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16. Abstract

The Louisiana Offshore Oil Port (LOOP) Environmental Monitoring Program includes an onshore pipeline vegetation and wildlife survey as a continuing study designed to measure the immediate and long-term impacts of LOOP-related pipeline construction and operation on surrounding wetland plant communities and associated waterfowl, wading-bird, fur bearing mammal, and alligator populations. In 1997, we sampled the vegetation biomass in the intermediate salinity zone of the LOOP pipeline. We then analyzed the intermediate vegetation biomass data collected from 1978 through 1997. We included controls to assess "baseline" change rates in the absence of the pipeline because any impacts of the LOOP pipeline occur within a rapidly changing wetland ecosystem. The controls were compared to areas adjacent to the pipeline to test for any pipeline effects. In the marshes surrounding the Clovelly salt dome we assessed plant species and cover to characterize the spatial patterns of vegetation occurrence. Because the frequency of waterfowl and wildlife censusing was reduced to once every three years, semi-annual pipeline corridor overflights by trained wetland biologists were conducted in the 1997 monitoring program.

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1997 Annual Report
Environmental Monitoring Program
Louisiana Offshore Oil Port Pipeline

by

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ABSTRACT

The Louisiana Offshore Oil Port (LOOP) Environmental Monitoring Program includes an onshore pipeline vegetation and wildlife survey as a continuing study designed to measure the immediate and long-term impacts of LOOP-related pipeline construction and operation on surrounding wetland plant communities and associated waterfowl, wading-bird, furbearing mammal, and alligator populations.

In 1997 we sampled the vegetation in the intermediate salinity zone of the LOOP pipeline. We then analyzed the intermediate vegetation biomass data collected from 1978 through 1997. We included controls to assess "baseline" change rates in the absence of the pipeline because any impacts of the LOOP pipeline occur within a rapidly changing wetland ecosystem. The controls were compared to areas adjacent to the pipeline to test for any pipeline effects. The comparison included primary indices of marsh disturbance: plant species composition, vigor of plant growth, and marsh condition (degradation to open water). In the marshes surrounding the Clovelly salt dome, we assessed plant species and cover to characterize the spatial patterns of vegetation occurrence. Because the frequency of waterfowl and wildlife censusing was reduced to once every three years, semi-annual pipeline corridor overflights by trained wetland biologists were conducted in 1997 monitoring program. We have also attempted, where possible, to assess the reasons for any changes in the baseline rates, in order to understand the processes contributing to wetland change and hence improve management practices.

ACKNOWLEDGMENTS

This study was funded by the Louisiana Offshore Oil Port, LLC, as part of their Environmental Monitoring Program. We thank those staff members and students at LSU who participated in various portions of this work, especially Rachel Teague, who assisted with data entry and verification.

EXECUTIVE SUMMARY

We sampled vegetation composition and biomass in control marshes and areas on and adjacent to the pipeline, because plant species composition, vigor of plant growth, and marsh condition (degradation to open water) are primary indices of marsh disturbance. Louisiana Offshore Oil Port (LOOP) must be able to respond with scientific and technical competence to any LOOP-related environmental problems that might arise in the Clovelly salt dome area. As a result we assessed cover values in this intermediate marsh to chararcterize the spatial patterns of vegetation occurrence. Because the frequency of waterfowl and wildlife censusing was reduced to once every three years, semi-annual pipeline corridor overflights by trained wetland biologists were added to the 1997 monitoring program.

Since any impacts of the LOOP pipeline occur within a rapidly changing wetland ecosystem, all our measurements included controls to assess "baseline" change rates in the absence of the pipeline. We have also attempted, where possible, to assess the reasons for any changes in the baseline rates, in order to understand the processes contributing to wetland change and hence improve management practices. This executive summary highlights the results of the vegetation surveys during 1997 and emphasizes findings that have particular significance for LOOP.

Vegetation

In 1997, we sampled and analyzed the vegetation biomass collected from 1978 through 1997 from the intermediate portion of the pipeline. Variability, both in space and time, is generally great. This means that any pipeline impacts would have to be rather severe to be statistically significant. The major source of variation in the statistical analysis of plant biomass was year-to-year fluctuation. Differences between pipeline and control transects are significant in the intermediate-*Sagittaria* marsh and intermediate-*Spartina* marsh.

In the intermediate-*Sagittaria* marsh, the differences are due to a change in species composition at the control site that did not occur in the experimental site, as noted earlier (1994 Annual Report). In 1995, the control site reverted to a species composition more similar to that found at the pipeline, and biomass from both the experimental and control sites tracked each other through 1997. In the intermediate-*Spartina* the significant results in the period 1990–93 seem to be due to a difference in muskrat grazing among sites during the peak of the muskrat population.

Conclusions

The Louisiana state legislature created the Louisiana Offshore Terminal Authority (LOTA) to regulate anticipated offshore ports. The enacting legislation requires a comprehensive environmental monitoring program, and part of LOTA's mission is to ensure the integrity of environments affected by large projects such as LOOP.

The planners of the LOOP facility recognized that the pipeline and oil-storage facility would cause environmental changes along the pipeline. The scar of the pipeline, effects of related construction activity (for example, dredged material deposits, marsh buggy tracks), and hydrologic changes associated with the pipeline were the anticipated primary impacts. A stringent effort was made to minimize these impacts by backfilling the canal and plugging all crossings of the pipeline with other waterways.

In general, this strategy has been successful. Although most of the LOOP pipeline has not revegetated, it has become a shallow water body that is an attractive waterfowl habitat. Through continuous maintenance of the plugs, hydrologic modification has apparently been minimized. Although quantitative hydrodynamic data supporting this statement have not been collected, the shallow depth of the pipeline canal and the relative stability of its banks suggest that the canal has not captured major flows.

It is more difficult to assess possible subtle long-term and indirect effects of the pipeline canal, for example, on saltwater intrusion and basin-level marsh degradation. Independent research studies implicate dredged canals in the acceleration of regional wetland loss. The LOOP canal system has not measurably accelerated this degradation process, which is a regional phenomenon with multiple interacting causes. On the other hand, the impact of individual canals (except for the major navigation channels) is generally not measurable; only in the aggregate is the cumulative impact seen as a serious, measurable change in the rate of natural processes. The LOOP construction project was designed to minimize these indirect effects, and as far as can presently be determined, the design has been successful. LOOP and LOTA have combined to bring a much higher level of environmental awareness, concern, and stewardship to Louisiana's coastal wetlands than has been experienced with other human activities in the Louisiana coastal zone.

Barataria Basin is changing rapidly, in part as a result of cumulative impacts of many human activities. This change makes the LOOP pipeline and storage facility increasingly vulnerable, and the interaction of natural processes with LOOP construction elevate the environmental risks to the basin. As we have noted in previous reports, we call attention to three areas of continued concern:

1. Marshes in some parts of the Clovelly area have degraded rapidly since 1969. Some marshes in this area have degraded more than others. In general, the more degraded marshes are in the southern region of the Clovelly area, while the most stable marshes are north of the Clovelly salt dome. Geographically, the LOOP storage facility is in the center of the area of most rapid marsh loss in the whole basin. We have not been able to pinpoint the causes of marsh loss; they are probably multiple and include a rapid subsidence rate, high levels of oil and gas extraction, and canals that isolate marsh and permit salt intrusion. All these factors act on a vulnerable organic marsh substrate. The degradation of the marsh makes the LOOP storage facility increasingly vulnerable to coastal storms. Any construction activities in wetlands, especially of canals and spoil banks, no matter how carefully engineered, most likely contribute cumulatively to wetland degradation. LOOP's activities cannot be separated from the multiplicity of other impacts. Both for LOOP and for the future of the state's coastal wetlands, maintaining an active research effort to understand this complex process is important. Highest priority should be given to understanding the hydrology of this region—both as it relates to the condition of marsh habitat and to our ability to anticipate the spread of oil in these inland waters in the event of an onshore oil

spill. Regardless, it is important that LOOP maintain its vigilance to prevent further environmental degradation.

2. We believe that the pipeline crossing at the beach is an environmentally vulnerable part of LOOP's onshore operation. Even though the semi-annual overflights in 1997 showed that much of the beach is vegetated at this time, the beach has been eroding at a retreat rate that in a relatively short time will allow the shoreline at the pipeline crossing to reach Bayou Moreau. As the beach retreats, the Gulf shoreface deepens, potentially exposing the pipeline. The beach is currently vulnerable to breaching into the open portion of the LOOP canal behind Bayou Moreau. If this occurs, more active intrusion of Gulf waters will follow. The erosion of the beach is a regional process but one with which LOOP will have to contend. We suggest filling the LOOP canal between the beach and Bayou Moreau and continuing with the vegetative planting and sediment fencing to establish a stable salt marsh. This will not prevent beach-front erosion, but it should improve the stability of the beach so that breaching through the pipeline corridor is less likely to occur.

3. The floating marshes along the pipeline right-of-way in the Lake Boeuf and Clovelly areas are a third area of concern. Our present state of knowledge is simply inadequate to fully understand the ecological processes controlling this unique marsh type. This is becoming increasingly clear all over the coast as more and more attempts are made to arrest the degradation of floating marshes. The data gap leaves us with a poor basis for managing floating marshes. A continued high level of monitoring and basic research in the floating marshes along the pipeline is appropriate.

As reported in the 1995 Annual Report to LOOP, Inc., in addition to the three areas of concern, our observations during 1994 and 1995 indicated new degradation of the marsh vegetation at the salt marsh site (SB) north of Lake Jesse (Visser et al. 1996). The *Spartina alterniflora*-dominated vegetation community at this site has until recently remained in good shape as compared to the surrounding region of the coast that has undergone severe degradation. This apparent change in marsh vegetation condition will be investigated further in the mapping component of the monitoring program to determine whether it is part of a general trend of degradation in the area or is related to its position adjacent to the LOOP pipeline.

INTRODUCTION

Louisiana Offshore Oil Port

The Louisiana Offshore Oil Port (LOOP) facilities in coastal Louisiana provide the United States with the country's only Superport for off-loading deep draft tankers. The facilities are located south of New Orleans in Lafourche Parish in southeast Louisiana and in adjacent offshore waters west of the Mississippi River Delta. The development is operated by LOOP LLC., a private corporation jointly owned by Shell Oil Company, Texaco Inc., Ashland Inc., Murphy Oil Corporation, and Marathon Pipeline Company.

LOOP INC. (later restructured as LOOP LLC.) was organized in 1972 as a consortium of companies to design, construct and operate a deepwater port on the Louisiana coast. Pre-permit baseline studies related to the proposed development were conducted from 1972 to 1975. Major documents related to these studies are listed in table 1. State and federal licenses to own and operate a deepwater port were issued in January 1977; they were accepted on 1 August 1977. The state license was issued to LOOP pursuant to the Louisiana Offshore Terminal Act (LA R.S. 34:3101 et seq.). A federal *License to Own, Construct and Operate a Deepwater Port* was issued to LOOP by the U.S. Department of Transportation (USDOT) pursuant to the federal Deepwater Ports Act (33 U.S.C. 1501, et seq.). The first oil tanker was offloaded on 5 May 1981.

Facility description

The Superport complex consists of an offshore marine terminal located approximately 30 km from the mainland in the Gulf of Mexico, an onshore storage facility at the Clovelly salt dome near Galliano approximately 50 km inland from the coast, and a large diameter pipeline system including a pumping booster station onshore near Fourchon to deliver oil to the storage facility (figure 1). The pipeline system also connects the Clovelly Dome Storage Facility to transportation facilities on the Mississippi River. A large brine storage reservoir (101 ha) is positioned near the Clovelly Dome Storage Facility. A small-boat harbor and logistics facility is located at Port Fourchon.

Table 1. List of reports produced for Superport planning (after Sasser et al. 1982).

Year	Title	Comment
1972	LOOP feasibility study	LOOP's Engineering Feasibility Study
1972	A Superport for Louisiana	Superport Task Force Report
1972	LSU Superport Study #1	Requested by Superport Task Force
1972	LSU Superport Study #2	Requested by National Sea Grant Program
1973	LSU Superport Study #3	Requested by LOTA to formulate EPP
1973	LSU Superport Study #4	Requested by LOTA to formulate EPP
1974	Alternate Site Location Evaluation	Prepared by Dames and Moore for LOOP, Inc.
1976	Environmental Baseline Studies Vols. 1–4	Prepared by LSU for LOOP, Inc.
1976	Environmental Impact Study	US Department of Transportation

The marine terminal consists of three Single Point Mooring (SPM) structures connected by pipelines to a platform-mounted pumping station in the Gulf of Mexico, 30 km southeast of Belle Pass, Louisiana. Water depth at the platform is 36 m. From the offshore marine terminal facility, crude oil is pumped northward through a large diameter (56 inch) buried pipeline, through the onshore booster station at Fourchon, to the Clovelly Dome Storage Facility near Galliano. The crude oil is stored in caverns constructed in subterranean salt domes. These storage chambers were formed by solution mining utilizing local surface water in the area. A second pipeline extends southward parallel to the oil pipeline and carries brine leached from the Clovelly Dome Storage Facility to the diffuser disposal site located in open Gulf of Mexico waters approximately 4.8 km offshore and adjacent to the LOOP oil pipeline. Additional distributary pipelines move oil from the Clovelly complex to outlying pipelines and refining centers.

Project area

The Barataria estuary and the offshore area where LOOP is located comprise an extremely diverse and complex natural system. Located in the Mississippi River Deltaic Plain, this region was formed and is continually influenced by processes associated with the deposition of massive amounts of sediments carried by the Mississippi River. The LOOP pipeline traverses the major wetland habitats in the

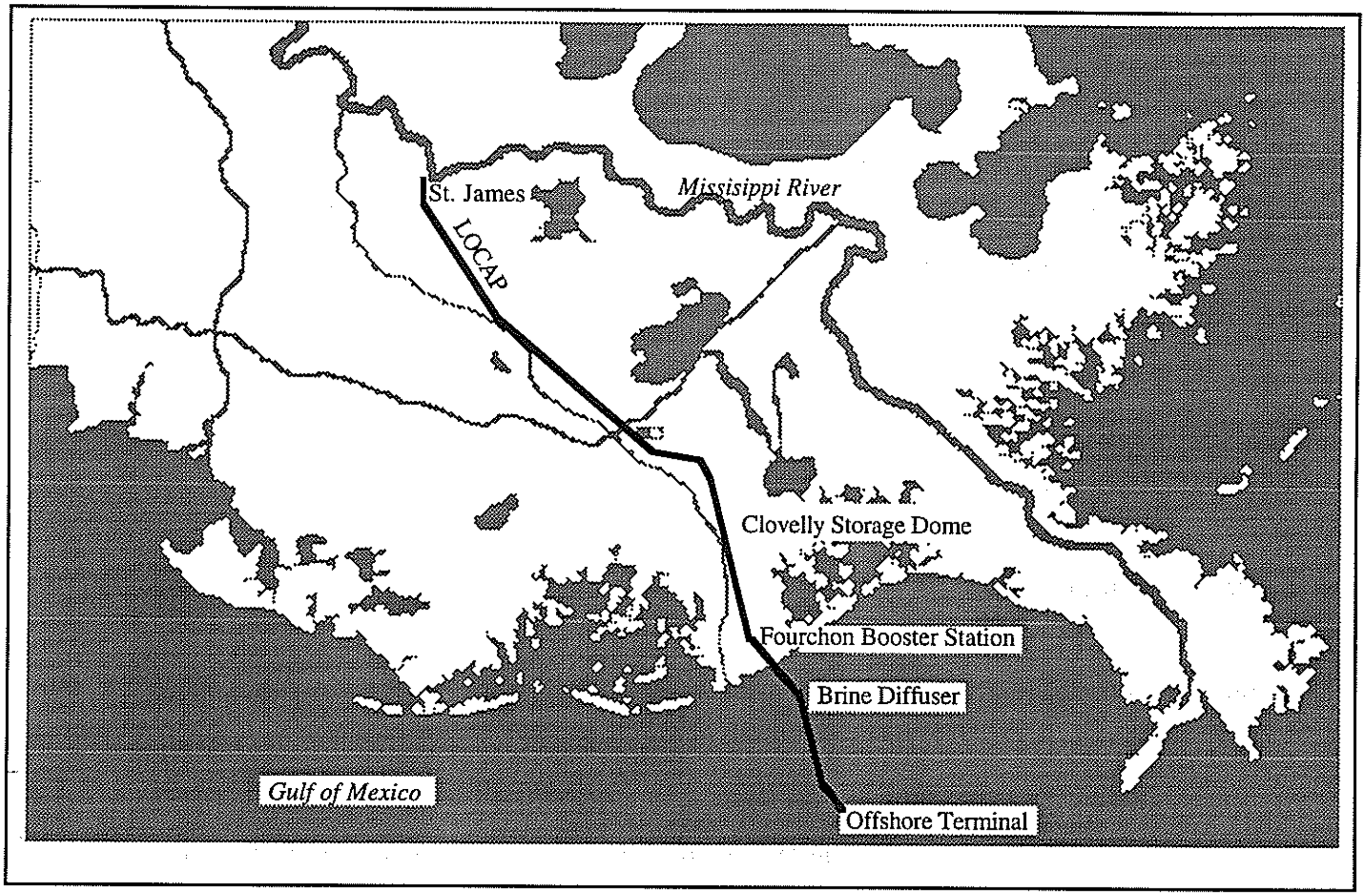

Figure 1. Location of the major components of LOOP operations. The pipeline north of the Clovelly storage dome is operated by LOCAP.

Louisiana coastal area. The 159 km pipeline crosses the near-offshore Gulf of Mexico and traverses all major wetland habitats (as defined by Chabreck 1972) in the Louisiana coastal area. The route extends from the Gulf of Mexico near Fourchon through beach/barrier headland, estuary, and bottomland hardwood and bald-cypress/water-tupelo swamp forests. Within the estuary, four salinity zones—saline, brackish, intermediate, and fresh—are traversed, each providing a unique habitat supporting a variety of species. The pipeline has two segments: south of the Clovelly salt dome oil storage facility, the pipeline is referred to as the LOOP pipeline; north of the storage facility, the pipeline is called the LOCAP pipeline. The pipeline terminates at St. James, where it connects to CAPLINE, a pipeline distributing crude oil to midwestern states.

The coastal marshes of Louisiana are among the most productive ecosystems in the world, supporting a wide variety of estuarine-dependent organisms. Louisiana leads fishery production within the northern Gulf of Mexico and is second only to Alaska among all states (NMFS 1997). Louisiana is the leader in the United States for the production of shrimp, blue crab, oyster, crawfish, tuna, red snapper, wild catfish, black drum, sea trout, and mullet (McKenzie et al. 1995). Ninety-five percent of the Louisiana fish and shellfish landings are estuarine-dependent species (McKenzie et al. 1995). The fish community of Barataria estuary is the most diverse of any estuary in Louisiana including 191 species from 68 families (Condrey et al. 1995).

Monitoring program

In recognition of the potential for significant environmental impacts much attention was given to environmental safeguards by state and federal agencies and by the Superport developers (see review by Sasser et al. 1982). Because of the potential risks associated with the construction and operation of the Superport (e.g. bringing the world's largest oil tankers to one of the most productive fisheries resources in the world), both state and federal licenses required environmental monitoring of LOOP construction and operational activities. The environmental monitoring program (EMP) was developed under mandate of the Superport Environmental Protection Plan (revised 1977), a regulation of the State of Louisiana implementing the Offshore Terminal Act. Ecological components of the estuarine/marine monitoring program include: water chemistry, physical hydrography (including brine discharge), zooplankton/ichthyoplankton, demersal nekton, benthos, and sediment quality. The Louisiana Department of Wildlife and Fisheries collected the data related to these components from 1978 to 1995. Vegetation and wildlife components were monitored by LSU (see Visser et al. 1996 and references therein). This report is the analysis of data collected in 1997 for the vegetation and wildlife components.

Vegetation and wildlife surveys

The Louisiana Offshore Oil Port (LOOP) Environmental Monitoring Program includes an onshore pipeline vegetation and wildlife survey as a continuing study designed to measure the immediate and long-term impacts of LOOP-related pipeline construction and operation on surrounding wetland plant communities and associated waterfowl, wading-bird, furbearing mammal, and alligator populations.

Environmental monitoring of the LOOP/LOCAP onshore pipeline began in 1978 and continues through the present. In this report, the period spanned by the monitoring program has been divided into three segments:

Pre-construction phase	1978
Construction phase	1979-80
Operation phase, including early recovery period,	1981-84
and late recovery period	1985 through the life of the project

Results from field sampling during the pre-construction phase were used to establish a quantitative data base describing vegetation and wildlife in the wetland communities adjacent to the pipeline prior to construction (Sasser et al. 1979).

The construction phase began in early 1979 on the LOOP pipeline and in early 1980 on the LOCAP pipeline. The 1979 LOOP annual report (Fuller et al. 1980) includes a detailed vegetation map of the one-mile-wide pipeline corridor, quantitative vegetation data from control marshes and swamp forest study sites, and population estimates of waterfowl, wading birds, furbearers, and alligators.

In 1980, the second year of the construction phase, we again sampled vegetation in control marshes, created a detailed vegetation map of the Clovelly salt dome area, initiated sampling to measure the recovery of vegetation on the backfilled pipeline, and began intensive sampling of the Clovelly salt dome marsh to assess the possible effects on marsh vegetation of the use of surface water for leaching oil storage caverns (Sasser et al. 1981). Waterfowl, wading-bird, furbearer, and alligator populations were estimated in the same manner as in 1978 and 1979. Backfilling was completed on the LOOP pipeline by mid-1980 and on the LOCAP pipeline later in 1980.

During the first three years of LOOP's operation phase, 1981–83, we sampled vegetation biomass in control and experimental (i.e., adjacent to the pipeline) marshes, measured vegetation recovery on the backfilled pipeline, continued intensive sampling of the Clovelly salt dome marsh, and constructed a detailed vegetation map of the Clovelly area in 1982. Waterfowl, wading-bird, furbearer, and alligator populations were again censused (Sasser et. al. 1982, 1983, 1984). To understand the background dynamics of wetland loss in this subsiding coastal plain, we mapped and analyzed rates of wetland degradation from 1945 to 1985 in the western half of the Barataria Basin, through which the LOOP pipeline passes (Evers et al. 1991). This analysis provides a basis for assessing any future wetland loss rates that might be linked to the LOOP pipeline.

The same level of monitoring was continued through 1984, the fourth year of the recovery (or operational) phase. In addition, we surveyed the submerged aquatic vegetation on the backfilled pipeline, mapped the surrounding marsh vegetation, and entered the data into a computerized geographic information system. Data collected during the 1984 monitoring program were presented in a data report to LOOP (Peterson et al. 1985).

The late recovery period of the LOOP Environmental Monitoring Program began in 1985. During this part of the program, field sampling of vegetation and wildlife has continued but at a reduced level. As a part of this reduction in the level of monitoring, statistical analyses and discussion of results are included only in the annual reports to LOOP covering odd-numbered years (1985 [Peterson et al. 1986], 1987 [Peterson et al. 1988], 1989 [Evers et al. 1990]), 1991 [Visser et al. 1992], and 1993 [Visser et al. 1994], whereas only the raw data and a summary of the findings are included in the "data reports" covering even-numbered years (1986 [Peterson et al. 1987],1988 [Evers et al. 1989], 1990 [Evers et al. 1991], 1992 [Visser et al. 1993], 1994 [Visser et al. 1995], and 1996 [Visser et al. 1997]).

The vegetation and wildlife components of the Environmental Monitoring Program were further reduced after 1995. With the frequency of overflights related to waterfowl and wildlife censusing reduced to once every three years, a semi-annual overflight of the pipeline area by an experienced wetland biologist was added to the program at this time. The semi-annual overflight provides the opportunity for relatively frequent observation by an experienced wetland biologist to visually assess the biological condition of the LOOP pipeline corridor. The present monitoring program for vegetation and wildlife is outlined in table 2. This report includes data from the 1997 monitoring program, statistical comparisons of these data with data from previous years, and a discussion of the results.

Table 2. Present vegetation and wildlife monitoring components of the LOOP, Inc. Environmental Monitoring Program.

Parameter	1995	1996	1997	1998	1999	2000	2001	2002
Aerial photography[1]	X			X			X	
Vegetation mapping		X----------------->			X			X
Radial transects		X------>			X			X
Biomass sampling								
Fresh	X			X			X	
Intermediate	X	X	X	X	X	X	X	X
Barackish	X							
Saline	X			X			X	
Beach revegetation	X	X		X		X		X
Beach elevation[2]	X	X	X	X	X	X	X	X
Overflight[3]	X	X	X	X	X	X	X	X
Waterfowl	X---X			X---X			X---X	
Wading birds	X---X			X---X			X---X	
Wading-bird colonies	X	X		X		X		X
Seabird colonies	X			X		X		X
Muskrat	X	X			X			X
Alligators	X			X			X	

[1] To be provided by LOOP.
[2] Survey performed LOOP personnel.
[3] Review of environmental condition of the pipeline during LOOP scheduled helicopter flight (2 flights).

METHODS

Beach surveys

Because beach erosion strongly affects the establishment of coastal vegetation, elevations on the beach at the pipeline crossing continue to be an annual element of the monitoring program. Measurements of elevations related to topography of the pipeline backfill at the beach in 1997 were the responsibility of LOOP, LLC. See Visser et al. (1997) for methods.

Pipeline corridor overflight

A semi-annual overflight of the LOOP pipeline corridor by an experienced wetland biologist was added to the monitoring program in 1997. These flights provide the opportunity for relatively frequent observations to visually assess the biological condition of the LOOP pipeline corridor from the Intracoastal Waterway to the beach. The 1997 overflights of the pipeline were flown on 5 August and 16 December 1997.

To assess the ecological condition of the LOOP pipeline we flew a helicopter approximately 100 feet above the marsh along the pipeline transect. The four components included in the pipeline assessment were:

1. Pipeline revegetation
2. Wildlife use in the vicinity of the pipeline
3. The condition of the marsh adjacent to the pipeline
4. the condition of plugs in the pipeline at intersections with other canals and pipelines

The pipeline was divided into seven sections as shown in figure 2.

Marsh Vegetation Biomass Sampling

Biomass control sites

Above-ground biomass was sampled at the same control sites in the intermediate marsh as used in previous years (figure 3). The Clovelly area encompasses all of the intermediate marsh sample sites in this study. Transect IS,

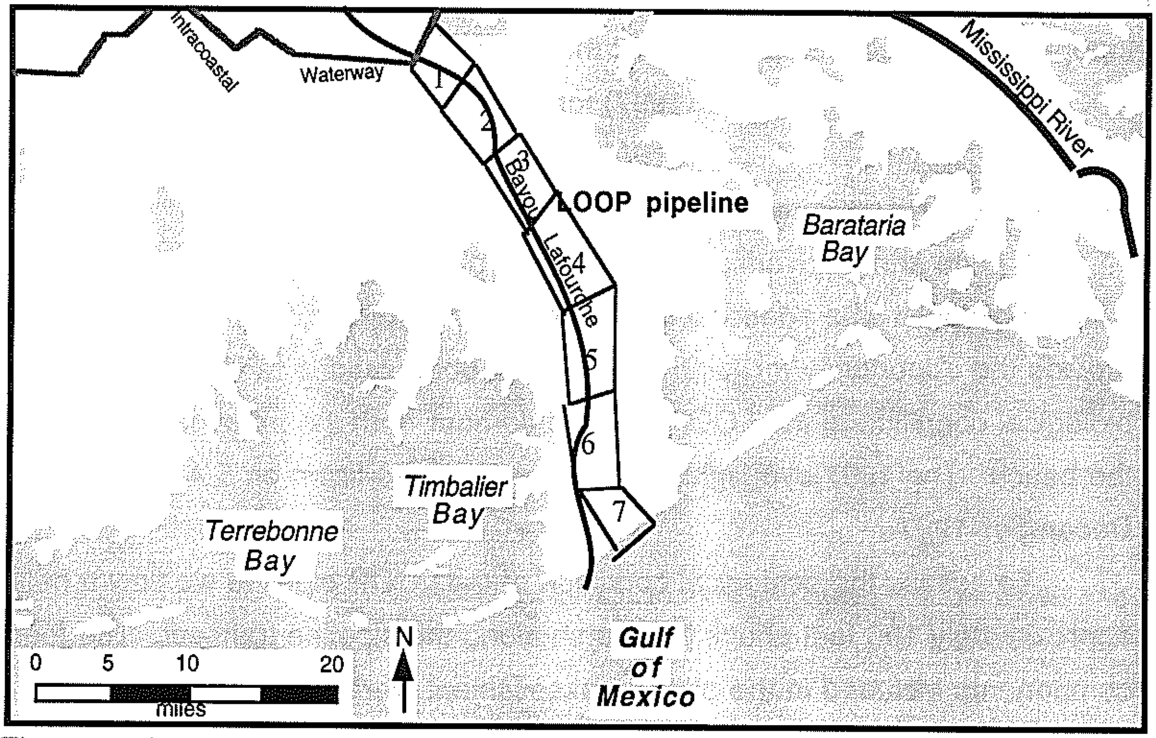

Figure 2. Locations of overflight sections for visual assessments along the LOOP piepline corridor. The nubmers within the boxes represent the sections.

the control for the bulltongue *(Sagittaria lancifolia*) plant association, is 200 m long and has ten 0.10-m^2 plots spaced at 20-m intervals. Transect IC, the control for the wiregrass (*Spartina patens*) plant association, is 200 m long and has ten 0.10-m^2 plots spaced at 20-m intervals.

Vegetation was sampled in early autumn of 1997. All plants (live and dead) within each plot were clipped at ground level and placed in plastic bags. Dead material (detritus) within each plot was removed with the clipped plants. The

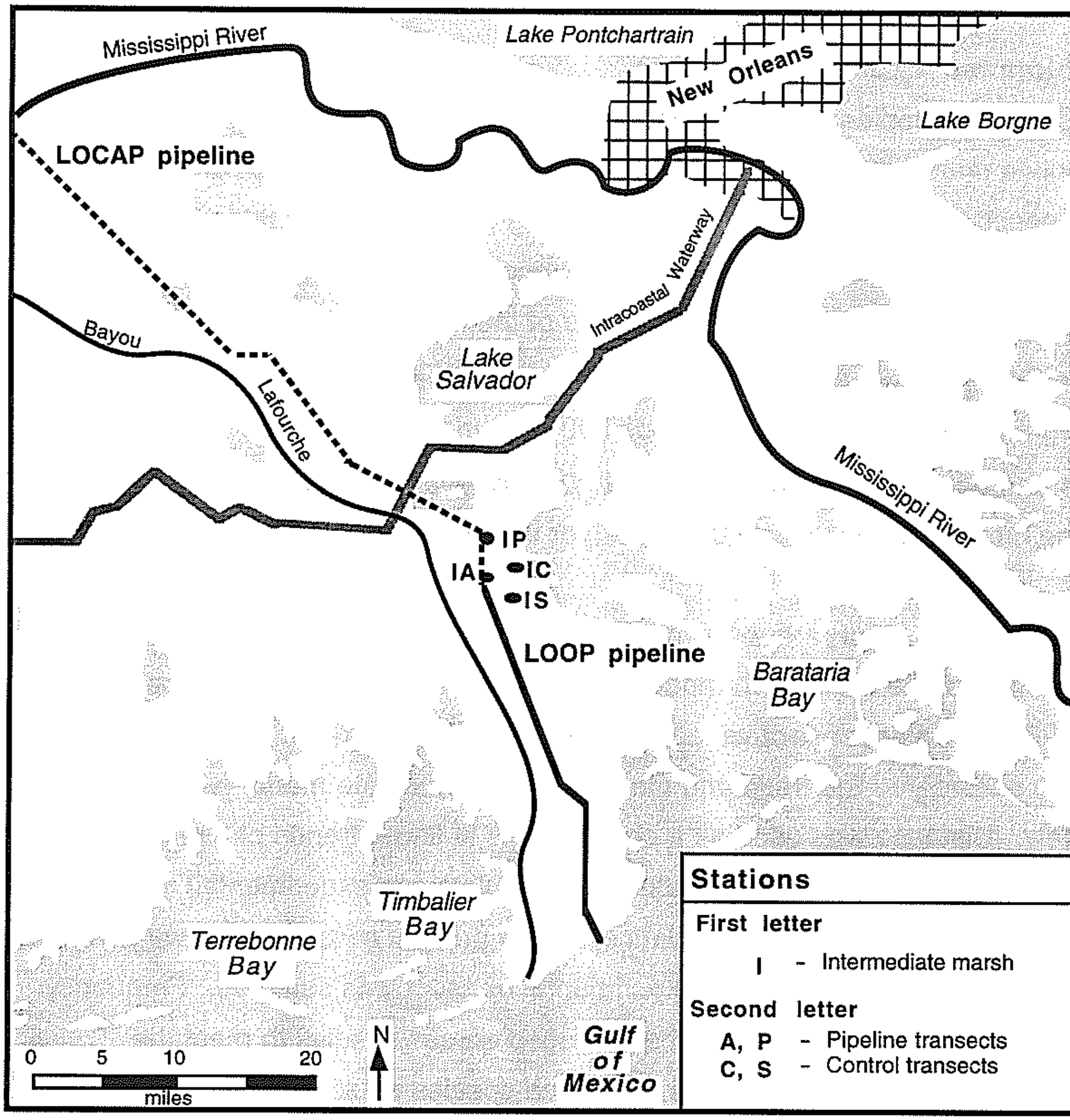

Figure 3. Locations of the study areas for plant biomass sampling.

harvested plant material was returned to the laboratory, where live material was separated from dead. Live plants were sorted by species and oven dried at 65° C to constant weight. The following parameters were recorded:

1. Species present
2. Stem density by species
3. Live biomass (dry wt) by species
4. Dead biomass (dry wt)

Biomass experimental sites

Clip-plot samples were harvested at two experimental study sites in the intermediate marsh (figure 3). We attempted to collect ten replicate samples from each transect; however, transect IA was not long enough to allow this. Transect IA, the bulltongue plant association, was long enough for only eight stations in 1997; it extends approximately 100 m from the edge of the backfilled pipeline and has replicate 0.25-m^2 plots at 20-m intervals. Transect IP, the experimental transect for the wiregrass plant association, extends 200 m from the edge of the backfilled pipeline and has 0.10-m^2 plots located at 20-m intervals. Samples were treated in the same manner as previously described for the intermediate control sites.

Statistical analysis of biomass data

A multisource regression model was used to analyze the data (Steele and Torrie 1980). The dependent variable was total dry live biomass. As in previous years, we considered the fresh and more saline intermediate marsh types separately. (Distance was used as a covariable to fit linear trends of plot biomass across the transects.) Year and treatment (control versus experimental) were used as class variables. To maximize balance, and to prevent missing cells, we used the average when more than one experimental transect was sampled. Frequency plots indicated that biomass had to be averaged across species to meet the assumptions for parametric analysis (i.e., each species could not be considered separately).

Clovelly radial transect survey

The vegetation of the marsh surrounding the Clovelly salt dome oil storage facility has been surveyed annually from 1980 to 1985, 1989, 1993, and on October 10, 1997. A series of 12 transects, varying from 3.5 to 12.0 km long and radiating from the center of the salt dome, was established by helicopter in 1980 (figure 4). At 0.5-km intervals along each transect, two 1-m^2 quadrats (one on each side of the helicopter) were surveyed with a circular device 57 mm in diameter,

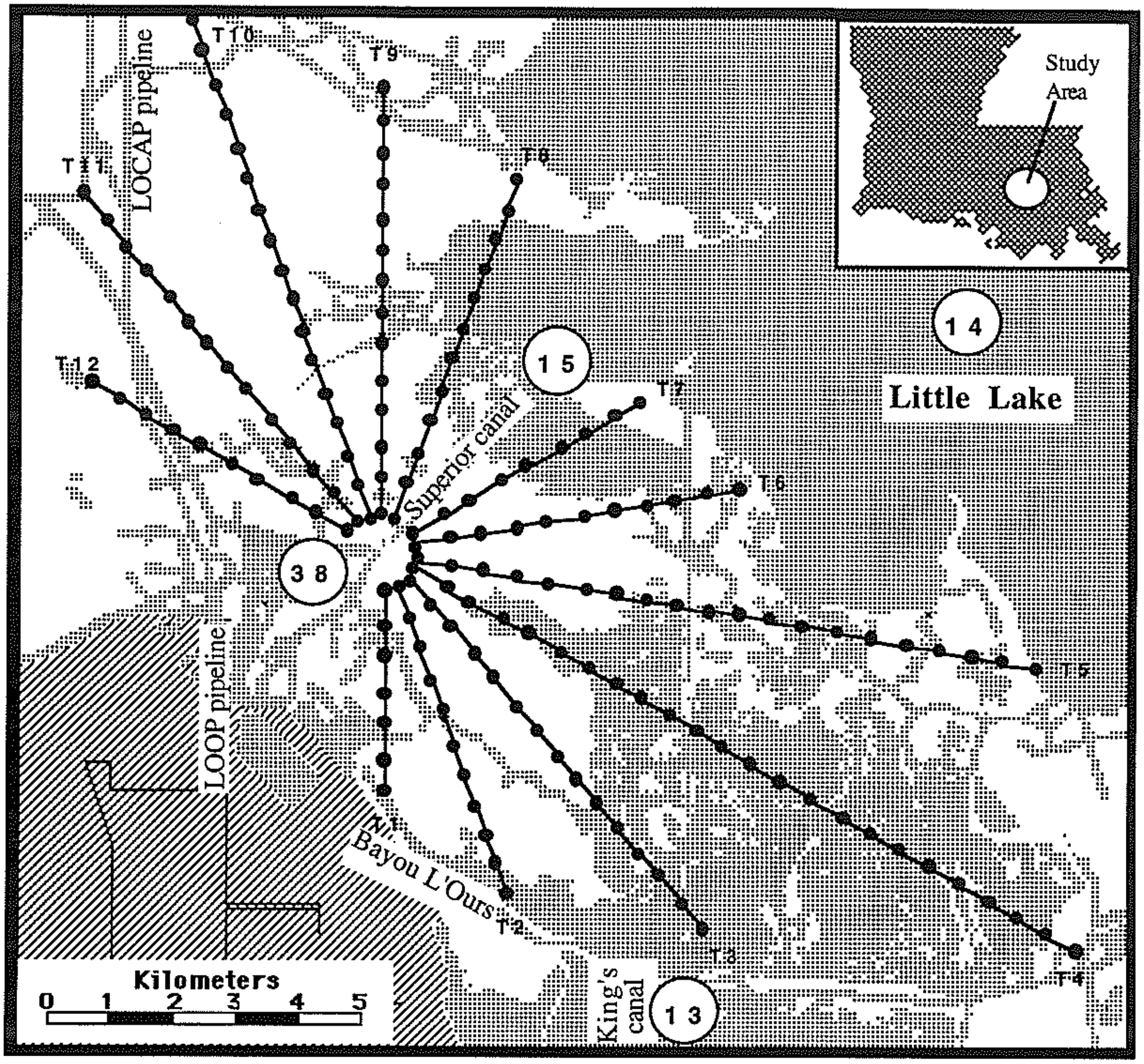

Figure 4. Location of the vegetation sample stations along the Clovelly radial transects.

calibrated to outline a 1-m^2 plot on the marsh when extended a precise distance and looked through by the observer. All vegetation within each plot was identified, and each species was assigned a cover value according to the following scale:

X= trace
1= 1–25 percent
2=26–50 percent
3=51–75 percent

4=76–99 percent
5=100 percent

In 1983–85, 1989, 1993, and 1997 we also collected surface sediments from each of the sample points. A core 2.3 cm in diameter and 12 cm long was extracted, returned to the laboratory, and analyzed for salinidy using a chlorodometer.

Statistical analysis of Clovelly radial transects

The vegetation was analyzed using TWINSPAN (Hill 1979) on the data from all sampled years. To determine the dynamics of individual plots, vegetation types of each plot were arranged in chronological order. Plots classified as one vegetation type for at least four of the six surveyed years were considered stable. Plots that changed back and forth between two vegetation types were considered transitional. Closer scrutiny of the vegetation in these plots revealed that these plots had characteristics of both vegetation types in most years. Plots that were classified as one vegetation type for two or three years and then changed to another vegetation type were categorized as changed.

DISCUSSION OF RESULTS

Pipeline corridor overflight

The seven sections surveyed in the overflight represent a gradient from intermediate to salt marshes (figure 2). Appendix A contains a summary sheet by section of percent vegetation coverage in the pipeline and adjacent marsh areas and wildlife species observed, along with a site map showing locations of plugs needing repairs. The information gained from the two flights provides us with baseline data to compare with future years.

Pipeline revegetation was more complete in sections 1–3, with over 50 percent of the pipeline and more than 70 percent of surrounding marsh vegetated with greater than 50 percent vegetation coverage. Section 4 is mostly contained within the hurricane protection levee. Only 10 percent of the pipeline was vegetated, with 5 percent–10 percent of the surrounding marsh area having greater than 50 percent vegetaion coverage. The pipeline in section 5 was only revegetated on the natural levee. Most of the pipeline in sections 6 and 7 had less than 25 percent revegetation. In section 7, only the pipeline and marsh on the beach had greater than 75 percent vegetation coverage.

Many different bird species were observed on both overflights. A more widespread distribution of the individual species, along with more species in general, were observed during the winter overflight. Great Egrets were the most widspread throughout the whole area for both flights. Snowy Egrets, White Ibis, and Tricolor Herons were observed on both overflights, but their ranges were wider during the winter overflight. More duck species were reported during the winter overflight. Brown and White pelicans were observed in sections 4 through 7 during the winter overflight.

Signs of alligator nest egg harvesting were noted during the summer overflight in sections 1 and 2. Other species noted during the summer overflight were white tail deer, muskrat, and nutria.

Marsh vegetation biomass sampling

The LOOP/LOCAP onshore pipeline traverses plant associations in the salt, brackish, intermediate, and fresh marshes similar to those described by

Chabreck (1972). Diversity of species is greatest in the fresh marsh and decreases with increasing salinity in intermediate, brackish, and salt marshes. Above-ground biomass samples were harvested in the intermediate–*Sagittaria* and intermediate–*Spartina* marshes in 1997. Appendix B contains 1997 biomass data.

Much of the marsh area through which the LOOP pipeline passes is degrading. The pipeline, which traverses a band of marsh generally parallel to and near Bayou Lafourche, crosses marshes that, in many cases, have been heavily impacted by oil and gas exploration. Thus, any effects of the LOOP pipeline are superimposed on the existing marsh deterioration resulting from both natural causes and oil and gas exploration predating the LOOP pipeline. Spatial variability is great. As a result, in any one year only large differences in plant biomass are statistically detectable in our analyses. Long-term data gathering, because it adds power to the statistical analyses, is therefore essential to reliably determine any impacts on marsh vegetation using biomass as an indicator.

Before construction of the LOOP/LOCAP pipeline, experimental study sites were established in marshes adjacent to the pipeline route, and control sites were located outside of the one-mile-wide pipeline corridor (see Methods section). The most complete plant biomass data spanning all years were collected during the autumn sampling periods; therefore, the autumn data sets are used in all marsh vegetation analyses in this report.

Live dry biomass data for 1997 from intermediate marshes are presented graphically in appendix B, along with data from 1996. Data from two replicate plots at each sample station along the experimental transect lines are plotted, together with the mean biomass values for the appropriate control sites.

Variation with distance from the pipeline

Analysis of the intermediate marsh vegetation data set for all years (1978–97) indicates that relationships are similar to those described in our 1995 annual report, which included data from 1978–95 (Visser et al. 1996). Dry mass of live plants decreased with distance from the pipeline in the intermediate-*Spartina* marsh (alpha = .01, table 3), with no apparent statistically

Table 3. Results of a multisource regression for different marsh types. Included are degrees of freedom (df), mean square (MS), F value, and the probability of obtaining a greater F value by chance alone (P > F).

Model		MS	F Value	P > F
Intermediate-*Sagittaria*				
Distance	1	2865.79	0.01	0.9082
Year	19	1304420.02	2.36	0.0481*
Treatment	1	3550610.94	16.51	0.0001**
Treatment*Year	15	552092.65	2.57	0.0013**
Distance*Treatment	1	641.55	0.00	0.9565
Error	272	215039.41		
Corrected Total	309			
Intermediate-*Spartina*				
Distance	1	10528886.26	48.34	0.0001**
Year	19	761353.05	1.20	0.3568
Treatment	1	2168951.18	9.96	0.0017**
Treatment*Year	17	635728.73	2.92	0.0001**
Distance*Treatment	1	42959.72	0.20	0.6573
Error	340	217817.32		
Corrected Total	379			

* Significant at alpha = 0.05 level
** Significant at alpha = 0.01 level

significant relationships between live biomass and distance from the pipeline in the intermediate-*Sagittaria* marshes. It should be noted that a significant DISTANCE (location along transect) effect does not differentiate between control and pipeline (experimental) transects. If the pipeline transect behaved differently than its control, the effect would show as a significant DISTANCE*TREATMENT interaction (table 3).

Annual variation

Annual live plant biomass can vary greatly, as noted by Evers et al. (1990). The overall year effect in our statistical model was significant for the intermediate–*Sagittaria* marsh at the 0.05 level (table 3). Live plant biomass did not vary significantly from year to year in the intermediate-*Spartina* marsh.

The annual variation in live biomass is probably due to a number of environmental factors, including variations in rainfall, insolation, and temperature, and is not attributable to the LOOP/LOCAP pipeline (Visser et al. 1994).

Variation between treatments

Differences were detected between control and experimental transects in the intermediate-*Sagittaria* and intermediate-*Spartina* marshes. Biomass from the control transect was greater overall than that from the experimental transect in the intermediate-*Sagittaria* marsh. The TREATMENT*YEAR interaction was significant for the intermediate-*Sagittaria* and intermediate-*Spartina* (figure 5).

The control-plots had significantly higher biomass than the experimental in the intermediate-*Sagittaria* marsh in 1992. This was due to a change in species composition at the control site that did not occur in the experimental site (Visser et al. 1994). In 1995, the species composition at the control site reverted to a species composition that is very similar to the pipeline site. Biomass in the control site continued to be greater than that in the experimental plots through 1997.

In the intermediate-*Spartina* marsh, the experimental-dry weight was significantly higher from 1990 through 1992. These differences occured during the peak of muskrat activity (see Visser et al. 1995, wildlife section) and might reflect different grazing levels between experimental and control sites which were also visually noted during the sampling trips (Jenneke Visser, personal observations). In 1993 the biomass in both the control and experimental sites became similar, and the trend continued through 1997.

Clovelly radial transects

Throughout the period of study, most of the Clovelly marsh dominated by *Spartina patens* remained stable (figure 6). However, marshes dominated by *Sagittaria lancifolia* have slowely been replaced by a marsh characterized by *Bacopa monnieri* in the period from 1981 to 1989. Since then, a few of these

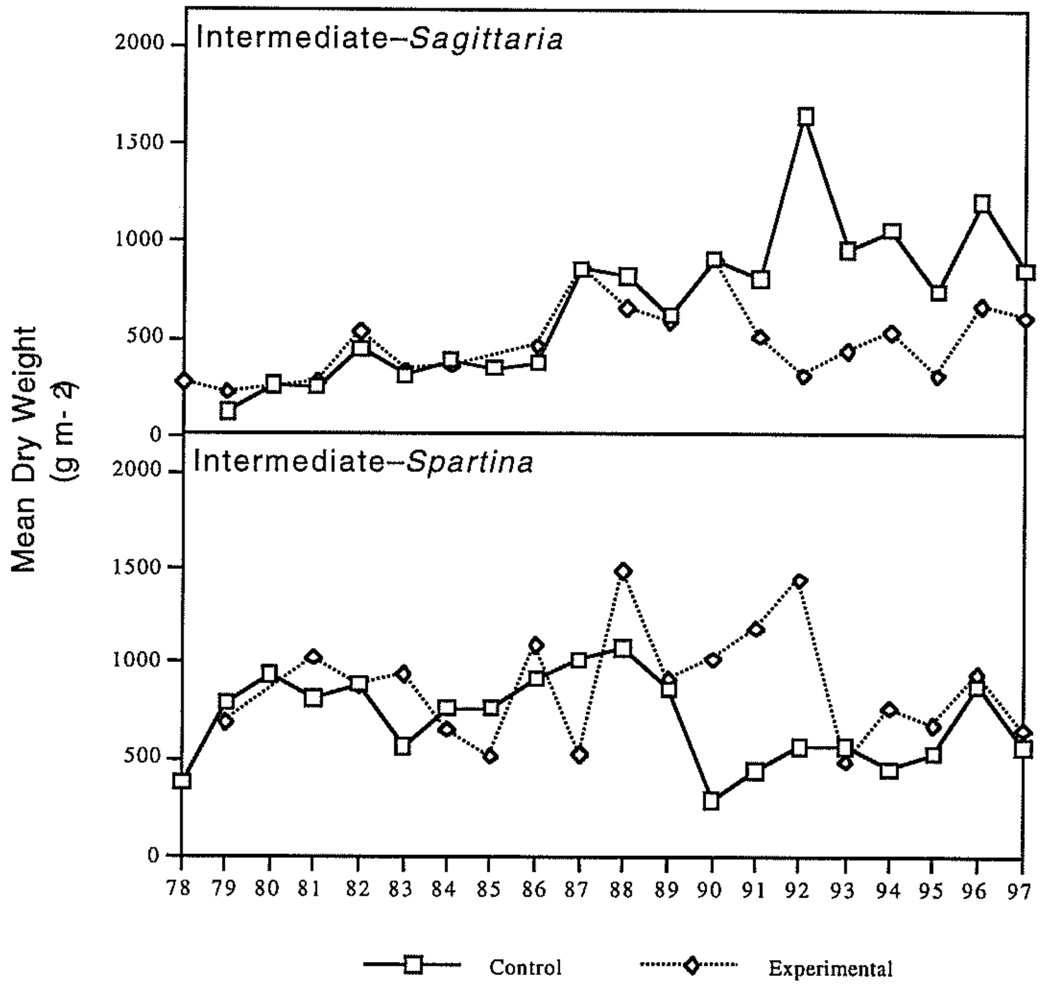

Figure 5. Plots of the means of the experimental and control transects for the intermediate marsh types over time.

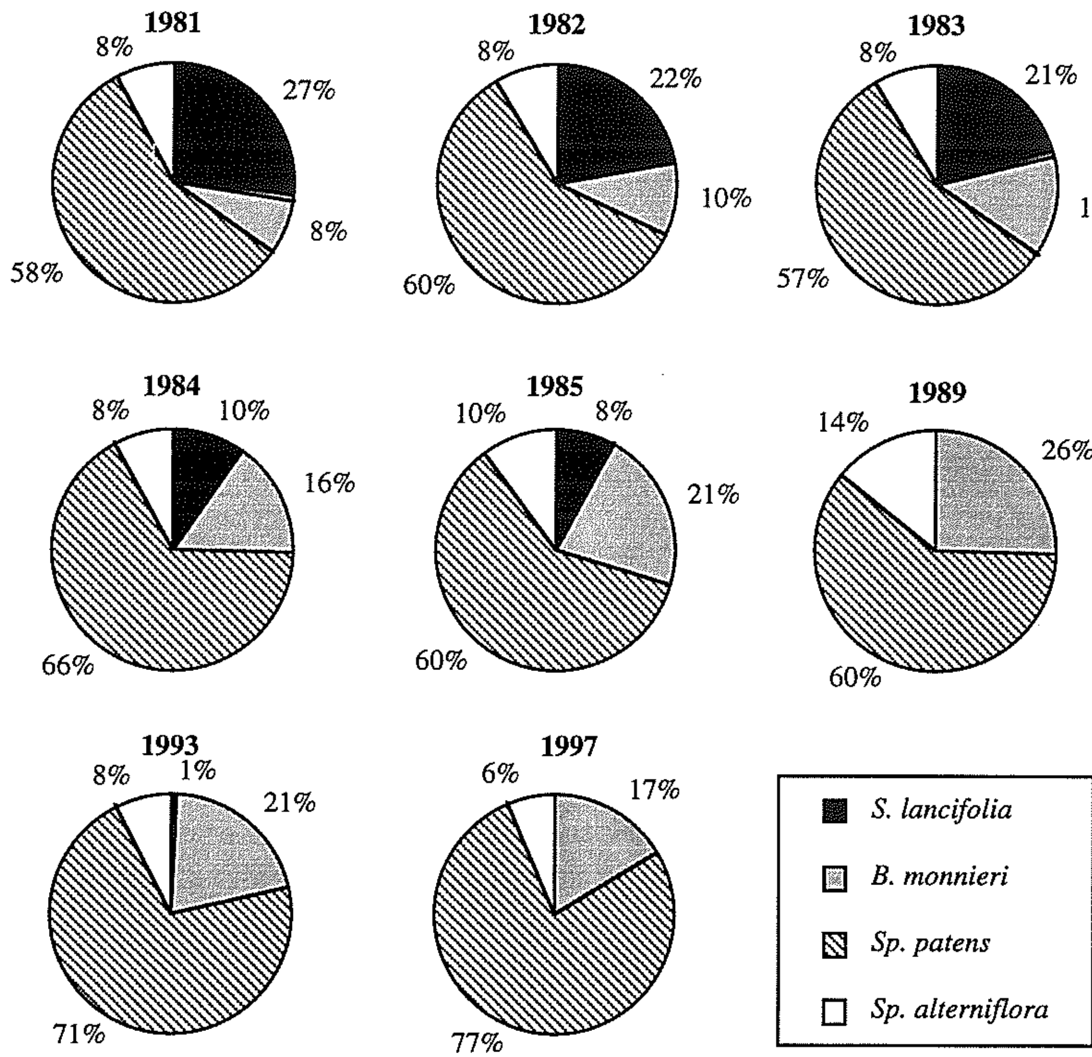

Figure 6. Change in vegetation types along the Clovelly radial transects.

Bacopa marshes have changed to *Spartina patens*-dominated marsh. Most of the changes occurred in the southern part of the Clovelly area, where a *Sagittaria lancifolia*-dominated marsh in the early 1980s (figure 7a) changed to a marsh characterized by *Bacopa monnieri* (figure 7b).

The vegetation change in the southeastern quadrant of the marsh might be associated with increased water salinities. Marsh degradation is also most rapid in this area. The salinity increase is apparently related to salt water intrusion through King's Canal, which cuts through the natural levee of Bayou L'Ours. This levee has historically protected the southern end of the marsh from salt water intrusion. Based on the distribution and stability of the vegetation surrounding Superior Canal, this canal does not appear to be a source of high salinity water. Another source of high salinity water might be the brine storage pond which is located just south of the area with the most rapid change.

Since the vegetation changes are continuing, it is unlikely that they are related to freshwater withdrawal for leaching of the LOOP caverns (most of which occurred in the early eighties). It is also unlikely that the LOOP pipeline canal is a major factor in salt intrusion, since it has been continuously plugged since its construction. Hence, the LOOP pipeline canal does not present a hydrologic route for salt water intrusion comparable to King's Canal. (1987 LOOP Report [Peterson et al. 1988])

Analyses relating vegetation dynamics to the hydrology of this region will be continued. In addition, the relationship between salinity intrusion, marsh degradation, and vegetation changes will be evaluated, as additional information and data are available.

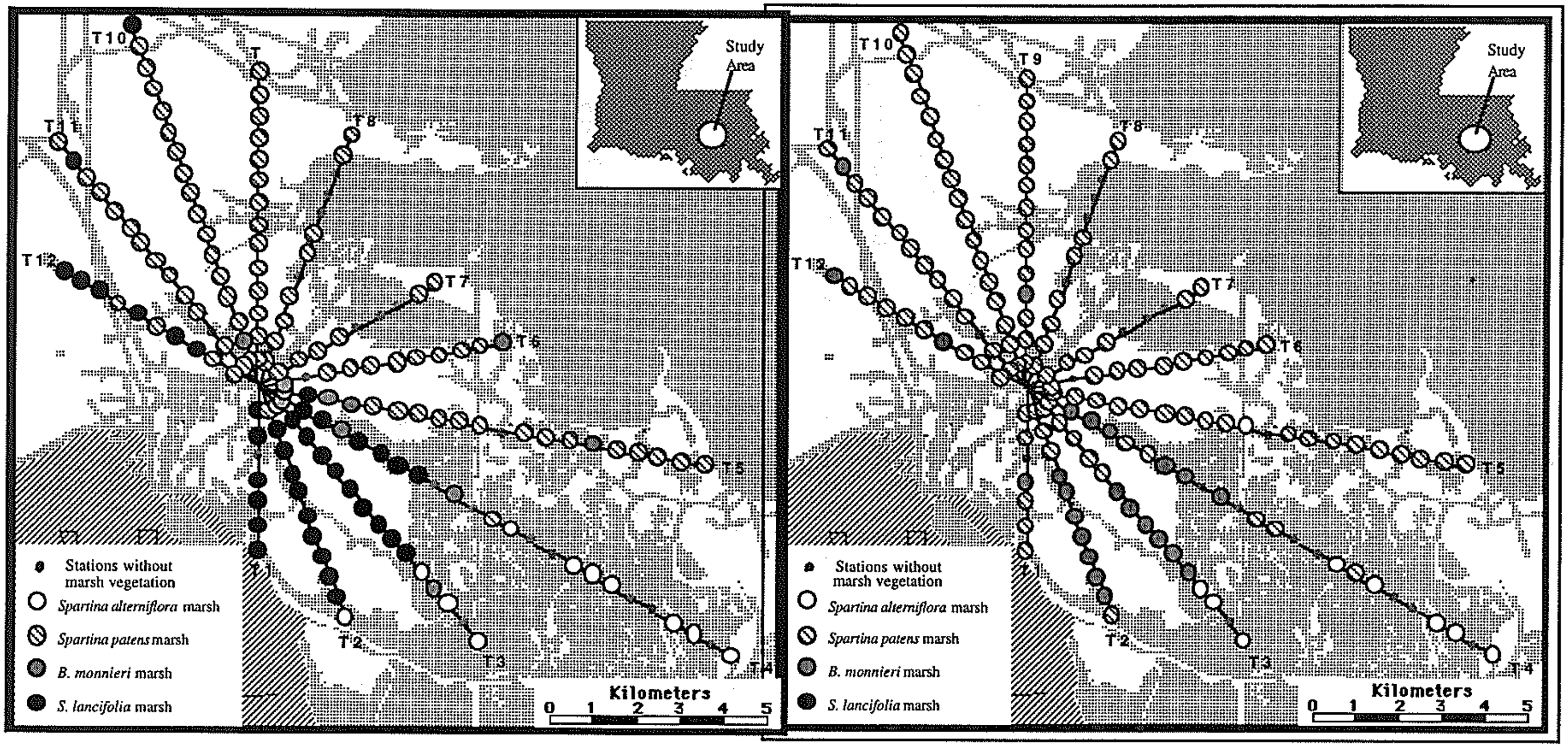

Figure 7. Distribution of vegetation types in 1981 (a) and 1997 (b).

CONCLUSIONS

The Louisiana state legislature created the Louisiana Offshore Terminal Authority (LOTA) to regulate anticipated offshore ports. The enacting legislation requires a comprehensive environmental monitoring program, and part of LOTA's mission is to ensure the integrity of environments affected by large projects such as LOOP.

The planners of the LOOP facility recognized that the pipeline and oil-storage facility would cause environmental changes along the pipeline. The scar of the pipeline, effects of related construction activity (for example, dredged material deposits, marsh buggy tracks), and hydrologic changes associated with the pipeline were the anticipated primary impacts. A stringent effort was made to minimize these impacts by backfilling the canal and plugging all crossings of the pipeline with other waterways.

In general, this strategy has been successful. Although most of the LOOP pipeline has not revegetated, it has become a shallow water body that is an attractive waterfowl habitat. Through continuous maintenance of the plugs, hydrologic modification has apparently been minimized. Although quantitative hydrodynamic data supporting this statement have not been collected, the shallow depth of the pipeline canal and the relative stability of its banks suggest that the canal has not captured major flows.

It is more difficult to assess possible subtle long-term and indirect effects of the pipeline canal, for example, on saltwater intrusion and basin-level marsh degradation. Independent research studies implicate dredged canals in the acceleration of regional wetland loss. The LOOP canal system has not measurably accelerated this degradation process, which is a regional phenomenon with multiple interacting causes. On the other hand, the impact of individual canals (except for the major navigation channels) is generally not measurable; only in the aggregate is the cumulative impact seen as a serious, measurable change in the rate of natural processes. The LOOP construction project was designed to minimize these indirect effects, and as far as can presently be determined, the design has been successful. LOOP and LOTA have combined to bring a much higher level of environmental awareness, concern, and stewardship to Louisiana's coastal wetlands than has been experienced with other human activities in the Louisiana coastal zone.

Barataria basin is changing rapidly, in part as a result of cumulative impacts of many human activities. This change makes the LOOP pipeline and storage facility increasingly vulnerable, and the interaction of natural processes with LOOP construction elevate the environmental risks to the basin. As we have noted in previous reports, we call attention to three areas of continued concern:

1. Marshes in some parts of the Clovelly area have degraded rapidly since 1969. Some marshes in this area have degraded more than others. In general, the more degraded marshes are in the southern region of the Clovelly area, while the most stable marshes are north of the Clovelly salt dome. Geographically, the LOOP storage facility is in the center of the area of most rapid marsh loss in the whole basin. We have not been able to pinpoint the causes of marsh loss; they are probably multiple and include a rapid subsidence rate, high levels of oil and gas extraction, and canals that isolate marsh and permit salt intrusion. All these factors act on a vulnerable organic marsh substrate. The degradation of the marsh makes the LOOP storage facility increasingly vulnerable to coastal storms. Any construction activities in wetlands, especially of canals and spoil banks, no matter how carefully engineered, most likely contribute cumulatively to wetland degradation. LOOP's activities cannot be separated from the multiplicity of other impacts. Both for LOOP and for the future of the state's coastal wetlands, maintaining an active research effort to understand this complex process is important. Highest priority should be given to understanding the hydrology of this region—both as it relates to the condition of marsh habitat and to our ability to anticipate the spread of oil in these inland waters in the event of an onshore oil spill. Regardless, it is important that LOOP maintain its vigilance to prevent further environmental degradation.

2. We believe that the pipeline crossing at the beach is an environmentally vulnerable part of LOOP's onshore operation. Even though the

semi-annual overflights in 1997 showed that much of the beach is vegetated at this time, the beach has been eroding at a retreat rate that in a relatively short time will allow the shoreline at the pipeline crossing to reach Bayou Moreau. As the beach retreats, the Gulf shoreface deepens, potentially exposing the pipeline. The beach is currently vulnerable to breaching into the open portion of the LOOP canal behind Bayou Moreau. If this occurs, more active intrusion of Gulf waters will follow. The erosion of the beach is a regional process but one with which LOOP will have to contend. We suggest filling the LOOP canal between the beach and Bayou Moreau and continuing with the vegetative planting and sediment fencing to establish a stable salt marsh. This will not prevent beach-front erosion, but it should improve the stability of the beach so that breaching through the pipeline corridor is less likely to occur.

3. The floating marshes along the pipeline right-of-way in the Lake Boeuf and Clovelly areas are a third area of concern. Our present state of knowledge is simply inadequate to fully understand the ecological processes controlling this unique marsh type. This is becoming increasingly clear all over the coast as more and more attempts are made to arrest the degradation of floating marshes. The data gap leaves us with a poor basis for managing floating marshes. A continued high level of monitoring and basic research in the floating marshes along the pipeline is appropriate.

As reported in the 1995 Annual Report to LOOP, Inc. (Visser et al. 1996), in addition to the three areas of concern, our observations during 1994 and 1995 indicated new degradation of the marsh vegetation at the salt marsh site (SB) north of Lake Jesse. The *Spartina alterniflora*-dominated vegetation community at this site has until recently remained in good shape as compared to the surrounding region of the coast that has undergone severe degradation. This apparent change in marsh vegetation condition will be investigated further in the mapping component of the monitoring program to determine whether it is part of a general trend of degradation in the area or is related to its position adjacent to the LOOP pipeline.

LIST OF ACRONYMS

EMP	Environmental Monitoring Program
EPP	Environmental Protection Plan
LOOP	Louisiana Offshore Oil Port, LLC
LOTA	Louisiana Offshore Terminal Authority

CONVERSION FACTORS AND ABBREVIATIONS

multiply English units	by	To obtain metric units
inch (in)	25.4	millimeter (mm)
cubic inch (in^3)	16.39	cubic centimeter (cm^3)
square inch (in^2)	6.452	square cm (cm^2)
foot (ft)	0.3048	meter (m)
square foot (ft^2)	929	square centimeter (cm^2)
square foot (ft^2)	0.0929	square meter (m^2)
cubic foot (ft^3)	0.02832	cubic meter (m^3)
cubic foot per second (ft^3/sec)	0.02832	cubic meter per second (m^3/sec)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.5	square kilometer (km^2)
cubic mile (mi^3)	4.168	cubic kilometer (km^3)
mile per hour (mi/hr)	1.609	kilometer per hour (km/hr)
acre	4,047	square meter (m^2)
acre	0.4047	hectare (ha)
acre-foot (acre-ft)	1,233	cubic meter (m^3)
ounce, avoirdupois (oz)	28.35	gram (g)
ounce, fluid (fl oz)	0.02957	liter (L)
pint (pt)	0.4732	liter (L)
quart (qt)	0.9464	liter (L)
gallon (gal)	3.785	liter (L)

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

°F=1.8°C+32

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APPENDIX A

PIPELINE OVERFLIGHT ASSESSMENT

Section 1—Intracoastal Waterway to North Clovelly Canal

Pipeline	70–80 percent of section had ≥ 50 percent vegetated area
Surrounding Marsh	70–100 percent of section had ≥50 percent vegetated area

Wildlife Observed:	On August 5, 1997	On December 16, 1997
Great Egret	Present	Present
Snowy Egret	Present	Present
Common Egret		
White Ibis		Present
Dark Ibises		Present
Tricolor Heron		
Great Blue Heron		
Little Blue Heron		
White Pelican		
Brown Pelican		
Roseate Spoonbill		
Night Heron		
Cormorant		
Coot		Present
Scaup		Present
Grebe		
Gadwall		
Blue-winged Teal		
Green-winged Teal		
Mottled Duck		
Hawk		
Deer	Present	
Muskrat		
Nutria		

Notes: 4 plugs need work
Signs of alligator egg harvesting

Section 2—North Clovelly Canal to LOOP Galliano storage facility

Pipeline	50 percent of section had ≥ 50 percent vegetated area
Surrounding Marsh	90–100 percent of section had ≥50 percent vegetated area

Wildlife Observed:	On August 5, 1997	On December 16, 1997
Great Egret	Present	Present
Snowy Egret		Present
Common Egret		
White Ibis		Present
Dark Ibises		Present
Tricolor Heron	Present	Present
Great Blue Heron		
Little Blue Heron		
White Pelican		
Brown Pelican		
Roseate Spoonbill		
Night Heron		
Cormorant		
Coot		
Scaup		
Grebe		
Gadwall		
Blue-winged Teal		
Green-winged Teal		
Mottled Duck		
Hawk		Present
Deer		
Muskrat		
Nutria		

Notes: 4 plugs need work
Signs of alligator egg harvesting

Section 3—LOOP Galliano storage facility to Yankee Canal

Pipeline	50–60 percent of section had ≥ 50 percent vegetated area
Surrounding Marsh	100 percent of section had ≥50 percent vegetated area

Wildlife Observed:	On August 5, 1997	On December 16, 1997
Great Egret		Present
Snowy Egret		
Common Egret	Present	
White Ibis	Present	
Dark Ibises		
Tricolor Heron		
Great Blue Heron		Present
Little Blue Heron		
White Pelican		
Brown Pelican		
Roseate Spoonbill		
Night Heron		
Cormorant		
Coot		
Scaup		
Grebe		
Gadwall		
Blue-winged Teal		
Green-winged Teal		
Mottled Duck		
Hawk		
Deer		
Muskrat		
Nutria		

Notes: many deer stands present

Section 4—Yankee Canal to Tidewater Canal

Pipeline	0 percent of section had ≥ 50 percent vegetated area; 10 percent had ≥25 percent vegetated area
Surrounding Marsh	5–10 percent of section had ≥50 percent vegetated area

Wildlife Observed:	On August 5, 1997	On December 16, 1997
Great Egret	Present	
Snowy Egret	Present	Present
Common Egret		
White Ibis		Present
Dark Ibises		
Tricolor Heron		Present
Great Blue Heron		
Little Blue Heron		Present
White Pelican		Present
Brown Pelican		Present
Roseate Spoonbill		
Night Heron		
Cormorant		Present
Coot		Present
Grebe		
Scaup		Present
Gadwall		
Blue-winged Teal		
Green-winged Teal	Present	
Mottled Duck		
Hawk		
Deer		
Muskrat		
Nutria		

Notes: This section is mostly within the hurricane protection levee

Section 5—Tidewater Canal to Southwest Louisiana Canal

Pipeline	15 percent of section had ≥ 50 percent vegetated area*
Surrounding Marsh	40–50 percent of section had ≥50 percent vegetated area

Wildlife Observed:	On August 5, 1997	On December 16, 1997
Great Egret	Present	Present
Snowy Egret		Present
Common Egret		
White Ibis		
Dark Ibises		
Tricolor Heron	Present	Present
Great Blue Heron		
Little Blue Heron		
White Pelican		Present
Brown Pelican		Present
Roseate Spoonbill		
Night Heron		
Cormorant		Present
Coot		
Scaup		
Grebe		Present
Gadwall		Present
Blue-winged Teal		Present
Green-winged Teal		
Mottled Duck		Present
Hawk		
Deer		
Muskrat	Present	
Nutria		

Notes: Some plugs need repair
* Only revegetated area is close to the Bayou Lafourche natural levee

Section 6—Southwest Louisiana Canal to LA Highway 1

Pipeline	0 percent of section had ≥ 50 percent vegetated area; 10 percent had ≥25 percent vegetated area
Surrounding Marsh	0 percent of section had ≥ 50 percent vegetated area; 20 percent had ≥25 percent vegetated area

Wildlife Observed:	On August 5, 1997	On December 16, 1997
Great Egret	Present	Present
Snowy Egret	Present	Present
Common Egret		
White Ibis		
Dark Ibises		
Tricolor Heron		
Great Blue Heron	Present	
Little Blue Heron	Present	
White Pelican		Present
Brown Pelican		
Roseate Spoonbill		Present
Night Heron		
Cormorant		Present
Coot		
Scaup		
Grebe		
Gadwall		Present
Blue-winged Teal		
Green-winged Teal		
Mottled Duck		
Hawk		
Deer		
Muskrat		
Nutria		

Notes: Plugs in need of repair
Muskrat houses noted
Much use of mudflat areas duing December overflight due to very low water

Section 7—LA Highway 1 to beach

Pipeline	5–10 percent of section had ≥ 50 percent vegetated area; 10 percent had ≥25 percent vegetated area
Surrounding Marsh	5 percent of section (beach); had ≥75 percent vegetated area; >95 percent had ≤50 percent vegetated area

Wildlife Observed:	On August 5, 1997	On December 16, 1997
Great Egret	Present	Present
Snowy Egret		
Common Egret		
White Ibis		
Dark Ibises		
Tricolor Heron		Present
Great Blue Heron		
Little Blue Heron		
White Pelican		
Brown Pelican		
Roseate Spoonbill	Present	Present
Night Heron		
Cormorant		
Coot		
Scaup		Present
Grebe		
Gadwall		
Blue-winged Teal		
Green-winged Teal		
Mottled Duck		
Hawk		
Deer		
Muskrat		
Nutria		

Notes: No plugs in need of repair

APPENDIX B

VEGETATION DATA LISTING

September 1997
Intermediate–*Sagittaria* Marsh
Transect A Side Left
Plot size=0.10 m^2

Plot #	Species	Dry weight ($g*m^{-2}$)	Stems
1	Dead Aboveground Biomass	365	
1	*Sagittaria falcata*	305	220
1	*Eleocharis macrostachya*	40	240
1	*Phyla lanceolata*	20	10
1	*Paspalum vaginatum*	45	270
1	*Eleocharis rostellata*	25	420
1	*Hydrocotyle* spp.	0	10
2	Dead Aboveground Biomass	450	
2	*Eleocharis macrostachya*	220	1300
2	*Paspalum vaginatum*	10	70
2	*Phyla lanceolata*	60	40
2	*Sagittaria falcata*	300	290
2	*Aster tenuifolius*	10	20
3	Dead Aboveground Biomass	450	
3	*Ammannia coccinea*	5	20
3	*Paspalum vaginatum*	120	390
3	*Sagittaria falcata*	460	170
3	*Eleocharis rostellata*	250	2500
3	*Phyla lanceolata*	150	120
3	*Eleocharis macrostachya*	50	310
3	*Hydrocotyle* spp.	10	20
3	*Eleocharis parvula*	0	70
4	Dead Aboveground Biomass	230	
4	*Aster tenuifolius*	50	30
4	*Polygonum punctatum*	5	10
4	*Sagittaria falcata*	155	220
4	*Hydrocotyle umbellata*	30	210
4	*Eleocharis rostellata*	145	1670
4	*Eleocharis macrostachya*	135	800
5	Dead Aboveground Biomass	750	
5	*Sagittaria falcata*	375	240
5	*Eleocharis rostellata*	200	1220
5	*Polygonum punctatum*	0	10
5	*Aster tenuifolius*	5	20
5	*Vigna luteola*	10	
6	Dead Aboveground Biomass	1015	
6	*Eleocharis macrostachya*	50	220
6	*Eleocharis rostellata*	100	630
6	*Hydrocotyle umbellata*	5	70
6	*Sagittaria falcata*	485	630
7	Dead Aboveground Biomass	450	
7	*Sagittaria falcata*	695	210
7	*Eleocharis rostellata*	170	1490
7	*Eleocharis macrostachya*	25	140
7	*Aster tenuifolius*	145	30
8	Dead Aboveground Biomass	315	
8	*Sagittaria falcata*	155	250

September 1997
Intermediate–*Sagittaria* Marsh
Transect A Side Left
Plot size=0.10 m^2

Plot #	Species	Dry weight ($g*m^{-2}$)	Stems
8	*Eleocharis rostellata*	5	60
8	*Eleocharis macrostachya*	25	120
8	*Eleocharis albida*	0	40
8	*Polygonum punctatum*	0	10
8	*Aster tenuifolius*	20	10
8	*Phyla lanceolata*	25	50

September 1997
Intermediate–*Sagittaria* Marsh
Transect A Side Right
Plot size=0.10 m²

Plot #	Species	Dry weight ($g*m^{-2}$)	Stems
1	Dead Aboveground Biomass	150	
1	*Sagittaria falcata*	250	230
1	*Eleocharis rostellata*	25	180
2	Dead Aboveground Biomass	200	
2	*Sagittaria falcata*	100	70
2	*Eleocharis rostellata*	170	1800
2	*Eleocharis macrostachya*	50	300
2	*Eleocharis albida*	20	1100
2	*Paspalum vaginatum*	210	400
2	*Acnida tamariscina*	165	10
2	*Echinochloa Walteri*		10
3	Dead Aboveground Biomass	260	
3	*Sagittaria falcata*	325	280
3	*Eleocharis macrostachya*	25	160
3	*Paspalum vaginatum*	20	40
3	*Hydrocotyle* spp.	10	40
4	Dead Aboveground Biomass	635	
4	*Sagittaria falcata*	110	240
4	*Eleocharis rostellata*	245	1500
4	*Eleocharis macrostachya*	85	350
4	*Polygonum punctatum*	65	80
4	*Aster tenuifolius*	445	250
4	*Galium tinctorium*	5	10
4	*Hydrocotyle* spp.	10	60
4	*Acnida tamariscina*	20	20
5	Dead Aboveground Biomass	325	
5	*Sagittaria falcata*	400	180
5	*Eleocharis rostellata*	0	10
5	*Eleocharis macrostachya*	5	90
5	*Polygonum punctatum*	10	10
6	Dead Aboveground Biomass	645	
6	*Sagittaria falcata*	280	210
6	*Eleocharis macrostachya*	25	120
6	*Eleocharis rostellata*	105	800
6	*Polygonum punctatum*	10	20
6	*Aster tenuifolius*	75	40
6	*Hydrocotyle* spp.	5	50
7	Dead Aboveground Biomass	250	
7	*Eleocharis rostellata*	180	1500
7	*Eleocharis macrostachya*	15	100
7	*Aster tenuifolius*	135	210
7	*Polygonum punctatum*	95	150
7	*Echinochloa crusgalli*	310	80
7	*Acnida tamariscina*	5	10
7	*Lythrum lineare*	10	10
7	*Cyperus polystachyos*	90	390
8	Dead Aboveground Biomass	465	

September 1997
Intermediate–*Sagittaria* Marsh
Transect A Side Right
Plot size=0.10 m^2

Plot #	Species	Dry weight ($g*m^{-2}$)	Stems
8	*Sagittaria falcata*	265	340
8	*Eleocharis macrostachya*	120	550
8	*Aster tenuifolius*	120	70
8	*Polygonum punctatum*	5	20
8	*Acnida tamariscina*	30	10

September 1997
Intermediate–*Sagittaria* Marsh
Transect S
Plot size=0.10 m²

Plot #	Species	Dry Weight ($g*m^{-2}$)	Stems
1	Dead Aboveground Biomass	1460	
1	*Spartina patens*	505	340
1	*Eleocharis rostellata*	5	80
1	*Vigna luteola*	0	
2	Dead Aboveground Biomass	1655	
2	*Spartina patens*	2045	1300
2	*Vigna luteola*	85	
3	Dead Aboveground Biomass	115	
3	*Spartina patens*	35	100
3	*Vigna luteola*	5	
3	*Sagittaria falcata*	165	140
3	*Eleocharis macrostachya*	5	50
3	*Bacopa Monnieri*	5	
3	*Phyla lanceolata*	40	
3	*Ammannia coccinea*	0	10
4	Dead Aboveground Biomass	280	
4	*Spartina patens*	15	110
4	*Vigna luteola*	0	
4	*Sagittaria falcata*	540	430
4	*Eleocharis macrostachya*	50	300
4	*Bacopa Monnieri*	0	
4	*Aster tenuifolius*	0	10
4	*Paspalum vaginatum*	50	190
4	*Eleocharis albida*	20	1500
5	Dead Aboveground Biomass	220	
5	*Spartina patens*	495	980
5	*Sagittaria falcata*	150	120
5	*Eleocharis macrostachya*	115	450
5	*Bacopa Monnieri*	0	
5	*Aster tenuifolius*	70	50
5	*Paspalum vaginatum*	0	230
5	*Eleocharis albida*	0	410
5	*Ammannia coccinea*	0	10
5	*Hydrocotyle* spp.	0	10
5	*Pluchea* spp.	0	10
5	*Cyperus polystachyos*	0	10
5	*Echinochloa Walteri*	20	10
6	Dead Aboveground Biomass	615	
6	*Spartina patens*	1045	1050
6	*Eleocharis macrostachya*	60	250
6	*Eleocharis rostellata*	0	20
6	*Lythrum lineare*	30	
6	*Bacopa Monnieri*	5	
6	*Lythrum lineare*	30	10
6	*Aster tenuifolius*	235	10
7	Dead Aboveground Biomass	215	
7	*Spartina patens*	165	250

September 1997
Intermediate–*Sagittaria* Marsh
Transect S
Plot size=0.10 m^2

Plot #	Species	Dry Weight ($g*m^{-2}$)	Stems
7	*Eleocharis macrostachya*	80	440
7	*Sagittaria falcata*	150	230
7	*Bacopa Monnieri*	15	
7	*Paspalum vaginatum*	50	270
7	*Ammannia coccinea*	110	30
7	*Pluchea* spp.	10	30
7	*Eleocharis albida*	405	7000
8	Dead Aboveground Biomass	195	
8	*Spartina patens*	140	600
8	*Eleocharis macrostachya*	90	590
8	*Sagittaria falcata*	15	50
8	*Bacopa Monnieri*	75	
8	*Paspalum vaginatum*	20	110
8	*Ammannia coccinea*	5	10
8	*Eleocharis albida*	10	1100
9	Dead Aboveground Biomass	280	
9	*Eleocharis macrostachya*	70	490
9	*Cyperus polystachyos*	15	40
9	*Aster tenuifolius*	130	260
9	*Ammannia coccinea*	15	30
9	*Paspalum vaginatum*	100	560
9	*Bacopa Monnieri*	235	
9	*Eleocharis rostellata*	325	2930
10	Dead Aboveground Biomass	145	
10	*Eleocharis macrostachya*	120	930
10	*Sagittaria falcata*	105	120
10	*Hydrocotyle umbellata*	0	20
10	*Paspalum vaginatum*	5	40
10	*Spartina patens*	35	190
10	*Bacopa Monnieri*	220	
10	*Eleocharis albida*	20	1800

September 1997
Intermediate–*Spartina* Marsh
Transect P Side Left
Plot size=0.10 m^2

Plot #	Species	Dry Weight ($g*m^{-2}$)	Stems
1	Dead Aboveground Biomass	540	
1	*Sagittaria falcata*	30	30
1	*Eleocharis rostellata*	155	1140
1	*Spartina patens*	80	60
1	*Lythrum lineare*	35	10
1	*Vigna luteola*	10	
1	*Cynanchum angustifolium*	0	
2	Dead Aboveground Biomass	345	
2	*Spartina patens*	15	20
2	*Eleocharis rostellata*	15	220
3	Dead Aboveground Biomass	1110	
3	*Eleocharis rostellata*	435	3480
3	*Spartina patens*	255	190
3	*Solidago sempervirens*	60	10
3	*Distichlis spicata*	10	50
3	*Thelypteris palustris*	10	70
3	*Hydrocotyle* spp.	5	50
3	*Setaria* sp.	5	20
3	*Phyla lanceolata*	0	20
3	*Galium tinctorium*	0	20
	Dead Aboveground Biomass	365	
4	*Spartina patens*	125	110
4	*Eleocharis rostellata*	115	1340
4	*Cyperus polystachyos*	0	30
4	*Sacciolepis striata*	5	10
4	*Setaria* sp.	5	40
4	*Hydrocotyle* spp.	0	20
5	Dead Aboveground Biomass	1440	
5	*Spartina patens*	765	680
5	*Eleocharis rostellata*	220	2150
5	*Cynanchum angustifolium*	0	
5	*Sacciolepis striata*	70	180
5	*Vigna luteola*	0	
5	*Hydrocotyle* spp.	5	30
5	*Aster tenuifolius*	10	30
6	Dead Aboveground Biomass	2985	
6	*Spartina patens*	1285	780
6	*Sacciolepis striata*	35	10
6	*Eleocharis rostellata*	75	450
6	*Sagittaria falcata*	35	30
6	*Vigna luteola*	115	
6	*Thelypteris palustris*	0	30
6	*Hydrocotyle* spp.	0	20
6	*Cynanchum angustifolium*	15	
6	*Ipomoea sagittata*	40	
7	Dead Aboveground Biomass	380	
7	*Sagittaria falcata*	195	180

September 1997
Intermediate–*Spartina* Marsh
Transect P Side Left
Plot size=0.10 m^2

Plot #	Species	Dry Weight ($g*m^{-2}$)	Stems
7	*Eleocharis rostellata*	35	240
7	*Hydrocotyle* spp.	5	30
8	Dead Aboveground Biomass	120	
8	*Eleocharis albida*	75	2050
8	*Cyperus polystachyos*	50	150
8	*Eleocharis macrostachya*	45	330
8	*Eleocharis rostellata*	10	100
8	*Pluchea* spp.	10	10
8	*Agalinis maritima*	5	70
8	*Distichlis spicata*	0	50
8	*Spartina patens*	0	30
8	*Panicum tenerum*	10	10
9	Dead Aboveground Biomass	775	
9	*Spartina patens*	500	360
9	*Eleocharis rostellata*	215	2050
9	*Polygonum punctatum*	25	10
9	*Cyperus polystachyos*	5	10
9	*Aster tenuifolius*	10	10
9	*Vigna luteola*	10	
9	*Cynanchum angustifolium*	0	
9	*Phyla lanceolata*	0	10
10	Dead Aboveground Biomass	140	
10	*Eleocharis rostellata*	125	1540
10	*Sacciolepis striata*	25	30
10	*Aster tenuifolius*	10	10
10	*Eleocharis macrostachya*	5	100
10	*Spartina patens*	50	100
10	*Cyperus polystachyos*	20	130
10	*Polygonum punctatum*	15	20
10	*Thelypteris palustris*	5	30
10	*Vigna luteola*	25	
10	*Setaria* sp.	0	10
10	*Hydrocotyle* spp.	0	40

September 1997
Intermediate–*Spartina* Marsh
Transect P Side Right
Plot size=0.10 m^2

Plot #	Species	Dry Weight ($g*m^{-2}$)	Stems
1	Dead Aboveground Biomass	425	
1	*Sagittaria falcata*	15	30
1	*Spartina patens*	35	30
1	*Solidago sempervirens*	115	10
1	*Vigna luteola*	15	
1	*Phyla lanceolata*	15	40
1	*Cynanchum angustifolium*		10
1	*Polygonum punctatum*	15	40
1	*Eleocharis rostellata*	120	840
2	Dead Aboveground Biomass	1260	
2	*Spartina patens*	1010	600
2	*Eleocharis rostellata*	150	1200
2	*Setaria* sp.	0	10
2	*Vigna luteola*	40	
3	Dead Aboveground Biomass	855	
3	*Spartina patens*	755	680
3	*Eleocharis rostellata*	120	1080
3	*Vigna luteola*	10	
3	*Kosteletzkya virginica*	330	10
4	Dead Aboveground Biomass	850	
4	*Eleocharis rostellata*	160	1410
4	*Hydrocotyle* spp.	0	30
4	*Setaria* sp.	10	30
4	*Spartina patens*	15	10
4	*Paspalum vaginatum*	0	10
5	Dead Aboveground Biomass	1245	
5	*Phyla lanceolata*	5	30
5	*Cynanchum angustifolium*	0	
5	*Eleocharis rostellata*	135	1190
5	*Hydrocotyle* spp.	5	70
5	*Spartina patens*	475	350
5	*Sagittaria falcata*	25	50
5	*Thelypteris palustris*	45	120
5	*Vigna luteola*	75	
6	Dead Aboveground Biomass	1940	
6	*Vigna luteola*	15	
6	*Spartina patens*	980	620
6	*Eleocharis rostellata*	30	170
6	*Sagittaria falcata*	85	80
6	*Cynanchum angustifolium*	0	
7	Dead Aboveground Biomass	1450	
7	*Spartina patens*	1240	880
7	*Eleocharis rostellata*	80	630
7	*Distichlis spicata*	30	70
7	*Cynanchum angustifolium*	10	
7	*Setaria* sp.	25	70
7	*Agalinis maritima*	0	10

September 1997
Intermediate–*Spartina* Marsh
Transect P Side Right
Plot size=0.10 m^2

Plot #	Species	Dry Weight ($g*m^{-2}$)	Stems
8	Dead Aboveground Biomass	1115	
8	*Eleocharis rostellata*	230	2270
8	*Spartina patens*	15	40
8	*Andropogon glomeratus*	55	70
8	*Distichlis spicata*	0	10
8	*Galium tinctorium*	0	30
9	Dead Aboveground Biomass	880	
9	*Eleocharis rostellata*	55	490
9	*Spartina patens*	325	270
9	*Sagittaria falcata*	95	50
9	*Hydrocotyle* spp.	5	50
9	*Vigna luteola*	10	
10	Dead Aboveground Biomass	1320	
10	*Eleocharis rostellata*	155	1800
10	*Spartina patens*	305	250
10	*Sacciolepis striata*	10	50
10	*Hydrocotyle* spp.	0	50

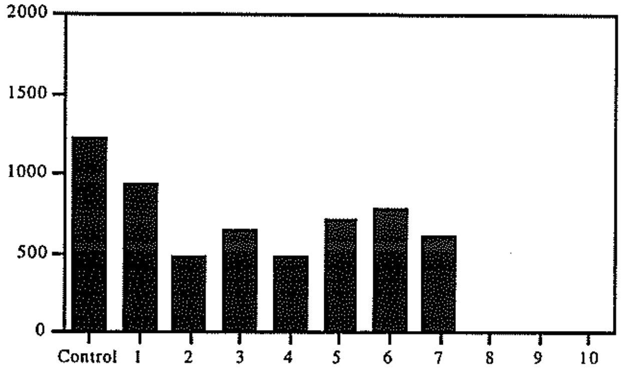
1	Dead Aboveground Biomass	400	
1	*Spartina patens*	635	760
1	*Eleocharis rostellata*	320	3500
1	*Cyperus polystachyos*	0	20
1	*Cyperus odoratus*	30	30
1	*Lythrum lineare*	10	20
1	*Setaria geniculata*	30	100
1	*Scirpus Olneyi*	5	10
1	*Ammannia coccinea*	5	20
1	*Pluchea* spp.	0	20
1	*Ipomoea sagittata*	15	
2	Dead Aboveground Biomass	495	
2	*Bacopa Monnieri*	5	
2	*Eleocharis rostellata*	460	2920
2	*Spartina patens*	265	400
2	*Distichlis spicata*	15	50
3	Dead Aboveground Biomass	65	
3	*Bacopa Monnieri*	50	
3	*Spartina patens*	235	660
3	*Eleocharis rostellata*	20	400
3	*Cyperus odoratus*	115	50
3	*Lythrum lineare*	40	40
3	*Ammannia coccinea*	0	20
3	*Scirpus Olneyi*	55	140
3	*Setaria geniculata*	25	40
3	*Cyperus polystachyos*	40	160
3	*Pluchea* spp.	15	10
3	*Polygonum punctatum*	35	40
4	Dead Aboveground Biomass	545	
4	*Spartina patens*	240	570
4	*Eleocharis macrostachya*	15	100
4	*Eleocharis rostellata*	275	2710
4	*Setaria geniculata*	30	60
4	*Lythrum lineare*	35	10
4	*Scirpus Olneyi*	135	190
5	Dead Aboveground Biomass	1910	
5	*Spartina patens*	320	160
5	*Eleocharis rostellata*	60	410
5	*Hydrocotyle umbellata*	0	50
5	*Scirpus Olneyi*	25	60
5	*Lythrum lineare*	5	
6	Dead Aboveground Biomass	1285	
6	*Spartina patens*	465	540
6	*Eleocharis rostellata*	160	
6	*Hydrocotyle umbellata*	0	50
6	*Aster tenuifolius*	105	40
6	*Cyperus polystachyos*	0	10
7	Dead Aboveground Biomass	1195	
7	*Juncus Roemerianus*	310	500
7	*Distichlis spicata*	40	110
7	*Cynanchum angustifolium*	0	
7	*Spartina patens*	0	10
7	*Eleocharis rostellata*	320	2410
8	Dead Aboveground Biomass	130	

8	*Scirpus Olneyi*	45	110
8	*Spartina patens*	25	170
8	*Eleocharis rostellata*	75	1940
8	*Hydrocotyle* spp.	0	80
8	*Cyperus polystachyos*	0	30
8	*Eleocharis parvula*	0	340
9	Dead Aboveground Biomass	240	
9	*Spartina patens*	135	340
9	*Scirpus Olneyi*	75	150
9	*Hydrocotyle umbellata*	0	20
9	*Eleocharis macrostachya*	5	40
9	*Eleocharis parvula*	0	940
9	*Eleocharis rostellata*	155	1940
9	*Pluchea* spp.	0	10
10	Dead Aboveground Biomass	255	
10	*Cynanchum angustifolium*	20	
10	*Scirpus Olneyi*	60	140
10	*Eleocharis rostellata*	40	580
10	*Spartina patens*	85	220
10	*Sacciolepis striata*	5	50
10	*Cyperus polystachyos*	5	80
10	*Ammannia coccinea*	0	10

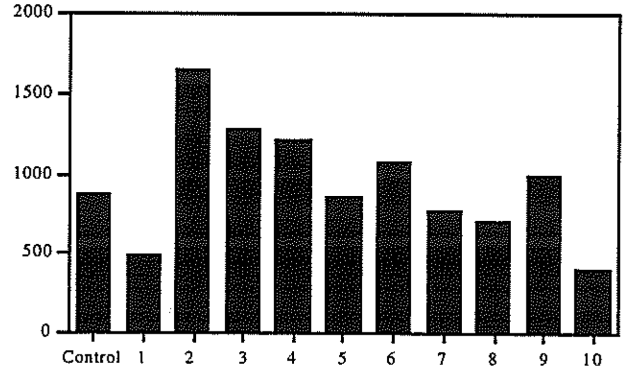
APPENDIX C

PLOTS OF BIOMASS DATA FOR INTERMEDIATE MARSHES

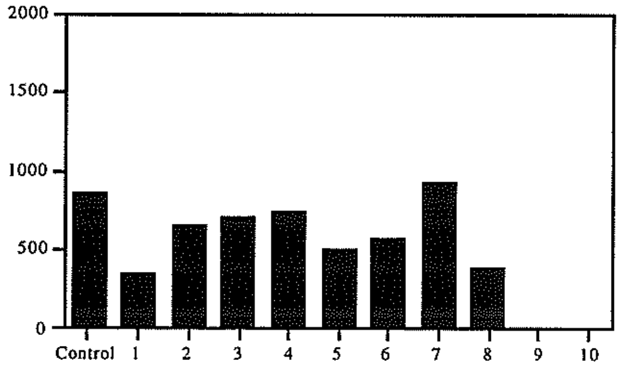
Intermediate–*Sagittaria* Marsh
Transect=A Year=1996



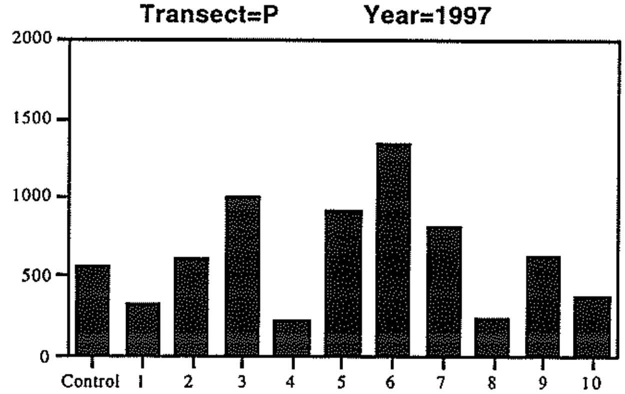
Intermediate–*Spartina* Marsh
Transect=P Year=1996



Intermediate–*Sagittaria* Marsh
Transect=A Year=1997



Intermediate–*Spartina* Marsh
Transect=P Year=1997



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