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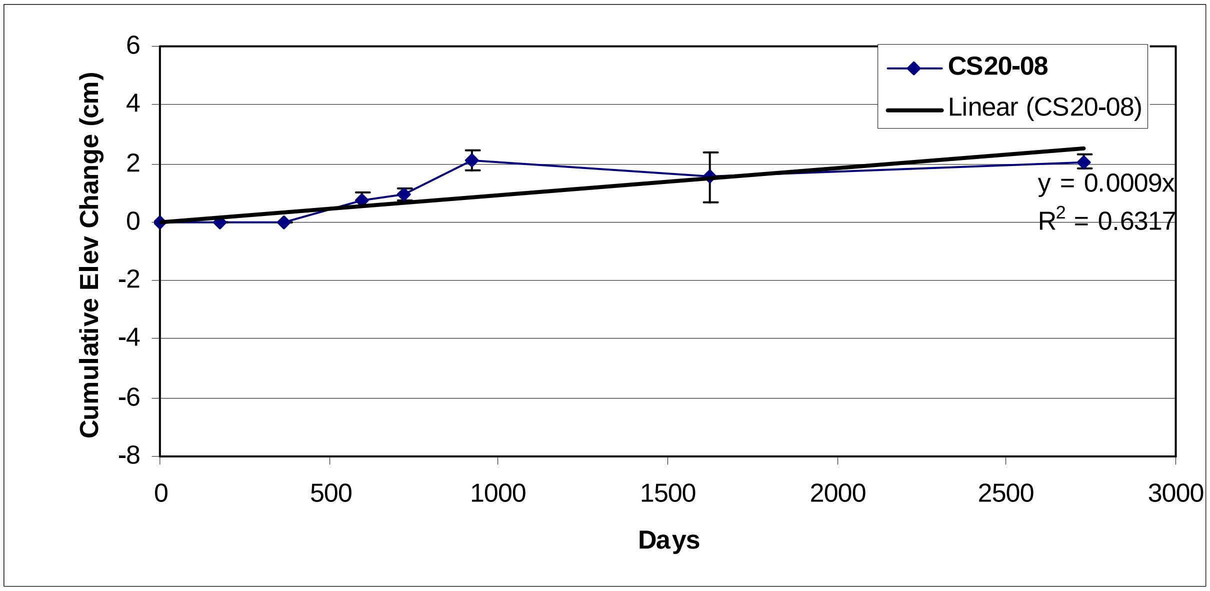

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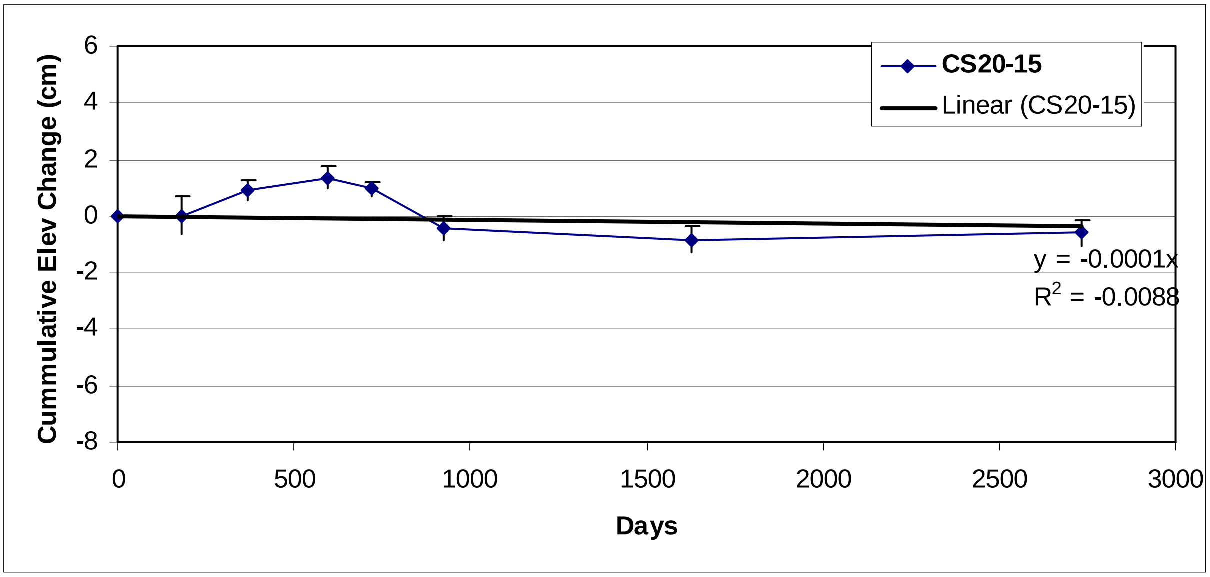

Figure A-4. Regression of cumulative elevation change for station CS20-15.

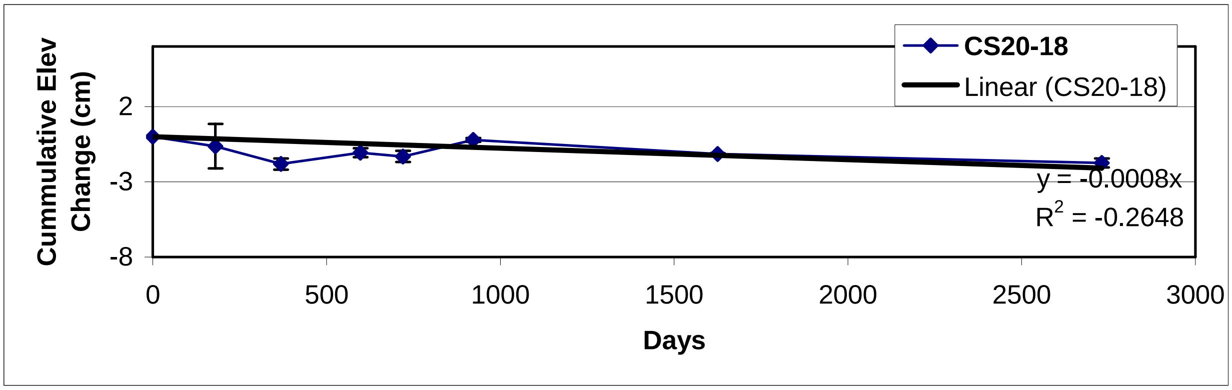

Figure A-5. Regression of cumulative elevation change for station CS20-18.

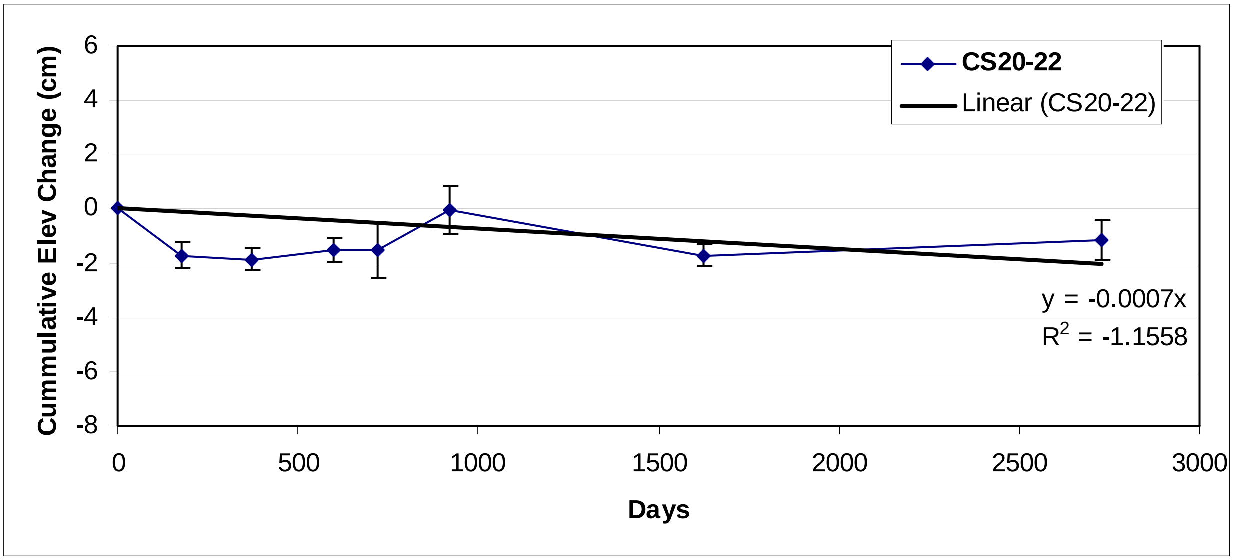

Figure A-6. Regression of cumulative elevation change for station CS20-22.

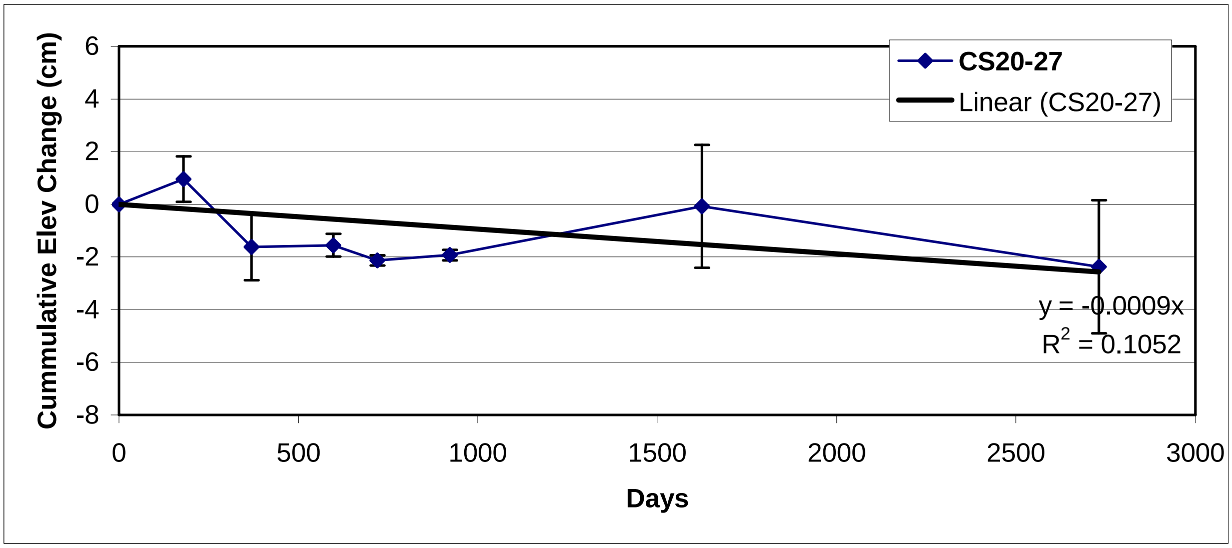

Figure A-7. Regression of cumulative elevation change for station CS20-27.

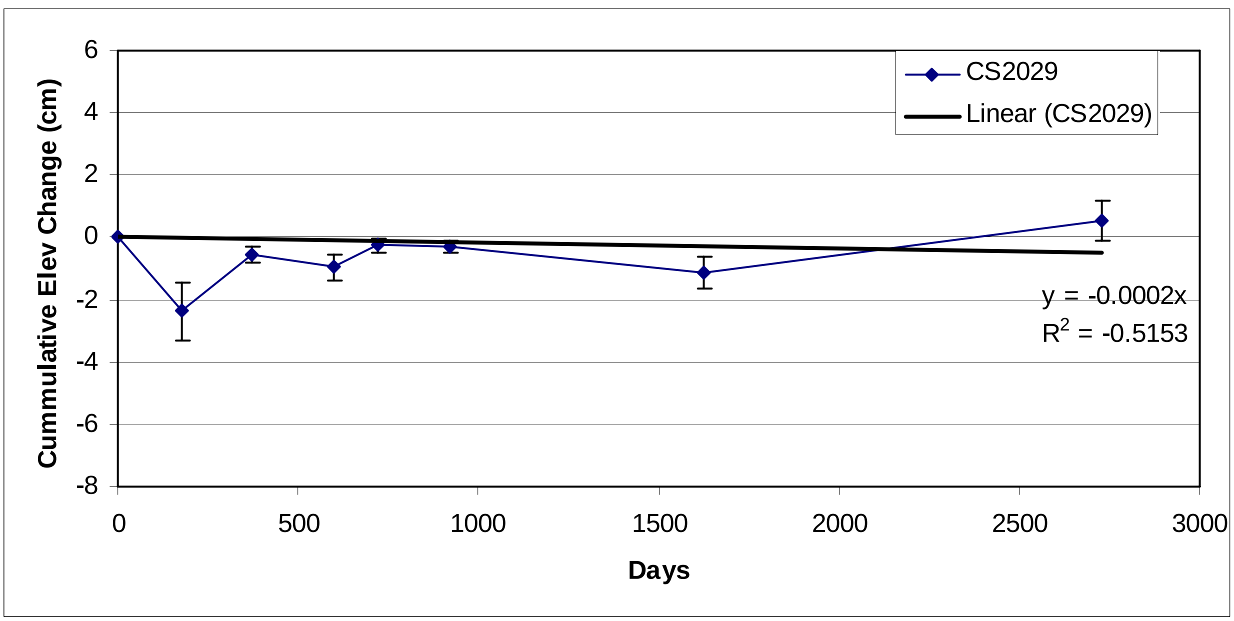

Figure A-8. Regression of cumulative elevation change for station CS20-29.

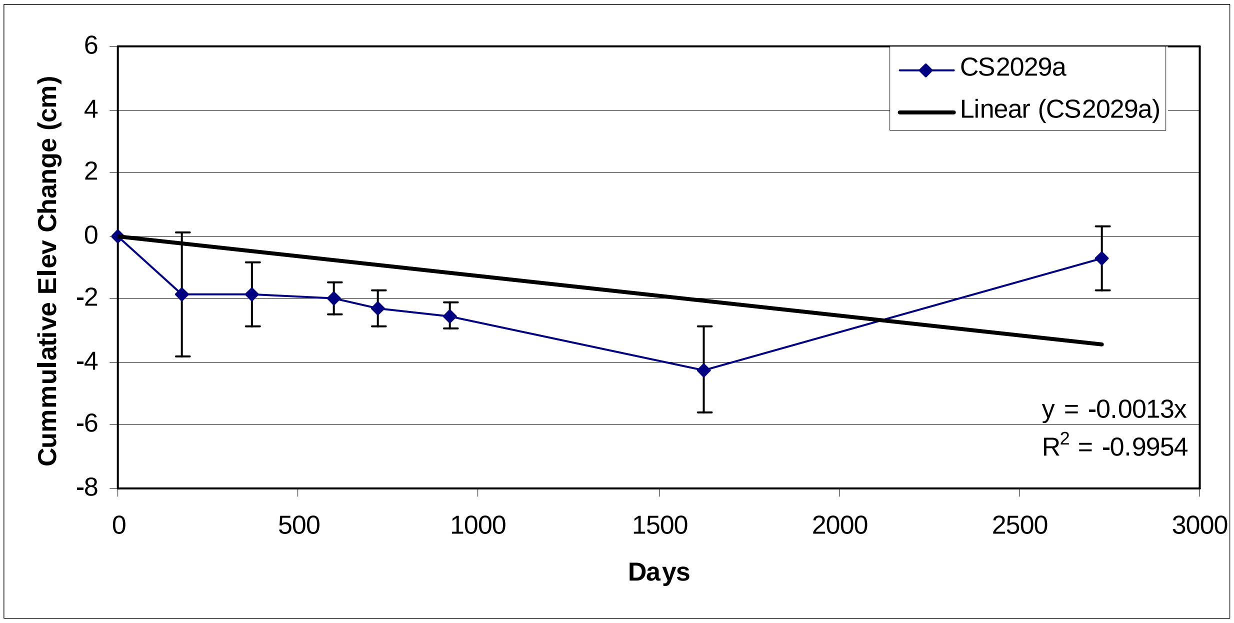

Figure A-9. Regression of cumulative elevation change for station CS20-29a.

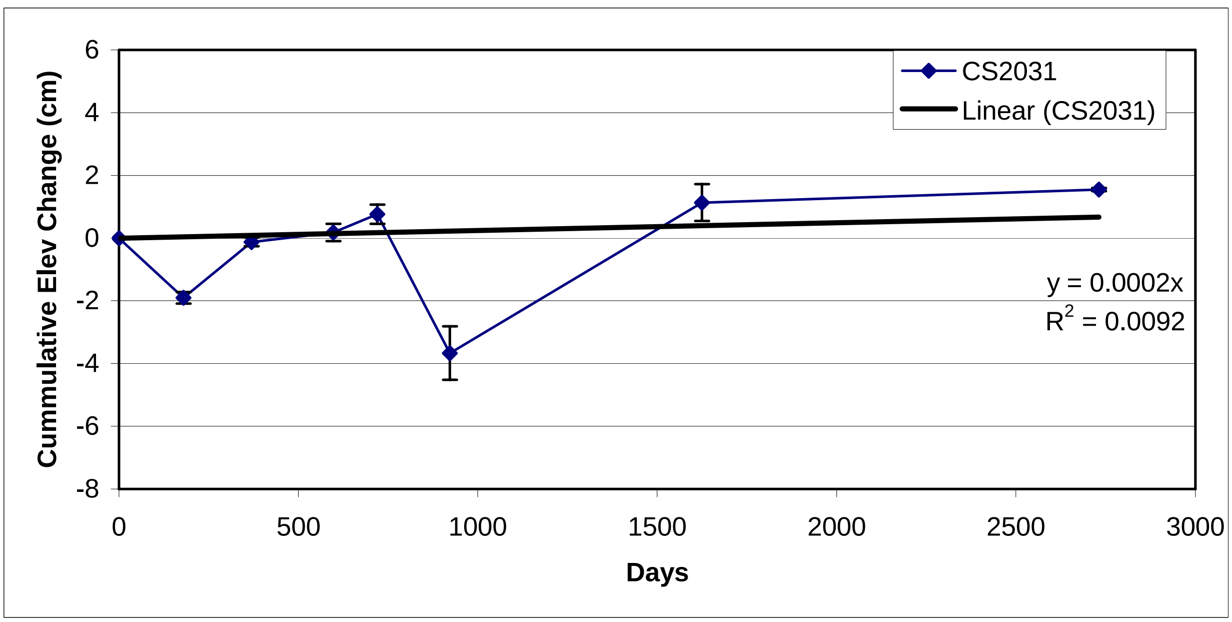

Figure A-10. Regression of cumulative elevation change for station CS20-31.

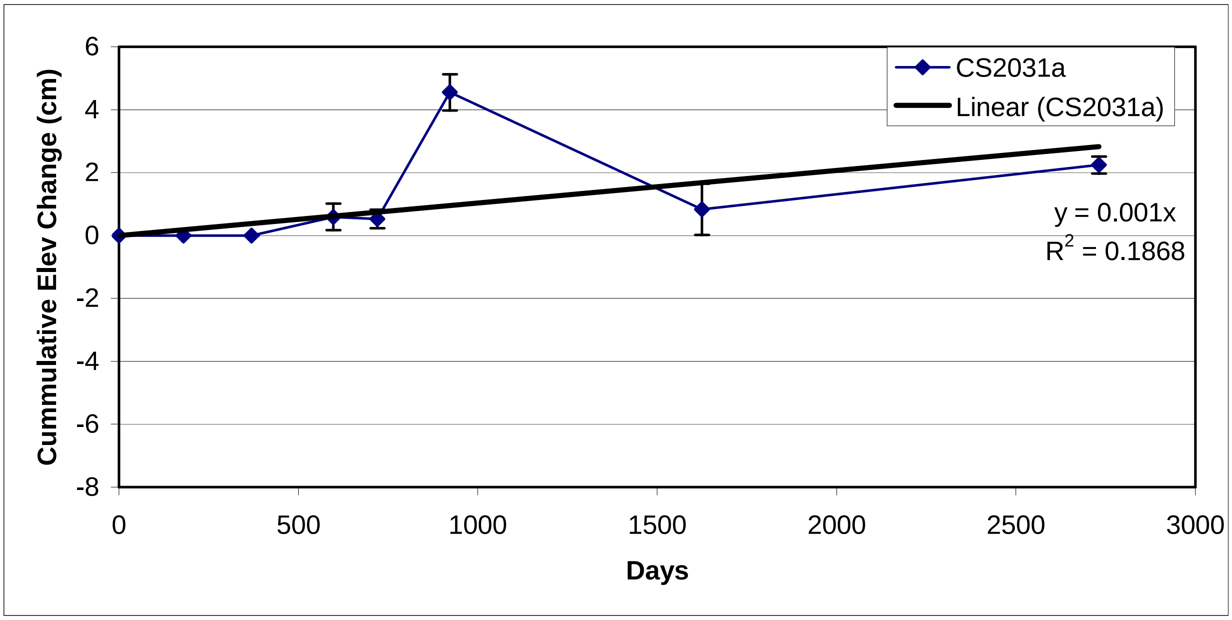

Figure A-11. Regression of cumulative elevation change for station CS20-31a.

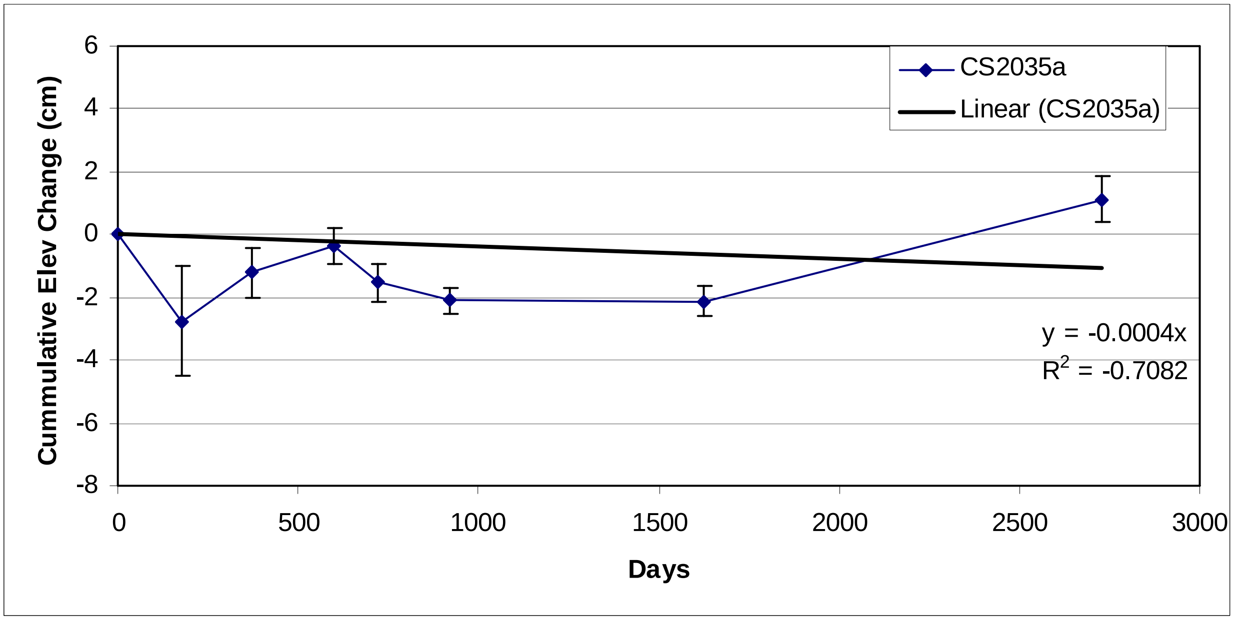

Figure A-12. Regression of cumulative elevation change for station CS20-35a.

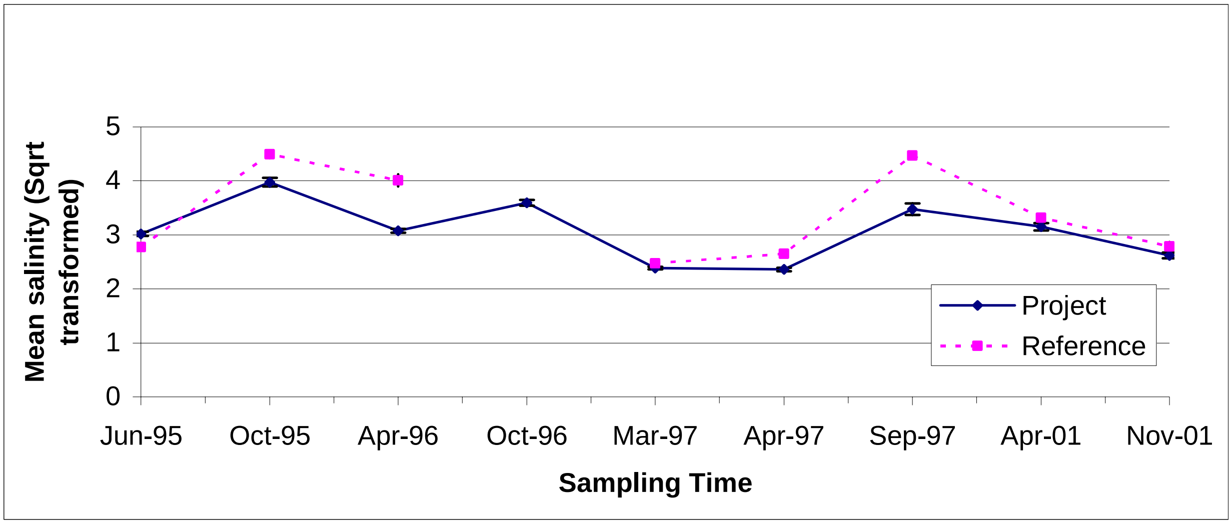

Figure A-13. Transformed mean salinity measured in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

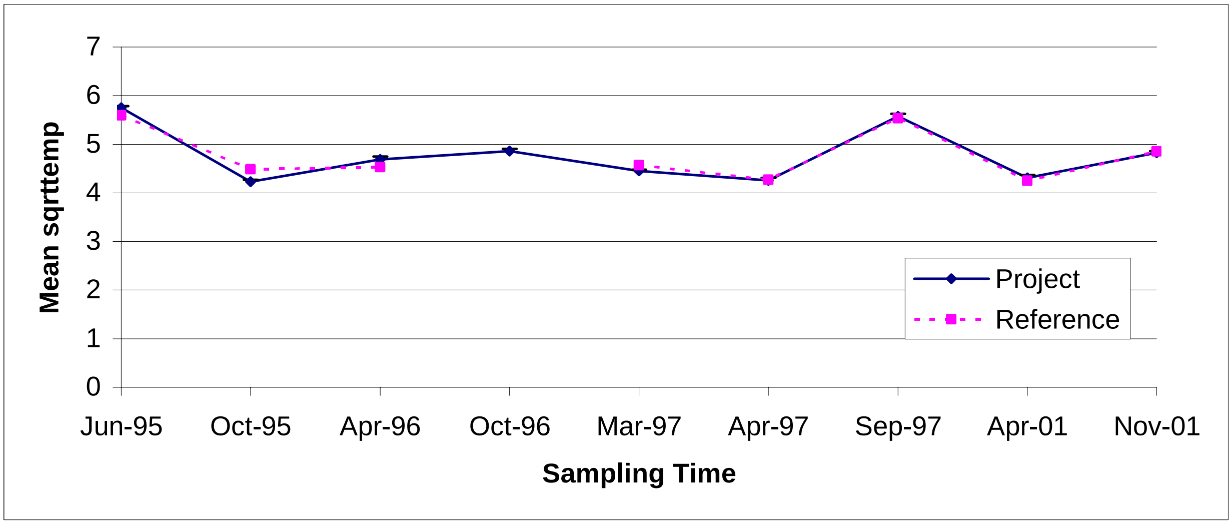

Figure A-14. Transformed mean temperature measured in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

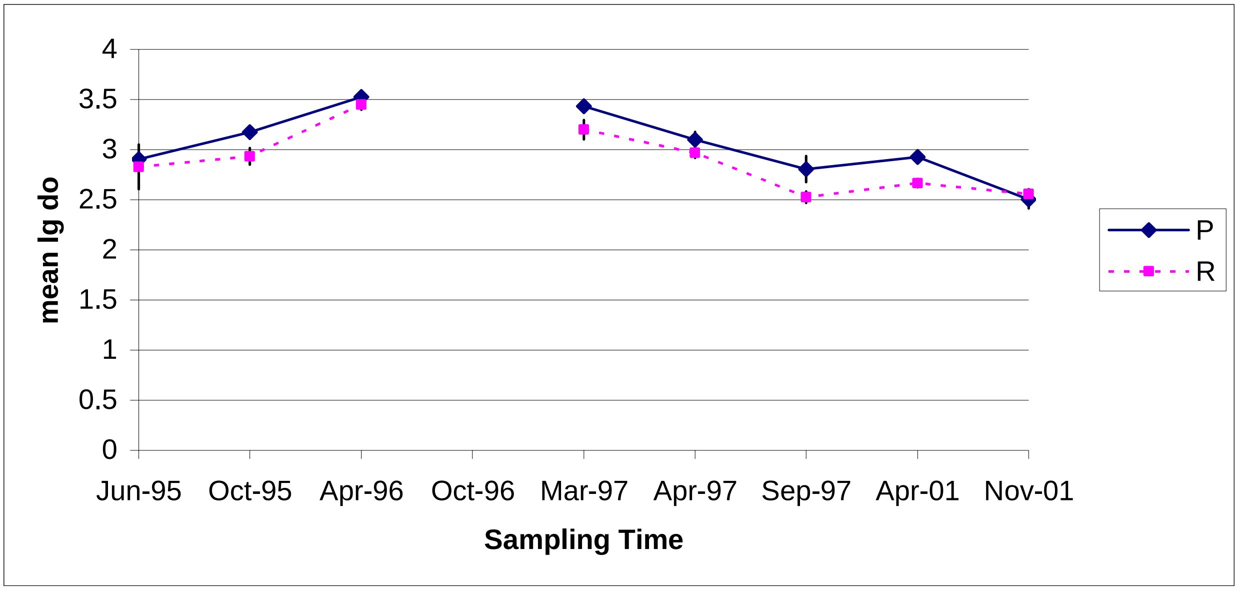

Figure A-15. Transformed mean dissolved oxygen measured in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

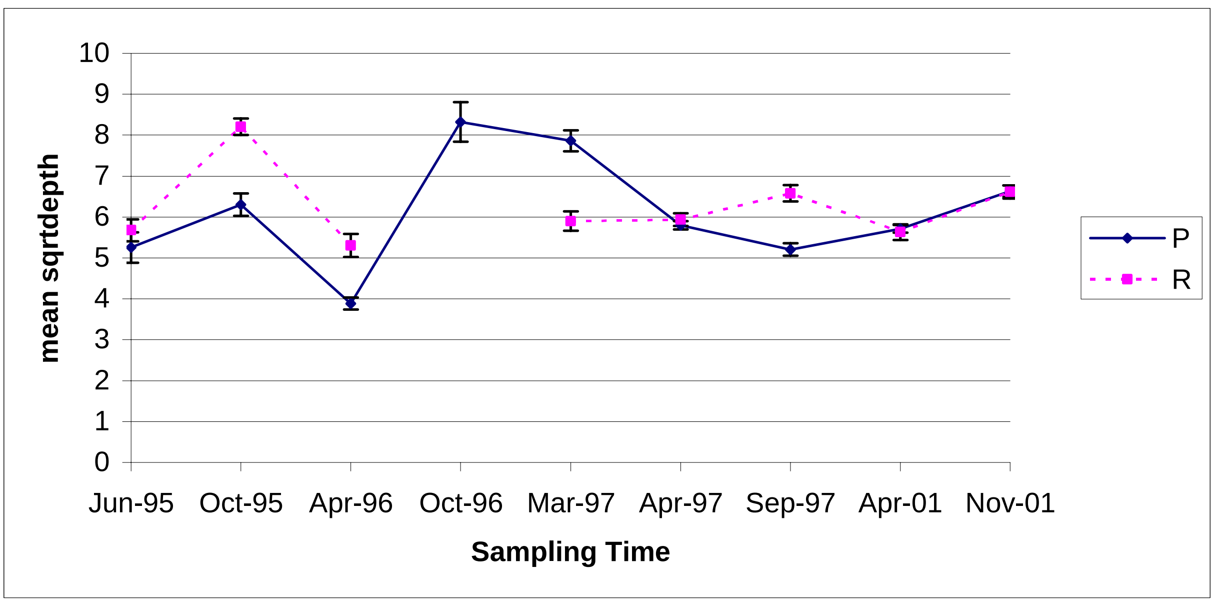

Figure A-16. Transformed mean water depth measured in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

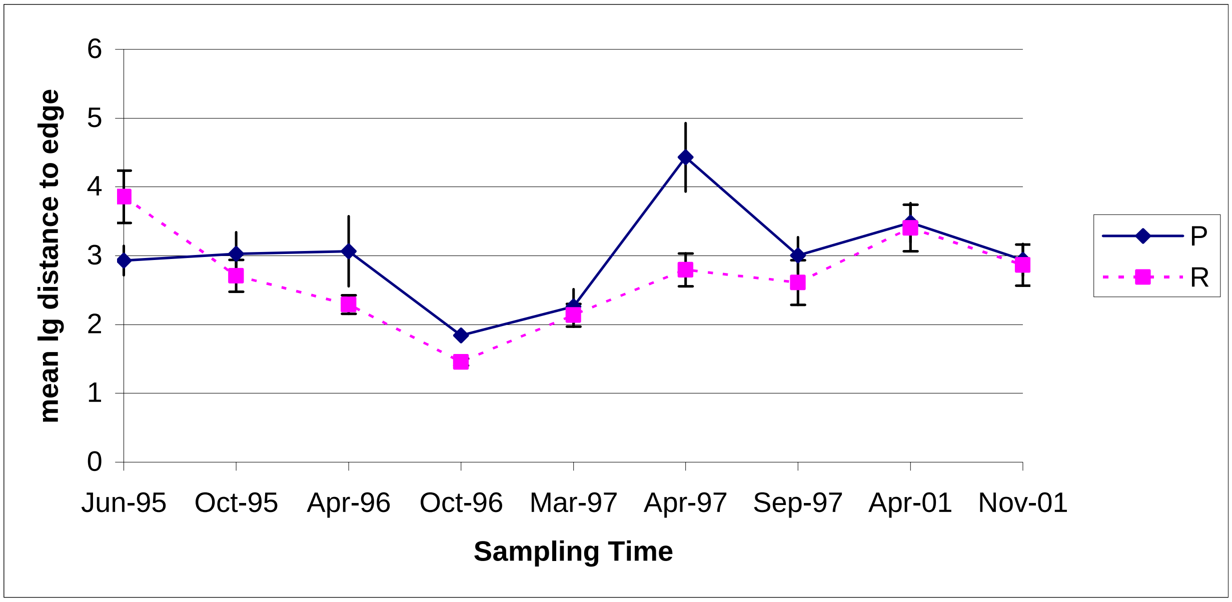

Figure A-17. Transformed mean distance of sample to marsh edge measured in the East Mud Lake (CS-20) project and reference areas at sampling dates between June 1995 and November 2001.

Table A-1. Untransformed data means and standard error (S.E.) of biomass and density of fish and crustaceans sampled in June 1995

	June 1995									
	Project Area n = 30				Reference Area n = 30					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
TOTAL FISHES	1.23	(0.38)	22.0	(2.46)	8.06	(4.22)	16.83	(9.89)	278	1165
Inland silverside *Menidia beryllina*	0.45	(0.16)	2.10	(0.79)	0.07	(0.04)	0.20	(0.10)	15.56	69
Spot *Leiostamus xanthurus**	0.31	(0.31)	0.07	(0.07)	0.45	(0.45)	0.07	(0.07)	22.67	4
Gulf killifish *Fundulus grandis*	0.17	(0.17)	0.03	(0.03)	0.00	(0.00)	0.00	(0.00)	5.05	1
Unidentified goby	0.12	(0.05)	1.83	(0.69)	0.01	(0.01)	0.10	(0.07)	3.99	58
Western mosquitofish *Gambusia affinis*	0.08	(0.04)	2.13	(1.47)	0.88	(0.69)	5.77	(4.02)	28.76	237
Sheepshead minnow *Cyprinodon variegatus*	0.03	(0.03)	0.10	(0.10)	0.55	(0.46)	0.43	(0.37)	17.54	16
Naked goby *Gobiosoma bosc*	0.03	(0.03)	0.03	(0.03)	0.01	(0.01)	0.13	(0.06)	1.09	5
Diamond killifish *Adinia xenica*	0.02	(0.02)	0.03	(0.03)	0.01	(0.01)	0.03	(0.03)	0.95	2
Sailfin molly *Poecilia latipinna*	0.01	(0.01)	0.07	(0.05)	3.62	(2.72)	7.53	(5.24)	109.3	228
Bayou killifish *Fundulus pulvereus*	0.01	(0.01)	0.03	(0.03)	0.51	(0.37)	0.67	(0.47)	15.62	21
Pipefish *Sygnanthus spp.*	0.01	(0.01)	0.03	(0.03)	0.00	(0.00)	0.00	(0.00)	0.21	1
Rainwater killifish *Lucania parva*	0.01	(0.01)	0.03	(0.03)	0.00	(0.00)	0.00	(0.00)	0.14	1
White mullet *Mugil cerema**	0.00	(0.00)	0.00	(0.00)	1.60	(1.60)	0.03	(0.03)	48.06	1
Bay anchovy *Anchoa mitchilli**	0.00	(0.00)	0.00	(0.00)	0.11	(0.07)	0.83	(0.38)	3.34	25
Gulf flounder *Paralicthys albigutta**	0.00	(0.00)	0.00	(0.00)	0.07	(0.05)	0.07	(0.05)	2.0	2
Gulf menhaden *Brevortia patronus**	0.00	(0.00)	0.00	(0.00)	(0.00)	(0.04)	0.03	(0.03)	1.29	1

Table A-1 (continued)

	June 1995									
	Project Area n = 30				Reference Area n = 30					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
Blackcheek tonguefish *Symphurus plagiusa**	0.00	(0.00)	0.00	(0.00)	0.04	(0.02)	0.40	(0.20)	1.04	12
Freshwater goby *Gobionellus shufeldti*	0.00	(0.00)	0.00	(0.00)	0.02	(0.01)	0.30	(0.13)	0.68	9
Sharptail goby *Gobionellus hastatus*	0.00	(0.00)	0.00	(0.00)	0.02	(0.02)	0.03	(0.03)	0.62	1
Darter goby *Gobionellus boleosoma*	0.00	(0.00)	0.00	(0.00)	0.01	(0.01)	0.03	(0.03)	0.42	1
Bay whiff *Citharicthys spilopterus**	0.00	(0.00)	0.00	(0.00)	0.02	(0.02)	0.03	(0.03)	0.45	1
Green goby *Microgobius thalassinus*	0.00	(0.00)	0.00	(0.00)	0.01	(0.01)	0.03	(0.03)	0.14	1
Speckled worm eel *Myrophis punctatus**	0.00	(0.00)	0.00	(0.00)	0.004	(0.03)	0.07	(0.05)	0.12	2
Pipefish *Sygnanthus louisiane*	0.00	(0.00)	0.00	(0.00)	0.04	(0.02)	0.03	(0.03)	1.04	1
TOTAL CRUSTACEANS	0.51	(0.28)	2.47	(1.47)	1.25	(0.39)	2.30	(0.86)	52.66	143
Brown shrimp *Penaeus aztecus**	0.25	(0.25)	0.03	(0.03)	1.10	(0.36)	1.43	(0.80)	40.44	44
Unidentified grass shrimp *Palaemonetes* spp.	0.25	(0.15)	2.27	(1.48)	0.14	(0.06)	0.83	(0.38)	11.52	93
Daggerblade grass shrimp *Palaemonetes pugio*	0.01	(0.01)	0.13	(0.08)	0.01	(0.01)	0.03	(0.03)	0.50	5
grass shrimp *Palaemonetes vulgaris*	0.01	(0.01)	0.03	(0.03)	0.00	(0.00)	0.00	(0.00)	0.20	1

Table A-2. Untransformed data means and standard error (S.E.) of biomass and density of fish and crustaceans sampled in October 1995.

	October 1995									
	Project Area n = 25				Reference Area n = 25					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
TOTAL FISHES	4.66	(1.47)	28.08	(8.40)	0.63	(0.25)	2.16	(0.74)	132.33	756
Western mosquitofish *Gambusia affinis*	1.91	(0.65)	13.92	(4.31)	0.01	(0.01)	0.04	(0.04)	48.04	349
Inland silverside *Menidia beryllina*	1.31	(0.94)	6.60.	(5.25)	0.25	(0.16)	0.56	(0.36)	38.99	179
Sheepshead minnow *Cyprinodon variegatus*	1.12	(0.42)	5.36	(1.74)	0.00	(0.00)	0.00	(0.00)	28.0	134
Unidentified goby	0.08	(0.07)	0.12	(0.01)	0.00	(0.00)	0.00	(0.00)	1.94	3
Sailfin molly *Poecilia latipinna*	0.21	(0.17)	2.00	(1.48)	0.00	(0.00)	0.00	(0.00)	5.36	50
Bay anchovy *Anchoa mitchilli**	0.02	(0.02)	0.04	(0.04)	0.27	(0.20)	0.96	(0.65)	7.27	25
Clown goby *Microgobius gulosus*	0.01	(0.01)	0.04	(0.04)	0.01	(0.01)	0.04	(0.04)	0.42	2
Naked goby *Gobiosoma bosc*	0.00	(0.00)	0.00	(0.00)	0.03	(0.02)	0.24	(0.14)	0.72	6
Red drum *Sciaenops ocellatus**	0.00	(0.00)	0.00	(0.00)	0.01	(0.01)	0.20	(0.14)	0.20	5
TOTAL CRUSTACEANS	0.80	(0.26)	9.44	(3.98)	1.14	(0.43)	1.56	(0.52)	48.39	275
Unidentified grass shrimp *Palaemonetes* spp.	0.65	(0.25)	9.20	(4.00)	0.03	(0.02)	0.28	(0.20)	16.2	237
Blue crab *Callinectes sapidus**	0.00	(0.00)	0.00	(0.00)	0.01	(0.00)	0.16	(0.07)	0.12	4
White shrimp *Peneaus setiferus**	0.13	(0.13)	0.04	(0.04)	1.01	(0.44)	0.6	(0.28)	28.35	16
Brown shrimp *Penaeus aztecus**	0.00	(0.00)	0.00	(0.00)	0.10	(0.05)	0.52	(0.40)	2.53	13
Daggerblade grass shrimp *Palaemonetes pugio*	0.02	(0.01)	0.20	(0.16)	0.00	(0.00)	0.00	(0.00)	0.44	5

Table A-3. Untransformed data means and standard error (S.E.) of biomass and density of fish and crustaceans sampled in April 1996.

	April 1996									
	Project Area n = 25				Reference Area n = 20					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
TOTAL FISHES	1.17	(0.36)	3.24	(1.10)	3.04	(1.29)	20.95	(10.35)	90.17	500
Inland silverside *Menidia beryllina*	0.57	(0.22)	0.68	(0.24)	0.05	(0.05)	0.05	(0.05)	15.30	18
Spot *Leiostamus xanthurus**	0.00	(0.00)	0.00	(0.00)	0.12	(0.06)	0.5	(0.27)	2.32	10
Western mosquitofish *Gambusia affinis*	0.46	(0.18)	2.16	(0.87)	0.12	(0.10)	0.75	(0.65)	13.89	69
Sheepshead minnow *Cyprinodon variegatus*	0.04	(0.04)	0.04	(0.04)	0.09	(0.07)	0.20	(0.09)	2.80	5
Sailfin molly *Poecilia latipinna*	0.05	(0.04)	0.16	(0.13)	0.00	(0.00)	0.00	(0.00)	1.18	4
Bayou killifish *Fundulus pulvereus*	0.03	(0.03)	0.08	(0.08)	0.00	(0.00)	0.00	(0.00)	0.77	2
White mullet *Mugil cerema**	0.00	(0.00)	0.00	(0.00)	0.04	(0.04)	0.05	(0.05)	0.82	1
Atlantic croaker *Micropogonius undulatus**	0.00	(0.00)	0.00	(0.00)	0.13	(0.06)	0.35	(0.17)	2.59	7
Sheepshead *Archosargus probatocephalus**	0.00	(0.00)	0.00	(0.00)	0.01	(0.01)	0.10	(0.10)	0.11	2
Gulf menhaden *Brevortia patronus**	0.02	(0.01)	0.12	(0.09)	2.50	(1.32)	18.95	(10.46)	50.39	382
TOTAL CRUSTACEANS	1.58	(0.66)	15.32	(7.63)	0.93	(0.24)	5.80	(1.09)	58.20	499
Unidentified grass shrimp *Palaemonetes* spp.	1.58	(0.66)	15.24	(7.63)	0.54	(0.15)	0.05	(0.05)	50.04	470
grass shrimp *Palaemonetes intermedius*	0.00	(0.00)	0.00	(0.00)	0.02	(0.02)	4.45	(0.97)	0.28	1
Blue crab *Callinectes sapidus**	0.01	(0.01)	0.08	(0.06)	0.40	(0.25)	1.30	(0.34)	7.88	28

Table A-4. Untransformed data means and standard error (S.E.) of biomass and density of fish and crustaceans sampled in October 1996.

	October 1996									
	Project Area n = 25				Reference Area n = 25					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
TOTAL FISHES	1.83	(0.62)	6.60	(2.32)	0.60	(0.21)	1.84	(0.73)	117.30	313
Inland silverside *Menidia beryllina*	1.68	(0.61)	5.2	(2.07)	0.12	(0.08)	0.20	(0.12)	36.54	135
Sheepshead minnow *Cyprinodon variegatus*	0.40	(0.25)	0.52	(0.30)	0.00	(0.00)	0.00	(0.00)	8.07	13
Western mosquitofish *Gambusia affinis*	0.07	(0.04)	0.36	(0.22)	0.11	(0.08)	0.96	(0.58)	4.10	33
Sailfin molly *Poecilia latipinna*	0.04	(0.03)	0.16	(0.13)	0.05	(0.05)	0.12	(0.12)	2.17	7
Unidentified goby	0.03	(0.03)	0.20	(0.16)	0.02	(0.01)	0.12	(0.09)	1.02	8
Bayou killifish *Fundulus pulvereus*	0.00	(0.00)	0.00	(0.00)	0.11	(0.11)	0.04	(0.04)	2.70	1
Pipefish *Sygnanthus* spp.	0.00	(0.00)	0.00	(0.00)	0.02	(0.02)	0.04	(0.04)	0.46	1
Unidentified fish	0.01	(0.01)	0.08	(0.06)	0.01	(0.01)	0.08	(0.06)	0.48	4
TOTAL CRUSTACEANS	2.59	(0.77)	5.40	(2.82)	3.76	(0.79)	6.56	(1.35)	158.15	299
White shrimp *Peneaus setiferus**	1.40	(0.66)	0.60	(0.21)	0.87	(0.43)	0.56	(0.27)	49.91	29
Unidentified grass shrimp *Palaemonetes* spp.	1.21	(0.58)	4.72	(2.68)	2.86	(0.52)	5.92	(1.20)	95.60	266
Blue crab *Callinectes sapidus**	0.01	(0.01)	0.08	(0.06)	0.02	(0.02)	0.08	(0.06)	0.88	4

Table A-5. Untransformed data means and standard error (S.E.) of biomass and density of fish and crustaceans sampled in March 1997.

	March 1997									
	Project Area n = 30				Reference Area n = 30					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
TOTAL FISHES	2.5	(1.13)	6.2	(2.79)	1.9	(0.89)	11.9	(7.18)	110.0	453
Gulf menhaden *Brevortia patronus**	0.8	(0.71)	2.6	(2.28)	1.0	(0.51)	10.1	(6.11)	44.3	318
Inland silverside *Menidia beryllina*	1.4	(0.68)	1.9	(0.87)	0.2	(0.12)	0.2	(0.12)	39.9	53
Spot *Leiostomus xanthurus* *	0.0	(0.01)	0.0	(0.04)	0.3	(0.35)	1.1	(1.08)	8.9	28
Sheepshead minnow *Cyprinodon variegatus*	0.2	(0.09)	1.5	(1.17)	0.1	(0.05)	0.0	(0.04)	5.5	38
Atlantic croaker *Micropogonias undulatus* *	0.0	(0.00)	0.0	(0.00)	0.2	(0.08)	0.3	(0.11)	4.8	7
Naked goby *Gobiosoma bosc*	0.1	(0.14)	0.1	(0.08)	0.0	(0.01)	0.0	(0.04)	3.9	3
Bay anchovy *Anchoa mitchilli**	0.1	(0.06)	0.1	(0.08)	0.0	(0.01)	0.0	(0.04)	1.9	3
Western mosquitofish *Gambusia affinis*	0.0	(0.02)	0.0	(0.04)	0.0	(0.00)	0.0	(0.00)	0.5	1
Code goby *Gobiosoma robustum*	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.04)	0.4	1
Rainwater killifish *Lucania parva*	0.0	(0.00)	0.0	(0.04)	0.0	(0.00)	0.0	(0.00)	0.1	1
TOTAL CRUSTACEANS	2.5	(1.27)	8.3	(4.28)	1.7	(0.59)	5.2	(1.40)	104.5	337
Blue crab *Callinectes sapidus**	1.3	(1.12)	0.5	(0.17)	1.0	(0.47)	1.0	(0.24)	57.7	38
Brackish grass shrimp *Palaemonetes intermedius*	0.6	(0.40)	3.6	(2.49)	0.3	(0.14)	1.7	(0.79)	22.3	134
Daggerblade grass shrimp *Palaemonetes pugio*	0.4	(0.20)	3.8	(1.86)	0.4	(0.10)	2.4	(0.70)	20.2	154
Marsh grass shrimp *Palaemonetes vulgaris*	0.1	(0.08)	0.4	(0.21)	0.0	(0.00)	0.0	(0.00)	2.9	9
Harris mud crab *Rhithropanopeus harrisi*	0.0	(0.00)	0.0	(0.00)	0.1	(0.06)	0.0	(0.04)	1.4	1
Brown shrimp *Penaeus aztecus**	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.04)	0.0	1

Table A-6. Untransformed data means and standard error (S.E.) of biomass and density of fish and crustaceans sampled in April 1997.

	April 1997									
	Project Area n = 30				Reference Area n = 30					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
TOTAL FISHES	1.3	(0.46)	3.5	(1.41)	2.0	(0.71)	4.1	(1.86)	99.9	229
Atlantic croaker *Micropogonias undulatus* *	0.2	(0.17)	0.0	(0.03)	1.0	(0.53)	0.3	(0.13)	35.2	10
Inland silverside *Menidia beryllina*	0.6	(0.42)	1.2	(0.67)	0.2	(0.17)	0.2	(0.08)	26.0	40
Gulf menhaden *Brevortia patronus**	0.2	(0.15)	0.3	(0.17)	0.3	(0.20)	2.7	(1.79)	16.0	89
Sheepshead minnow *Cyprinodon variegatus*	0.1	(0.05)	1.5	(1.04)	0.1	(0.09)	0.1	(0.06)	7.1	48
Gulf killifish *Fundulus grandis*	0.0	(0.00)	0.0	(0.00)	0.1	(0.11)	0.0	(0.03)	3.3	1
Western mosquitofish *Gambusia affinis*	0.1	(0.09)	0.5	(0.47)	0.0	(0.00)	0.0	(0.00)	3.0	15
White mullet *Mugil cerema**	0.1	(0.08)	0.0	(0.03)	0.0	(0.00)	0.0	(0.00)	2.3	1
Bay anchovy *Anchoa mitchilli**	0.0	(0.00)	0.0	(0.00)	0.1	(0.04)	0.2	(0.10)	2.1	7
Clown goby *Microgobius gulosus*	0.0	(0.00)	0.0	(0.00)	0.1	(0.06)	0.1	(0.05)	2.0	2
Southern flounder *Paralicthys lethostigma**	0.0	(0.00)	0.0	(0.00)	0.0	(0.04)	0.0	(0.03)	1.2	1
Diamond killifish *Adinia xenica*	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.03)	0.6	1
Bay whiff *Citharicthys spilopterus**	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.1	(0.06)	0.5	1
Ladyfish *Elops saurus* *	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.0	(0.03)	0.3	2
Darter goby *Gobionellus boleosoma*	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.1	(0.07)	0.2	2
Speckled worm eel *Myrophis punctatus**	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.0	(0.03)	0.2	2
Rainwater killifish *Lucania parva*	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	2
Skilletfish *Gobiesox strumosus*	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	1
Unidentified goby Family Gobiidae	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.0	1

Table A-6 (continued)

	April 1997									
	Project Area n = 30				Reference Area n = 30					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
TOTAL CRUSTACEANS	13.4	(6.01)	3.3	(1.84)	7.3	(3.33)	11.6	(3.49)	620.7	445
Blue crab *Callinectes sapidus* *	12.8	(6.02)	0.6	(0.15)	4.7	(3.26)	1.7	(0.38)	526.4	68
Brown shrimp *Penaeus aztecus**	0.0	(0.02)	0.1	(0.05)	1.3	(0.35)	5.6	(1.55)	41.1	169
Daggerblade grass shrimp *Palaemonetes pugio*	0.1	(0.08)	0.7	(0.60)	1.0	(0.42)	2.9	(1.21)	32.2	109
Brackish grass shrimp *Palaemonetes intermedius*	0.4	(0.31)	1.9	(1.28)	0.3	(0.15)	1.3	(0.73)	20.2	97
Harris mud crab *Rhithropanopeus harrisii*	0.0	(0.00)	0.0	(0.00)	0.0	(0.02)	0.0	(0.03)	0.6	1
Marsh grass shrimp *Palaemonetes vulgaris*	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.0	(0.03)	0.2	1

Table A-6. Untransformed data means and standard error (S.E.) of biomass and density of fish and crustaceans sampled in September 1997.

	September 1997									
	Project Area n = 30				Reference Area n = 30					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
TOTAL FISHES	18.4	(4.48)	92.2	(25.41)	2.3	(0.83)	9.3	(3.27)	621.2	3044
Sailfin molly *Poecilia latipinna*	8.1	(2.80)	43.8	(15.04)	0.2	(0.23)	1.7	(1.70)	248.4	1364
Sheepshead minnow *Cyprinodon variegatus*	5.3	(1.25)	14.9	(2.66)	0.1	(0.09)	1..5	(1.13	162.6	492
Western mosquitofish *Gambusia affinis*	2.8	(1.11)	30.5	(10.28)	0.0	(0.00)	0.0	(0.00)	84.6	916
Gulf menhaden *Brevortia patronus**	1.6	(1.57)	0.4	(0.40)	0.5	(0.51)	0.1	(0.07)	62.4	14
Blackcheek tonguefish *Symphurus plagiusa**	0.0	(0.00)	0.0	(0.00)	0.5	(0.49)	0.0	(0.03)	14.8	1
Inland silverside *Menidia beryllina*	0.2	(0.06)	0.6	(0.23)	0.2	(0.13)	1.4	(0.88)	11.6	59
Bay anchovy *Anchoa mitchilli**	0.0	(0.00)	0.0	(0.00)	0.4	(0.25)	1.4	(0.95)	11.0	41
Rainwater killifish *Lucania parva*	0.3	(0.17)	1.3	(0.79)	0.0	(0.05)	0.2	(0.20)	9.8	46
Gulf killifish *Fundulus grandis*	0.2	(0.20)	0.3	(0.21)	0.0	(0.01)	0.2	(0.14)	7.0	15
Spotted seatrout *Cynoscion nebulosus**	0.0	(0.00)	0.0	(0.00)	0.2	(0.19)	0.1	(0.09)	5.7	4
Speckled worm eel *Myrophis punctatus**	0.0	(0.00)	0.0	(0.00)	0.0	(0.03)	0.0	(0.03)	0.9	1
Code goby *Gobiosoma robustum*	0.0	(0.02)	0.3	(0.18)	0.0	(0.00)	0.0	(0.03)	0.8	9
Naked goby *Gobiosoma bosc*	0.0	(0.00)	0.0	(0.03)	0.0	(0.01)	1.4	(0.66)	0.7	44
Saltmarsh topminnow *Fundulus jenkinsi*	0.0	(0.01)	0.1	(0.05)	0.0	(0.00)	0.0	(0.00)	0.4	2
Clown goby *Microgobius gulosus*	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.3	(0.19)	0.2	10
Unidentified goby	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.8	(0.35)	0.2	24
Darter goby *Gobionellus boleosoma*	0.0	(0.00)	0.0	(0.03)	0.0	(0.00)	0.0	(0.03)	0.1	1

Tabel A-6 (continued)

	September 1997									
	Project Area n = 30				Reference Area n = 30					
	Biomass		Density		Biomass		Density			
TAXA	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	TOTAL BIOMASS	TOTAL DENSITY
Green goby *Microgobius thalassinus*	0.0	(0.00)	0.0	(0.03)	0.0	(0.00)	0.0	(0.00)	0.0	1
TOTAL CRUSTACEANS	3.1	(0.90)	16.6	(5.63)	3.2	(1.26)	12.7	(4.02)	188.1	879
White shrimp *Peneaus setiferus**	1.1	(0.50)	0.8	(0.33)	2.0	(0.85)	7.0	(2.49)	90.9	233
Brackish grass shrimp *Palaemonetes intermedius*	1.1	(0.39)	8.4	(3.22)	0.3	(0.19)	2.1	(1.31)	42.0	316
Daggerblade grass shrimp *Palaemonetes pugio*	0.8	(0.38)	7.2	(2.82)	0.1	(0.05)	1.5	(0.61)	27.8	29.6
Brown shrimp *Penaeus aztecus**	0.0	(0.01)	0.0	(0.03)	0.5	(0.29)	0.6	(0.32)	14.7	20
Blue crab *Callinectes sapidus**	0.1	(0.06)	0.1	(0.07)	0.3	(0.17)	1.1	(0.38)	12.2	35
Harris mud crab *Rhithropanopeus harrisi*	0.0	(0.00)	0.0	(0.00)	0.0	(0.01)	0.1	(0.07)	0.4	2
Unidentified grass shrimp *Palaemonetes* spp.	0.0	(0.00)	0.1	(0.07)	0.0	(0.00)	0.2	(0.14)	0.1	8
Unidentified penaeid*	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.1	(0.05)	0.1	2
Unidentified xanthid crab	0.0	(0.00)	0.0	(0.00)	0.0	(0.00)	0.1	(0.07)	0.0	2

Table A-7. Untransformed data means and standard error (S.E.) of environmental variables sampled from June 1995 to September 1997.

ENVIRONMENTAL VARIABLES

Sampling Period and Site	Salinity (ppt)		D. O. (ppm)		Temp (C)		Depth (cm)		Distance (m)		SAV(%)
	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean	S.E.	Mean
Jun 95 Project	7.91	(0.32)	7.52	(0.31)	32.15	(0.40)	30.48	(6.49)	8.90	(6.49)	8
Jun 95 Reference	6.73	(0.24)	7.34	(1.20)	30.29	(0.26)	33.29	(2.99)	17.80	(3.69)	7
Oct 95 Project	14.95	(0.62)	9.18	(0.42)	16.92	(0.34)	40.43	(3.49)	10.05	(2.32)	64
Oct 95 Reference	19.46	(0.59)	7.66	(0.45)	18.53	(0.47)	68.48	(3.54)	8.10	(2.09)	12
Apr 96 Project	8.50	(0.23)	11.49	(0.41)	21.05	(0.58)	14.61	(1.20)	14.65	(7.84)	0
Apr 96 Reference	15.39	(0.96)	10.91	(0.35)	19.71	(0.76)	20.06	(3.60)	4.66	(0.69)	0
Oct 96 Project	11.99	(0.38)	nd	nd	22.68	(0.48)	69.67	(8.05)	2.43	(0.23)	31
Oct 96Reference	nd	nd	nd	nd	nd	nd	nd	nd	1.15	(0.15)	26
Mar 97 Project	4.7	(0.11)	10.9	(0.37)	18.9	(0.19)	62.4	(4.30)	5.6	(1.89)	4
Mar 97 Reference	5.2	(0.30)	9.3	(0.63)	19.9	(0.31)	35.2	(2.87)	50.6	(16.54)	0
Apr 97 Project	4.6	(0.14)	8.8	(0.39	17.2	(0.43)	32.9	(1.13)	25.3	(4.91)	14
Apr 97 Reference	6.1	(0.20)	7.9	(0.28)	17.3	(0.44)	35.0	(1.81)	8.5	(1.55)	0.7
Sept 97 Project	11.4	(0.72)	7.4	(0.76)	30.2	(0.58)	26.8	(1.65)	10.0	(1.99)	37
Sept 97 Reference	19.0	(0.39)	5.5	(0.29)	29.7	(0.35)	43.4	(2.29)	8.8	(2.64)	7

Table A-8. Mean densities, number per m^2, (with standard errors, S.E.) of animals collected in marsh ponds within project and reference areas at East Mud Lake sampled in April 2001. Each mean and standard error are estimated from 30 samples. The total number of animals collected is given for each taxon and major category (fishes and crustaceans). The relative abundance (RA) of taxa within each major category also is given when it is at least 1%. Results (P values) of t-tests comparing mean densities between areas are given for each taxon included in the analyses. Transient taxa identified with *.

	Project Area		Reference Area				
TAXA	MEAN	S. E.	MEAN	S. E.	Total	RA (%)	P
TOTAL FISHES	14.0	(2.70)	88.1	(32.06)	3063		0.0288
Gulf menhaden Brevoortia patronus *	5.4	(2.05)	85.6	(32.00)	2729	89.1%	0.0183
Sheepshead minnow Cyprinodon variegatus	4.5	(1.77)	0.0	(0.00)	135	4.4%	0.0167
Inland silverside Menidia beryllina	2.1	(1.01)	0.2	(0.12)	70	2.3%	0.0761
Bay whiff Citharichthys spilopterus *	0.0	(0.03)	0.7	(0.26)	22		
Striped mullet Mugil cephalus *	0.6	(0.29)	0.1	(0.08)	21		
Bay anchovy Anchoa mitchilli *	0.0	(0.00)	0.6	(0.31)	17		
Spot Leiostomus xanthurus *	0.4	(0.20)	0.1	(0.05)	14		
Pinfish Lagodon rhomboides	0.2	(0.11)	0.2	(0.14)	12		
Atlantic croaker Micropogonias undulatus *	0.0	(0.03)	0.3	(0.14)	11		
Alligator gar Lepisosteus spatula	0.3	(0.20)	0.0	(0.00)	8		
Rainwater killifish Lucania parva	0.1	(0.10)	0.0	(0.00)	4		
Speckled worm eel Myrophis punctatus *	0.0	(0.00)	0.1	(0.06)	4		
Unidentified Atherinidae	0.1	(0.10)	0.0	(0.00)	4		
Western mosquitofish Gambusia affinis	0.1	(0.10)	0.0	(0.00)	3		
Longnose killifish Fundulus similis	0.1	(0.07)	0.0	(0.00)	2		
Unidentified fish	0.0	(0.00)	0.1	(0.05)	2		
Sailfin molly Poecilia latipinna	0.0	(0.03)	0.0	(0.00)	1		
Sand seatrout Cynoscion arenarius *	0.0	(0.00)	0.0	(0.03)	1		
Highfin goby Gobionellus oceanicus	0.0	(0.00)	0.0	(0.03)	1		
Southern flounder Paralichthys lethostigma *	0.0	(0.03)	0.0	(0.00)	1		
Clown goby Microgobius gulosus	0.0	(0.03)	0.0	(0.00)	1		
TOTAL CRUSTACEANS	11.7	(4.10)	6.9	(1.24)	558		0.2708
Brackish grass shrimp Palaemonetes intermedius	9.3	(3.69)	0.0	(0.00)	279	50.0%	0.0175

Table A-8 (continued)

Brown shrimp Farfantepenaeus aztecus *	0.9	(0.33)	4.0	(0.67)	145	26.0%	0.0001
Daggerblade grass shrimp Palaemonetes pugio	0.1	(0.07)	1.5	(0.71)	47	8.4%	0.0654
Blue crab Callinectes sapidus *	0.2	(0.07)	1.2	(0.30)	42	7.5%	0.0016
Unidentified grass shrimp Palamonetes spp.	1.2	(0.57)	0.1	(0.10)	40	7.2%	
Lesser blue crab Callinectes similus *	0.0	(0.00)	0.1	(0.10)	3		
Marsh grass shrimp Palaemonetes vulgaris	0.1	(0.05)	0.0	(0.00)	2		
NUMBER OF TAXA	3.7	(0.26)	4.0	(0.26)			0.3623
RESIDENT SPECIES	2.3	(0.23)	0.63	(0.13)			0.0001
TRANSIENT SPECIES	1.4	(0.24)	3.37	(0.22)			0.0001

Table A-9. Mean biomass, g wet weight per m^2, (with standard errors, S.E.) of animals collected in marsh ponds within project and reference areas at East Mud Lake sampled in April 2001. Each mean and standard error are estimated from 30 samples. The total biomass of animals collected is given for each taxon and major category (fishes and crustaceans). The relative biomass (RB) of taxa within each major category also is given when it is at least 1%. Results (P values) of t-tests comparing mean biomasses between areas are given for each taxon included in the analyses. Transient taxa identified with *.

	Project Area		Reference Area				
TAXA	MEAN	S. E.	MEAN	S. E.	Total	RB (%)	P
TOTAL FISHES	9.5	(2.48)	23.3	(10.10)	985.1		0.1944
Gulf menhaden Brevoortia patronus *	3.6	(1.86)	21.7	(10.09)	756.7	76.8	0.0878
Spot Leiostomus xanthurus *	2.0	(1.23)	0.2	(0.16)	64.7	6.6	0.1572
Sheepshead minnow Cyprinodon variegatus	1.7	(0.80)	0.0	(0.00)	50.0	5.1	0.0448
Inland silverside Menidia beryllina	0.8	(0.40)	0.3	(0.22)	33.4	3.4	0.2679
Atlantic croaker Micropogonias undulatus *	0.3	(0.27)	0.7	(0.28)	28.0	2.8	
Striped mullet Mugil cephalus *	0.9	(0.50)	0.0	(0.02)	26.2	2.7	
Pinfish Lagodon rhomboides	0.2	(0.10)	0.1	(0.10)	10.2	1.0	
Bay whiff Citharichthys spilopterus *	0.0	(0.03)	0.2	(0.06)	6.2		
Bay anchovy Anchoa mitchilli *	0.0	(0.00)	0.1	(0.09)	4.2		
Southern flounder Paralichthys lethostigma *	0.0	(0.05)	0.0	(0.00)	1.4		
Clown goby Microgobius gulosus	0.0	(0.04)	0.0	(0.00)	1.1		
Longnose killifish Fundulus similis	0.0	(0.02)	0.0	(0.00)	0.7		
Sand seatrout Cynoscion arenarius *	0.0	(0.00)	0.0	(0.02)	0.5		
Sailfin molly Poecilia latipinna	0.0	(0.02)	0.0	(0.00)	0.4		
Rainwater killifish Lucania parva	0.0	(0.01)	0.0	(0.00)	0.4		
Speckled worm eel Myrophis punctatus *	0.0	(0.00)	0.0	(0.01)	0.4		
Alligator gar Lepisosteus spatula	0.0	(0.01)	0.0	(0.00)	0.3		
Western mosquitofish Gambusia affinis	0.0	(0.01)	0.0	(0.00)	0.3		
Highfin goby Gobionellus oceanicus	0.0	(0.00)	0.0	(0.00)	0.0		
Unidentified Atherinidae	0.0	(0.00)	0.0	(0.00)	0.0		
Unidentified fish	0.0	(0.00)	0.0	(0.00)	0.0		
TOTAL CRUSTACEANS	2.1	(0.42)	3.9	(1.24)	181.6		0.1879
Brown shrimp Farfantepenaeus aztecus *	0.6	(0.21)	1.9	(0.40)	74.5	41.0	0.0102

Table A-9 (continued)

Blue crab Callinectes sapidus *	0.5	(0.28)	1.7	(0.87)	65.6	36.2	0.2217
Brackish grass shrimp Palaemonetes intermedius	0.9	(0.30)	0.0	(0.00)	27.5	15.1	0.0050
Daggerblade grass shrimp Palaemonetes pugio	0.0	(0.01)	0.3	(0.18)	10.2	5.6	0.0877
Unidentified grass shrimp Palamonetes sp.	0.0	(0.01)	0.0	(0.05)	2.4	1.3	
Marsh grass shrimp Palaemonetes vulgaris	0.0	(0.02)	0.0	(0.00)	0.9		
Lesser blue crab Callinectes similus *	0.0	(0.00)	0.0	(0.02)	0.4		
Total Resident Taxa	3.8	(0.92)	0.8	(0.34)	137.8		0.0046
Total Transient Taxa	7.9	(2.56)	26.4	(10.29)	1028.8		0.0904

Table A-10. Environmental characteristics of sample sites at East Mud Lake. Mean and (one standard error, S.E.) are given for variables measured in marsh ponds at project and reference areas sampled in April 2001. Each mean and standard error are estimated from 30 samples (except Oxygen in Reference Area=23). P values are given for the t-tests examining differences in variables between project and reference areas.

	Project Area		Reference Area		
VARIABLE	MEAN	S. E.	MEAN	S. E.	P
SALINITY (‰)	9.1	(0.40)	10.0	(0.18)	0.0311
OXYGEN (ppm)	7.7	(0.37)	6.1	(0.23)	0.0009
WATER TEMPERATURE (^{o}C)	17.7	(0.51)	17.1	(0.51)	0.4604
WATER DEPTH (cm)	31.8	(1.09)	31.8	(2.34)	0.9795
TURBIDITY (FTU)	10.7	(1.95)	22.5	(2.88)	0.0013
DISTANCE TO EDGE (m)	13.5	(2.37)	13.9	(3.04)	0.9197
VEGETATION COVER (%)	31.9	(7.61)	0.8	(0.83)	0.0003

Table A-11. Mean densities, number per m^2, (with standard errors, S.E.) of animals collected in marsh ponds within project and reference areas at East Mud Lake sampled in November 2001. Each mean and standard error are estimated from 30 samples. The total number of animals collected is given for each taxon and major category (fishes and crustaceans). The relative abundance (RA) of taxa within each major category also is given when it is at least 1%. Results (P values) of t-tests comparing mean densities between areas are given for each taxon included in the analyses. Transient taxa identified with *.

	Project Area		Reference Area				
TAXA	MEAN	S. E.	MEAN	S. E.	Total	RA (%)	P
TOTAL FISHES	6.9	(2.02)	4.0	(1.59)	328		0.2691
Inland silverside Menidia beryllina	2.3	(0.68)	1.6	(1.24)	119	36.3%	0.6228
Sheepshead minnow Cyprinodon variegatus	1.3	(0.82)	0.4	(0.30)	52	15.9%	0.3289
Western mosquitofish Gambusia affinis	1.4	(0.82)	0.0	(0.03)	43	13.1%	
Sailfin molly Poecilia latipinna	1.1	(0.93)	0.1	(0.07)	36	11.0%	
Naked goby Gobiosoma bosc	0.2	(0.10)	0.3	(0.19)	17	5.2%	
Clown goby Microgobius gulosus	0.3	(0.14)	0.1	(0.05)	11	3.4%	
Bay anchovy Anchoa mitchilli *	0.0	(0.00)	0.3	(0.12)	9	2.7%	
Atlantic croaker Micropogonias undulatus *	0.0	(0.00)	0.3	(0.24)	8	2.4%	
Code goby Gobiosoma robustum	0.0	(0.03)	0.2	(0.11)	6	1.8%	
Rainwater killifish Lucania parva	0.0	(0.00)	0.2	(0.12)	5	1.5%	
Gulf killifish Fundulus grandis	0.0	(0.03)	0.1	(0.07)	4	1.2%	
Darter goby Gobionellus boleosoma	0.0	(0.00)	0.1	(0.08)	4	1.2%	
Speckled worm eel Myrophis punctatus *	0.0	(0.00)	0.1	(0.06)	3		
Red drum Sciaenops ocellatus *	0.0	(0.00)	0.1	(0.05)	2		
Bayou killifish Fundulus pulvereus	0.1	(0.05)	0.0	(0.00)	2		
Gulf kingfish Menticirrhus littoralis *	0.0	(0.00)	0.0	(0.03)	1		
Spot Leiostomus xanthurus *	0.0	(0.00)	0.0	(0.03)	1		
Least killifish Heterandria formosa	0.0	(0.03)	0.0	(0.00)	1		
Spotted seatrout Cynoscion nebulosus *	0.0	(0.00)	0.0	(0.03)	1		
Southern flounder Paralichthys lethostigma *	0.0	(0.00)	0.0	(0.03)	1		
Unidentified goby	0.0	(0.03)	0.0	(0.00)	1		

Table A-11 (continued)

Unidentified fish	0.0	(0.00)	0.0	(0.03)	1		
TOTAL CRUSTACEANS	67.0	(49.81)	11.7	(5.37)	2361		0.2790
Daggerblade grass shrimp Palaemonetes pugio	39.1	(34.96)	1.1	(0.74)	1206	51.1%	0.2852
Unidentified grass shrimp Palamonetes spp.	19.6	(14.87)	1.8	(1.44)	642	27.2%	
Brackish grass shrimp Palaemonetes intermedius	8.2	(2.97)	3.8	(3.05)	359	15.2%	0.3087
White shrimp Litopenaeus setiferus *	0.0	(0.03)	2.0	(0.45)	61	2.6%	0.0001
Blue crab Callinectes sapidus *	0.0	(0.03)	1.9	(0.70)	57	2.4%	0.0139
Brown shrimp Farfantepenaeus aztecus *	0.0	(0.00)	0.6	(0.26)	18		
Pink shrimp Farfantepenaeus duorarum *	0.0	(0.00)	0.6	(0.53)	17		
Unidentified river shrimp Macrobrachium spp.	0.0	(0.00)	0.0	(0.03)	1		
NUMBER OF TAXA	2.8	(0.28)	3.5	(0.41)			0.1662
RESIDENT SPECIES	73.8	(51.47)	9.8	(6.71)	2509		0.2274
TRANSIENT SPECIES	0.1	(0.05)	5.9	(1.40)	179		0.0003

Table A-12. Mean biomass, g wet weight per m^2, (with standard errors, S.E.) of animals collected in marsh ponds within project and reference areas at East Mud Lake sampled in November 2001. Each mean and standard error are estimated from 30 samples. The total biomass of animals collected is given for each taxon and major category (fishes and crustaceans). The relative biomass (RB) of taxa within each major category also is given when it is at least 1%. Results (P values) of t-tests comparing mean biomasses between areas are given for each taxon included in the analyses. Transient taxa identified with *.

	Project Area		Reference Area				
TAXA	MEAN	S. E.	MEAN	S. E.	Total	RB (%)	P
TOTAL FISHES	1.2	(0.41)	3.1	(1.73)	127.79		0.3038
Southern flounder Paralichthys lethostigma *	0.0	(0.00)	1.6	(1.61)	48.25	37.8%	
Inland silverside Menidia beryllina	0.5	(0.21)	0.3	(0.21)	24.71	19.3%	0.5069
Spot Leiostomus xanthurus *	0.0	(0.00)	0.7	(0.66)	19.77	15.5%	0.3256
Sheepshead minnow Cyprinodon variegatus	0.2	(0.11)	0.0	(0.02)	7.37	5.8%	0.0970
Sailfin molly Poecilia latipinna	0.2	(0.19)	0.0	(0.02)	6.88	5.4%	
Gulf killifish Fundulus grandis	0.1	(0.06)	0.1	(0.06)	3.92	3.1%	
Western mosquitofish Gambusia affinis	0.1	(0.07)	0.0	(0.00)	3.46	2.7%	
Bay anchovy Anchoa mitchilli *	0.0	(0.00)	0.1	(0.05)	2.88	2.3%	
Clown goby Microgobius gulosus	0.1	(0.04)	0.0	(0.02)	2.81	2.2%	
Speckled worm eel Myrophis punctatus *	0.0	(0.00)	0.1	(0.05)	2.64	2.1%	
Naked goby Gobiosoma bosc	0.0	(0.00)	0.1	(0.04)	1.94	1.5%	
Rainwater killifish Lucania parva	0.0	(0.00)	0.0	(0.03)	1.19		
Atlantic croaker Micropogonias undulatus *	0.0	(0.00)	0.0	(0.01)	0.53		
Spotted seatrout Cynoscion nebulosus *	0.0	(0.00)	0.0	(0.01)	0.33		
Bayou killifish Fundulus pulvereus	0.0	(0.01)	0.0	(0.00)	0.26		
Code goby Gobiosoma robustum	0.0	(0.00)	0.0	(0.01)	0.24		
Gulf kingfish Menticirrhus littoralis *	0.0	(0.00)	0.0	(0.01)	0.22		
Red drum Sciaenops ocellatus *	0.0	(0.00)	0.0	(0.01)	0.20		
Darter goby Gobionellus boleosoma	0.0	(0.00)	0.0	(0.00)	0.14		
Unidentified fish	0.0	(0.00)	0.0	(0.00)	0.03		
Least killifish Heterandria formosa	0.0	(0.00)	0.0	(0.00)	0.02		

Table A-12 (continued)

Unidentified goby	0.0	(0.00)	0.0	(0.00)	0.00		
TOTAL CRUSTACEANS	3.9	(2.55)	2.8	(0.78)	200.72		0.6979
Daggerblade grass shrimp Palaemonetes pugio	2.0	(1.78)	0.1	(0.06)	62.34	31.1%	0.2903
White shrimp Litopenaeus setiferus *	0.1	(0.11)	1.8	(0.47)	58.42	29.1%	0.0011
Unidentified grass shrimp Palamonetes spp.	1.1	(0.77)	0.2	(0.15)	39.12	19.5%	
Brackish grass shrimp Palaemonetes intermedius	0.6	(0.25)	0.5	(0.39)	33.07	16.5%	0.6724
Brown shrimp Farfantepenaeus aztecus *	0.0	(0.00)	0.1	(0.08)	4.46	2.2%	
Blue crab Callinectes sapidus *	0.0	(0.00)	0.1	(0.04)	3.06	1.5%	
Pink shrimp Farfantepenaeus duorarum *	0.0	(0.00)	0.0	(0.01)	0.21		
Unidentified river shrimp Macrobrachium spp.	0.0	(0.00)	0.0	(0.00)	0.04		
RESIDENT SPECIES	5.0	(2.90)	1.3	(0.89)	187.51		0.2348
TRANSIENT SPECIES	0.1	(0.11)	4.6	(1.87)	140.97		0.0232

Table A-13. Environmental characteristics of sample sites at East Mud Lake. Mean and (one standard error, S.E.) are given for variables measured in marsh ponds at project and reference areas sampled in November 2001. Each mean and standard error are estimated from 30 samples. P values are given for the t-tests examining differences in variables between project and reference areas.

	Project Area		Reference Area		
VARIABLE	MEAN	S. E.	MEAN	S. E.	P
SALINITY (‰)	6.0	(0.27)	7.0	(0.48)	0.0761
OXYGEN (ppm)	5.5	(0.42)	5.6	(0.22)	0.8057
WATER TEMPERATURE (^{o}C)	22.3	(0.32)	22.6	(0.33)	0.5667
WATER DEPTH (cm)	43.5	(1.90)	43.4	(2.14)	0.9815
TURBIDITY (FTU)	38.7	(5.14)	19.5	(1.84)	0.0012
DISTANCE TO EDGE (m)	9.2	(1.82)	9.8	(2.50)	0.8570
VEGETATION COVER (%)	4.2	(3.41)	6.0	(3.73)	0.7178