Project Number 2

EFFECT OF OIL SPILLS AND RECOVERY ON COASTAL WETLANDS

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Figures

Tables

ABSTRACT

Oil spills can have a significant short-term impact on coastal marshes, but the long-term effects and perhaps eventual recovery are not well documented The overall three-year goal of this investigation is to document the long-term recovery rate of a brackish marsh affected by an oil spill on April 23, 1985, to separate the effect of the oil spill on marsh deterioration from ambient rates of marsh degradation, and to test means by which recovery can be accelerated and the damage mitigated. These goals will be accomplished through both remote sensing and ground truth assessments. The specific objectives for the first year of study were to initiate the mapping of historical aerial photography of the study area, squire new photography and map the study area and conduct on the initial ground recovery assessment. These objectives have been accomplished,

During the second year of the project, a national search for available historical photography of the study *area* has been completed and the data tabulated A total of fourteen (14) compatible dates of photography have been acquired and nine (9) have been mapped for further spatial analysis. In addition, the 1985 study site maps (produced in the original oil spill effect study) were digitized and entered into the project database using AUTOCAD software. Current color aerial photography of the study area was acquired and printed by Aero-Data Corporation in 1990 and has been mapped. Visual inspection of the 1990 imagery in comparison to that acquired immediately after the spill in 1985 indicates significant marsh recovery.

The permanent plots established in the oiled and control marshes at the study site in 1985 were re-surveyed for plant recovery in the Fall of 1989. All 68 permanent plots were found and assessed for species composition, live and dead percentage cover, and residual oil impact. This analysis demonstrated significant vegetative recovery of the Impacted Marsh four years after the spill. However, there was also a tendency for vegetative plots that were initially highly impacted to still have higher levels of total saturated hydrocarbons in the soils. Plant photosynthetic response was measured in 24 of the permanent plots in August 1990. Half of these selected plots were initially heavily impacted by oil and the other half were not impacted and served as controls. There were no significant differences in plant photosynthetic response between control and oiled plots for either *Spartina alterniflora* or *Spartina patens*. There *were also* no significant differences in interstitial water salinity, sulfide, and pH, or soil Eh between control and oiled plots, further demonstrating recovery of the Impacted Marsh.

Year 3 activities will include (1) determination of plant vegetative cover in the permanent plots in July 1991, so as to be sampled at the time of the year as the initial post spill cover values; and (2) measurement of *Spartina alterniflora* transplant survival at two elevations in oil impacted dieback areas to determine if the failure of certain areas to revegetate is due to a residual oil effect, or due to increased water depth inhibiting successful seedling establishment. From the mapping perspective, all acreage data will be assembled into a digital GIS and aerial data with respect to plant recovery will be squired and analyzed The goal is to begin to separate the effects of the oil spill on marsh deterioration from background rates (i.e., shoreline erosion).

PROJECT GOALS AND OBJECTIVES

This project is expanding on a previous short-term oil spill study in a brackish Louisiana marsh (Fig. la) which occurred in 1985. In the initial study, both photointerpretation of aerial imagery and ground based vegetation stress measurements were used to assess the near-immediate (within the first year) impact of the oil spill on the marsh vegetation. Oil spill impact studies to date have not documented potential spill impacts on a brackish marsh

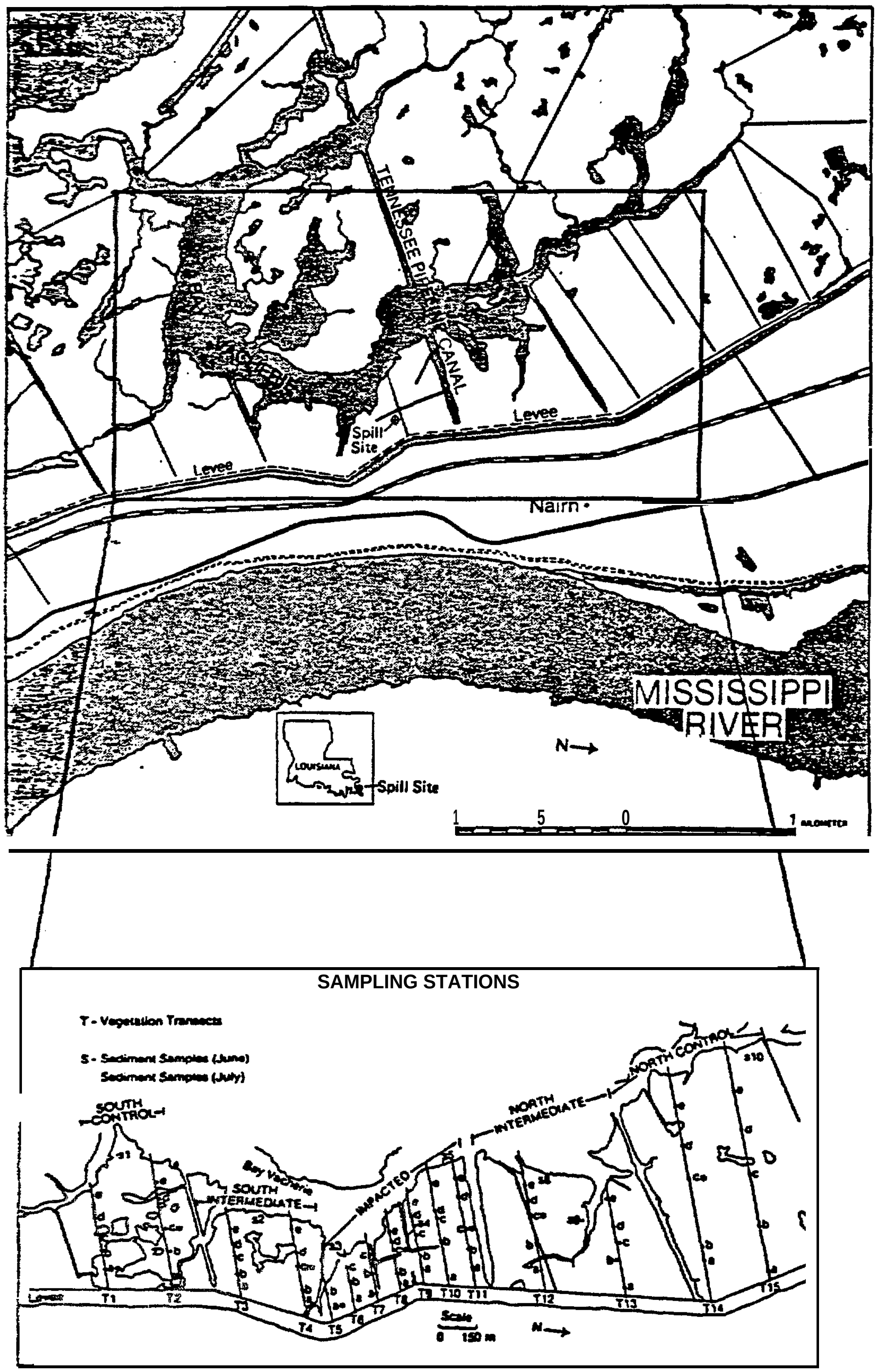
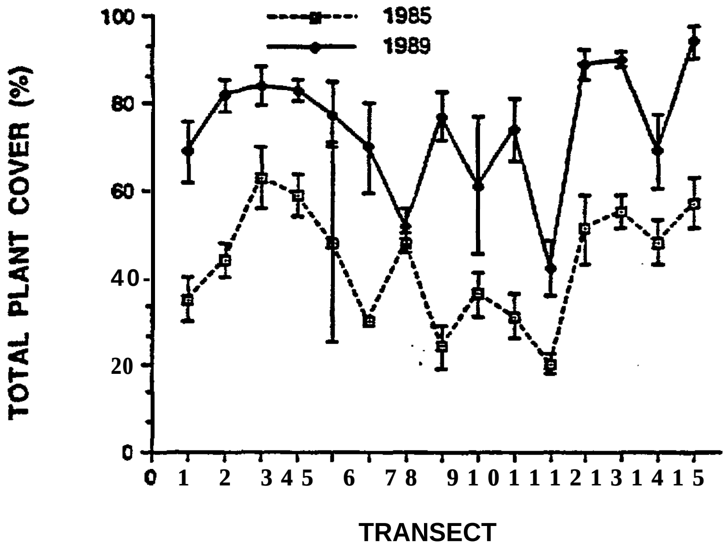


Figure 1a. Location of pipeline oil spill, vegetation sampling transects and plots and sediment sample sites. Sampling plots are indicated by letters a-e.

Figure 1. Total plant rover (live cover plus dead cover) by transect for the 1985 and 1989 sampling dates.



and have not assessed rates of recovery beyond one to three years. The overall goal of this investigation is to (1) document the long-term recovery rate of the oil-effected brackish marsh, (2) to separate the effect of the oil spill on marsh deterioration from ambient (background) rates of marsh degradation, and (3) to test revegetative means by which recovery can be accelerated and the damage mitigated.

The specific objectives of this three-year project areas follows: 1) document pm-spill land loss rates using historical aerial photography and field based vegetation stress analyses, 2) document post-spill rates of marsh recovery using recent aerial photography and vegetation stress analyses, 3) determine the effect of the oil spill on the study area's rate of deterioration, and 4) determine growth rates of transplanted marsh grasses in impacted areas for remediation strategy considerations. The specific objective for the first two years of study were to acquire historical aerial photography and map the study area, acquire new photography and map the study area, and conduct anon the ground recovery assessment of vegetative cover and plant photosynthetic response.

PROJECT PARTICIPANTS

All the major project participants are still involved in the project. Mr. Mark Hester and Dr. Irv Mendelssohn of the Laboratory for Wetland Soils and Sediments, LSU are conducting the field recovery assessments, and Mr. Wayne Grip of Aero Data Corporation and Dr. John Hill of the Houston Advanced Research Center are analyzing marsh recovery from remotely sensed data.

ACCOMPLISHMENTS TO DATE

Photointerpretation - Years 1 and 2

The two years of this project were used to conduct a national search of available historical imagery of the study area. Aero-Data Corporation (ADC), Baton Rouge, Louisiana conducted the above search. Twenty-nine (29) individual dates of historic and recent (new) imagery were located. Table 1 describes the summary of accessible and useful imagery (i.e., dates, scale, source, etc.). The initial goal was to acquire imagery of the study area that could be mapped for 8-10 year intervals. Unique events, such as very rapid rates of land loss, could then be singled out and added to the digital map database. Upon acquisition and visual assessment of the available imagery, nine (9) dates were selected for mapping and analysis (Table 1). Not all dates of historical imagery that were listed in the Year 1 annual report were accessible from the U.S. Army Corps of Engineers photographic archives in New Orleans, Louisiana and additional dates were located within NOAA/NOS.

The photographic mapping procedure was as follows:

1) The first step was to produce scaled and cropped 16 x 20" stereo graphic pairs for each selected date. A suitable scale was selected which enabled the full study area to be covered by a single 16" x 20" print. No attempt was de to round this off to an even number scale, as this would have caused the print to cover a larger area than necessary and would have reduced the scale of the prints and mapping accuracy.

A standard work print was produced from the 12/6/85 high altitude CIR photography, as this date was found to be the most distortion-free photograph of those in the date sequence. This date, thereby, was used as the baseline data set to register and map all other data sets. In the darkroom, the prints for all other dates were scaled, cropped, and leveled to produce the best possible match with the work print. All stereo pairs were produced in this manner.

Table 1. Available, appropriate historical and recent aerial photography acquired for this project.

	Photo Date	Photo Scale	Photo Type	Photo Source	Selected
1)	12/7/50	20,000	B&W	COE	Yes
2)	3/22/60	20,000	B&W	COE	Yes
3)	10/18/69	20,000	B&W	COE	Yes
4)	1 1/30/70	40,000	B&W	NOS	Yes
5)	3/17/72	121,031	CIR	NASAJS	No
6)	10/17/74	118,000	CIR	NASAJS	No
7)	10/15/78	64,375	CIR	EROS	Yes
8)	1/24/'82	36,000	Color	NOS	Yes
9)	6/13/85	12,000	CIR	Aero-Data	Yes
10)	12/6/85	64,500	CIR	EROS	No
11)	10/15/86	12,000	CIR	Aero-Data	Yes
12)	1/17/89	65,000	CIR	EROS	No
13)	6/24/90	12,000	Color	Aero-Data	Yes
14)	10/20/90	12,000	CIR	Aero-Data	No

2) Mapping began by generating a baseline control map from the 12/6/85 photography. A clear overlay was placed over one of the stereo pairs and using a stereoscope, each polygon was interpreted and traced using a colored Pilot permanent SC-UF pen. Particular attention was given to the shoreline details. Appropriate control points and a coordinate system were next added to the overlay by transferring to the overlay photoidentifiable points from the USGS quadrangle sheet (scale; 1:24,000) of the area.

The overlay was next placed on a digitizing tablet where registration points were entered into the AutoCad map file. The overlay information was digitized and a clear plot was generated on 5 mil mylar film. The overlay was then placed back on the print and edited. The final edited 1985 overlay was then used as the control overlay for all other dates as they were interpreted In this way the interpretations for all dates were kept within an accurate geographic registration system. As a result of this control system, later change detection calculations will reflect actual spatial changes taking place within the study area rather than changes caused by miss-registration of small polygons.

3) The first comparative date to be interpreted and mapped in detail was the Aero-Data flight of 6/13/85. The 1985 baseline overlay with its features was registered to the much higher resolution CIR print showing the site two weeks after the spill. Each mapped polygon was then traced on the overlay with the aid of a stereoscope.

The overlay was then placed on a digitizing tablet and digitally registered Each polygon was then digitized and color coded to show the the type of mapping category. Each mapping category was assigned a separate data layer and color for each date. The coordinate grid and title block was common for all dates interpreted. The mapping categories agreed upon and to be utilized in the final report are as follows:

Mapping Category	Color	Description
Baywater	blue	Open water connected to the bay
Canwater	blue/hatched	Water from canal dredging or associated erosion
Intwater	brown	Interior water bodies in the marsh
Veg	green	Marsh with 50% or greater vegetation cover
Spoilbank	red/hatched	Areas where spoil was placed
Levee	red	Areas where the levee was located

If a canal widened into an interior water body, the interior water remains interior water. Maps will likely be enlarged to visually discern mapped categories in the final report.

The information digitized was next plotted at the same scale as the photograph, placed on the photograph and, edited. After all corrections were made, the plot was produced once again, this time at the precise scale of the next date in the photointerpretation sequence.

4) The detailed and edited 6/13/85 interpretation overlay had many details that precisely matched the features seen in the next date further in the past (1/24/82). This allowed for accurate registration of the control overlay (1985) to the 1982 stereo prints. Interpreters could then identify and reinterpret the polygons which had changed, appeared or disappeared between the two dates. Once interpretation was completed for a specific date, the information was digitized, plotted, and edited. In editing, both dates were reviewed to assure that mapping was consistent through all dates and that depicted changes were supported by the photography. Close attention was also placed in the association of visible changes with logical sequences of marsh processes.

5) In the same manner described above, all dates were interpreted, mapped, and registered to one another both prior to and after the starting date of 6/13/85. This was accomplished by using the previously interpreted and plotted overlay for each date as control. It was necessary to reinterpret and digitize the dates previously studied in the original or initial oil spill study, because earlier interpretations did not match the mapping accuracy obtainable with these methods.

Soil and Vegetation Recovery - Years 1 and 2

We have completed our primary objective for years 1 and 2 which were to (1) assess the recovery of the vegetation and soil in permanent plots that were established in July of 1985, and (2) measure net CO_2 exchange rates of vegetation in oil-impacted and non-impacted (control) plots.

The 68 randomly selected permanent plots, which were marked by white PVC pipes placed vertically in the ground, were sampled for vegetation cover in November 1989. At each

1.0 m^2 permanent plot the following data were collected (1) live plus dead percent vegetative cover, (2) percent vegetative cover of the live vegetation by species, (3) percent vegetative cover of the dead vegetation (not differentiated by species), and (4) oil *presence* on the soil and vegetation. Two other parameters were mathematically derived (1) adjusted live percent cover= live percent cover x (100% cover/% total cover) and (2) adjusted dead percent cover = dead percent cover x (100% cover/% total cover). These parameters adjust the live and dead percent cover to values based on 100% cover of the plot, thus natural differences in degree of total cover among plots were normalized In addition, soil samples of the surface 10 cm were collected for petroleum hydrocarbon analyses. A subsample of five of these soil samples, ranging in initial oil impact from heavily oiled to control, were analyzed by Dr. Jay Means of the Department of Environmental Sciences, LSU.

In August, 1990 plant photosynthetic response was measured in 24 selected permanent plots in order to determine if any subtle effect of the oil was still present. The criteria for plot selection was that both *Spartina patens* and *Spartina alterniflora be* present, and that percentage cover by these two species be at least 10% for *Spartina patens* and 5% for *Spartina alterniflora.* Pairs of oiled and control plots were then established such that percentage covers were similar within a pair. From this set, 12 pairs of oiled plots (ten plots with initial oil impact rating of 3 and two plots with an initial rating of 2) and control plots (all with initial oil impact rating of O) were randomly selected. Plant photosynthetic response (net CO_2 exchange rate) was measured on leaves of *Spartina patens* and *Spartina alterniflora in* each plot using a portable infrared gas analyzer (Analytical Development Company, Herts, England; model LCA-2). Sampling of control and oiled plots was alternated every two plots to reduce the possibility of any diurnal fluctuations in photosynthesis from interfering with treatment responses. Soil cores were also collected at each plot and preserved under an anaerobic atmosphere (N_2 gas) for sulfide, pH, and salinity analysis. Redox potential (Eh) was measured at the marsh surface and at 15cm depth using brightened platinum electrodes and adjusted for the potential of the calomel reference electrode. Vegetative cover by species was also measured as described above.

PROBLEMS OR DELAYS ENCOUNTERED AND PROPOSED SOLUTIONS

We have not encountered, *nor* do we anticipate any problems or delays, in this research effort.

SIGNIFICANT FINDINGS

Field Acquired Analyses

Data for the 1985 and 1989 plant cover categories and oil impact index are summarized in Table 2 by marsh area. Significant year differences (1%.05) were detected for total plant cover (live plus dead percent cover), adjusted live percent cover, adjusted dead percent cover, and oil impact index (Table 2). In generaI, these significant year effects can be attributed to increases in total and adjusted live percent cover (Figs. 3 and 4) and decreases in adjusted dead percent cover and oil impact index from 1985 to 1989 (Figs. 5 and 6; Table 2). It is important to note that in 1989 there were no longer any significant main effects due to marsh area, whereas the 1985 data consistently showed an oil effect and reduction in plant cover in the impacted area compared to the intermediate and control areas (Table 1: Figs. 4 and 6). In 1989 there were no longer any visual signs of oil on the vegetation or the marsh surface (Fig. 6).

Although the impacted area doubled in total percent cover from 1985 to 1989, the other areas also showed an increase in total percent cover (Table 2; Fig. 3). This increase in total

Table 2. Total percent cover (TPC), adjusted live percent cover (ALPC), adjusted dead percent cover (ADPC), and oil impact index (011) by marsh area for 1985 and 1989.

		Variable							
		T P c .		ALPC		ADPC		011	
Marsh Area	n	1985	1989	1985	1989	1985	1989	1985	1989
North Control	10	53 ab[1]	82a	63a	84a	37 b	16a	0.00 b	0.00 a
North Intermediate	10	53 ab	90a	83a	85a	17 b	15a	0.00 b	0.00 a
Impacted	28	32c	64a	28 b	80a	72a	16a	2.27 a	0.00 a
South Intermediate	10	61 a	84a	77a	83a	23 b	17a	0.05 b	0.00 a
South Control	10	4obc	76a	88a	85a	12 b	15a	0.10 b	0.00 a

[1] Column means followed by the same letter are not significantly different (P>.05) based on a Duncan's Multiple Range Test.

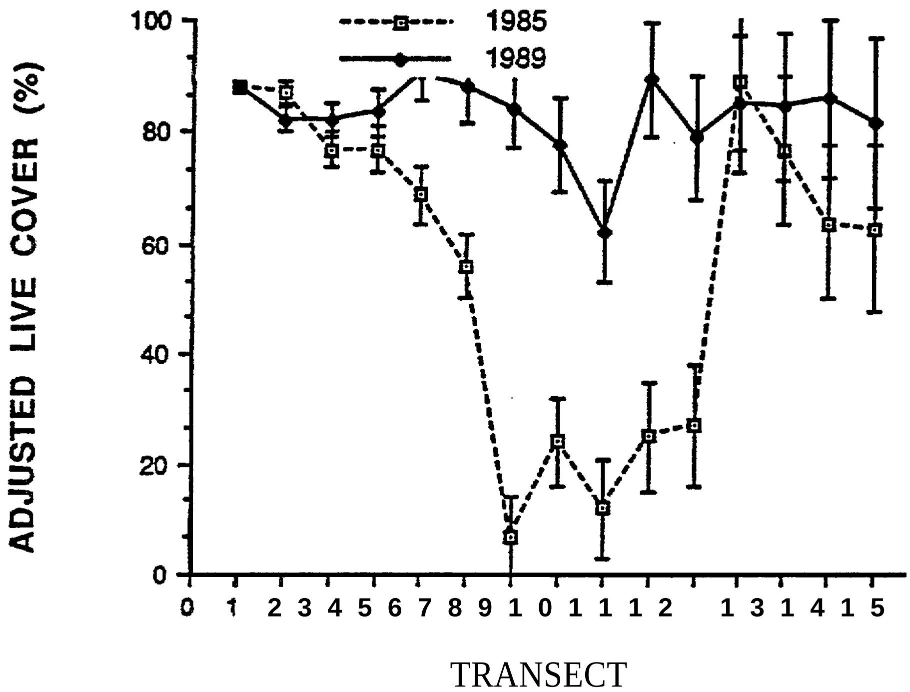


Figure 2. Adjusted live plant cover (100% x live cover/total cover) by transect for the 1985 and 1989 sampling dates.

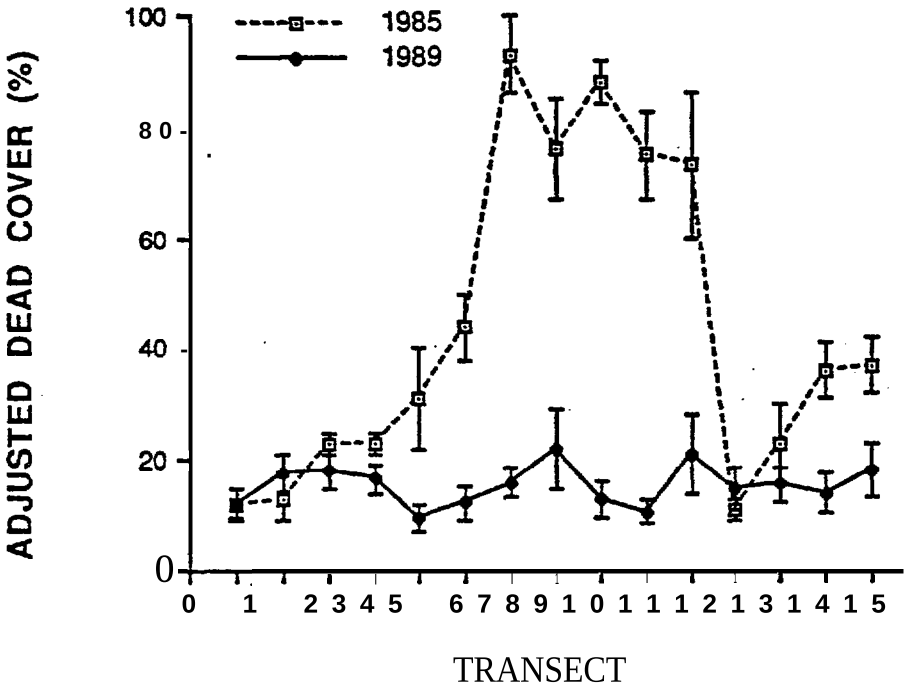


Figure 3. Adjusted dead **plant** cover (100% x dead cover/total cover) by transect for the 1985 and 1989 sampling dates.

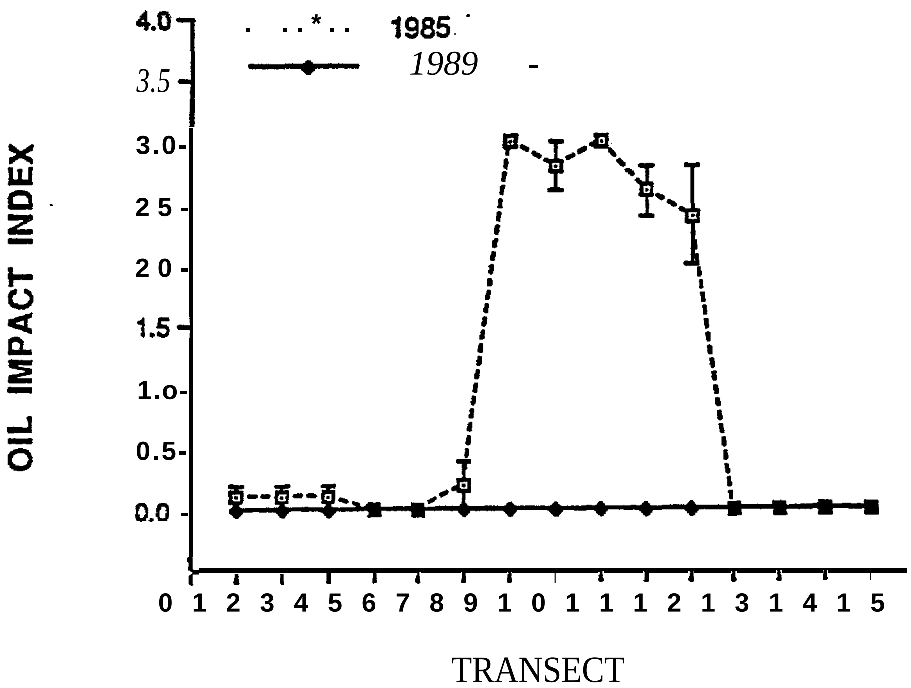


Figure 4. Oil impact index by transect for the 1985 and 1989 sampling dates.

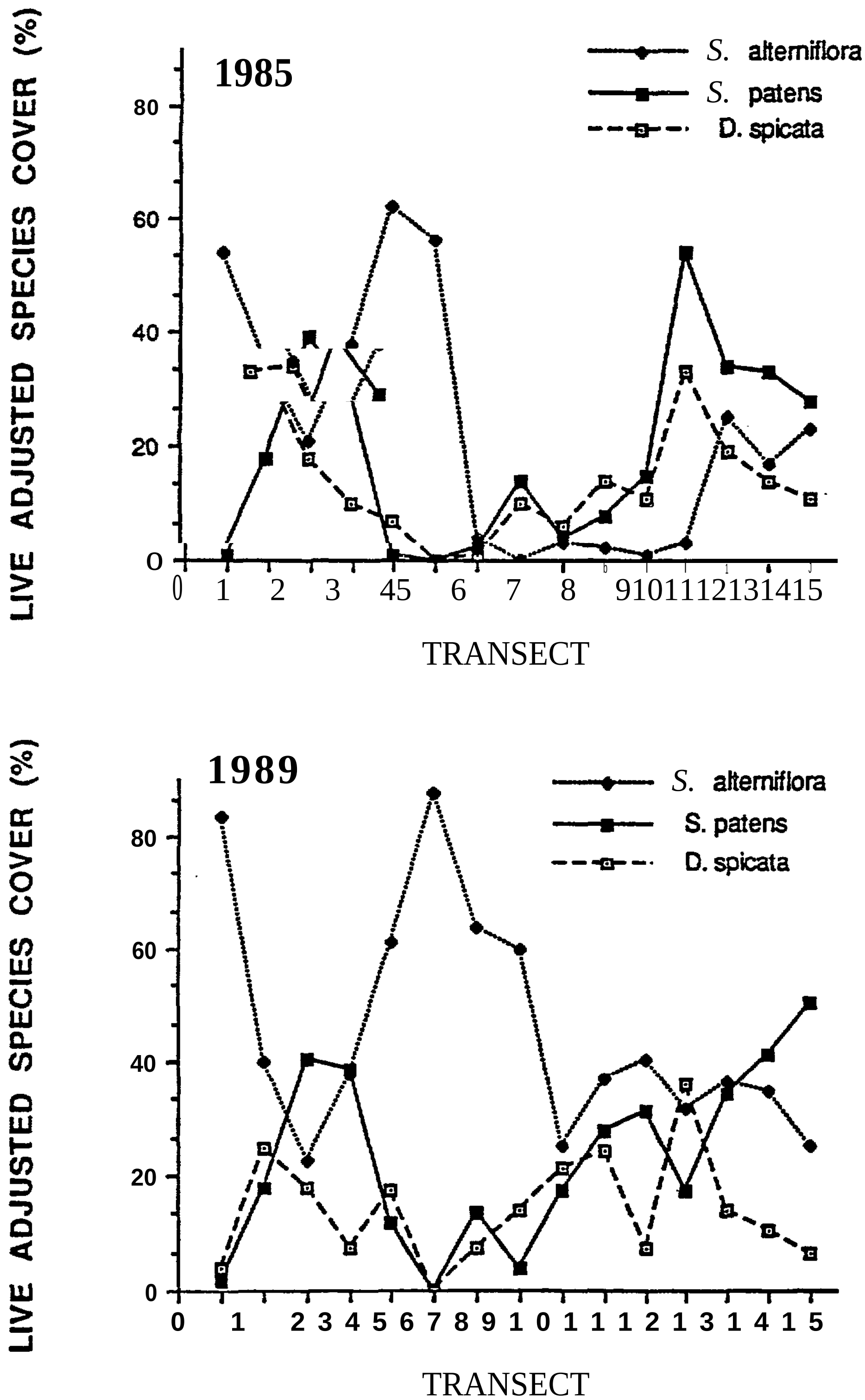


Figure 5. Live adjusted species cover by transect for the 1985 and 1989 sampling dates.

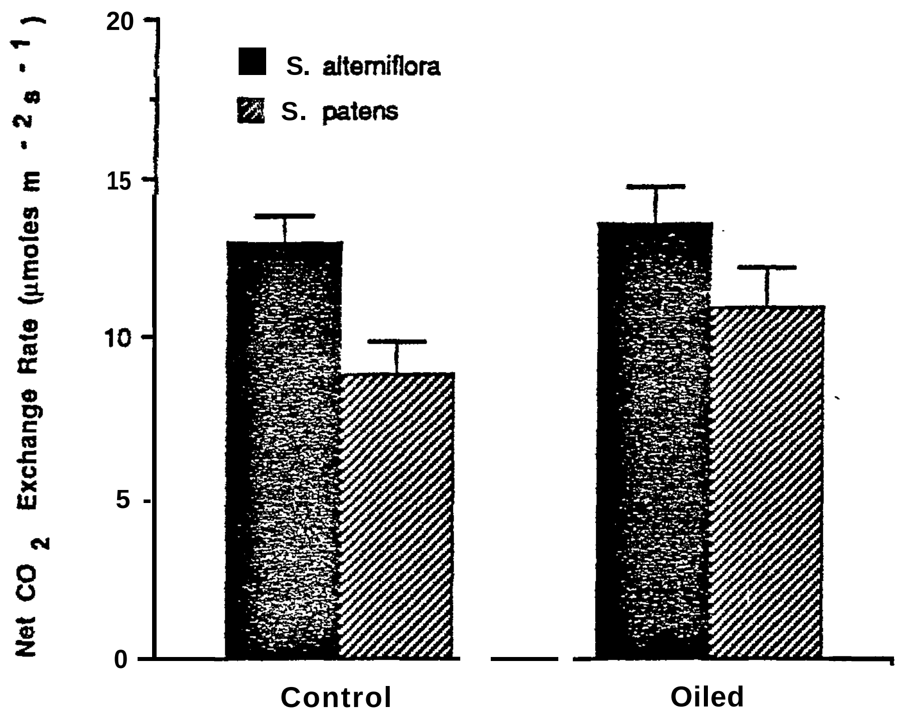


Figure 6. Plant photosynthetic response (mean net CO_2 exchange rate with standard error) of *Spartina alterniflora* and *Spartina patens in* control and oiled plots (August 1990; n = 12).

percent cover in the intermediate and control areas maybe a seasonal effect, since the 1985 data were collected earlier in the growing season (July) than the 1989 data, which were collected at the end of the growing season (November) when total cover would be expected to be near the yearly maximum, Our final survey of the vegetation will be scheduled in July so as to alleviate the possibility of any seasonal effects.

Despite the lack of a significant main effect due to marsh area in the 1989 data, *a priori* single-degree-of-freedom contrasts that compare the impacted area to the intermediate and control areas still show a significant reduction in total percent cover and live percent cover, but not adjusted live percent cover in the impacted area. This is interpreted to mean that although the impacted area has not attained as high a percentage of total plant cover as the other areas, the proportion of live healthy vegetation in the impacted area is comparable to the other areas, and is indicative of recovery. The recovery of the vegetation in the impacted area is more clearly evident from the increase in adjusted live percent cover (Fig. 4) and decrease in adjusted dead percent cover in the impacted area (Fig. 5) between 1985 and 1989, while the other areas did not change appreciably. Highly significant ($P<.01$) area-by-year interactions for these two variables support this statement.

Overall trends in species cover values in 1989 were similar to those in 1985 (Fig. 7). The same three species (*Spartina alterniflora*, *Spartina patens*, and *Distichlis spicata*) *were* present in the plots, but *Spartina alterniflora* displayed the greatest increase in live adjusted percent cover in the 1989 impacted area transects (transects 5-11; Fig. 7). *Spartina patens* and *Distichlis spicata also* showed some increase in live adjusted percent cover in the 1989 impacted area transects (Fig. 7).

Hydrocarbon analysis of the subsample of soil cores collected in November 1989 showed that of the three cores collected from oil-impacted plots, 11-C and 1O-A had higher levels of total saturated hydrocarbons (134,000 to 160,000 ppb) than the control cores from 2-C and 14-C (20,000 to 42,000 ppb; Table 3). However, the total saturated hydrocarbons of 9-C (54,000) also an oil impacted plot, did not show as much of increase over the control levels (Table 3). Interestingly, 9-C and 11-C both showed trace amounts of Cl, C2, and C3-dibenzothiophene (characteristic substitution products of parent dibenzothiophene in weathered oil) whereas 14-C did not have detectable levels of these compounds, despite the fact that it had the greatest total saturated hydrocarbon value. We plan to have more of these cores analyzed over the next year.

Plant photosynthetic response (net C02 exchange rate) showed no significant differences between oiled and control plots for either *Spartina alterniflora or Spartina patens* (Figure *8).* Unadjusted live percentage cover was significantly greater in the control plots (Figure 9). However, all other plant cover values (total cover, dead cover, adjusted live cover) were not significantly different between oiled and control plots (Figure 9). Similarly, there were no significant differences between plots in interstitial water pH, salinity, and sulfide, or soil Eh (Figure 10). Similarity of plant covers between oiled and control plots was desirable to ensure that our comparison of photosynthetic response was not affected by differences in plot vegetation composition, and therefore was a valid test of any residual oil effect.

Photointerpretive Analyses

The following represent the initial visual findings resulting from the detailed photointerpretation and mapping of historical and recent aerial imagery of the study area:

A) Shoreline erosion at the site is rather constant from 1950 to the present (1990), averaging approximately 50 feet during the forty (40) year project period. The actual amount varies from area to area.
B) Internal marsh breakup was almost nonexistent through 1970 (Figs. 9 and 10). By

Table 3. Total saturated hydrocarbons (1 1/89), initial plot oil impact index (7/85), and initial total and dead percentage vegetative cover (7/85) from a subsample of five representative plots.

Plot	Total Saturated Hydrocarbons (ppb)	Initial Oil Impact Index	Initial Total Vegetative Cover (%)	Initial Dead Vegetative Cover (%)
2-c	42,000	0.0	55	5
14-C	20,000	0.0	35	10
1 1-C	134,000	2.0	15	10
9-C	54,000	3.0	35	32
10-A	160,000	3.0	50	50

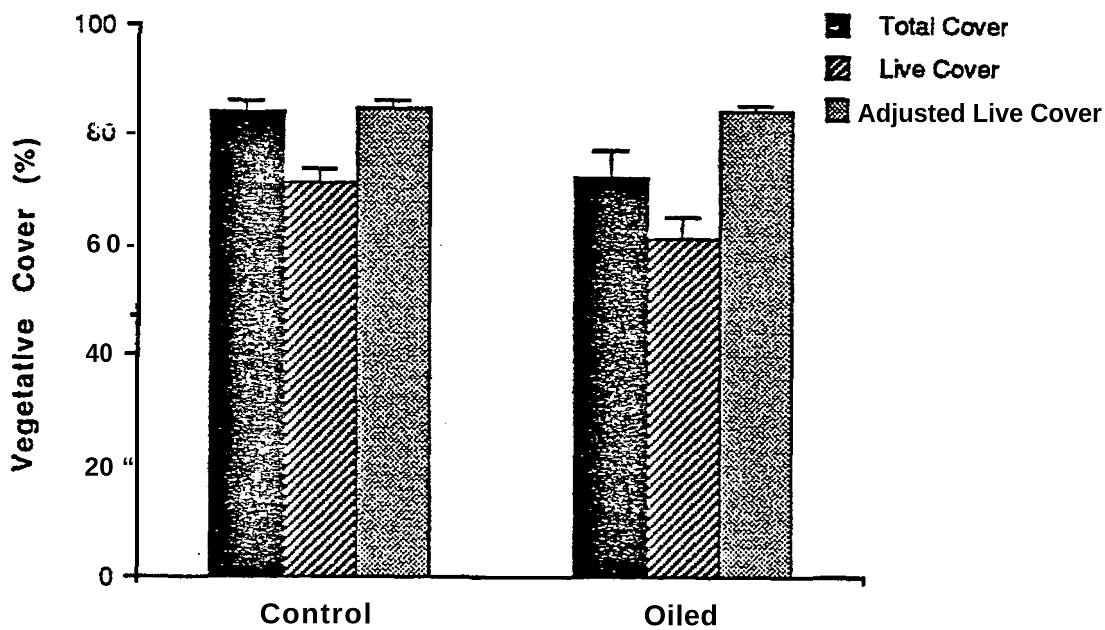


Figure 7. Total, live, and adjusted live vegetative cover (mean with standard error) in the control and oiled plots used in assessing plant photosynthetic response (August 1990; n = 12).

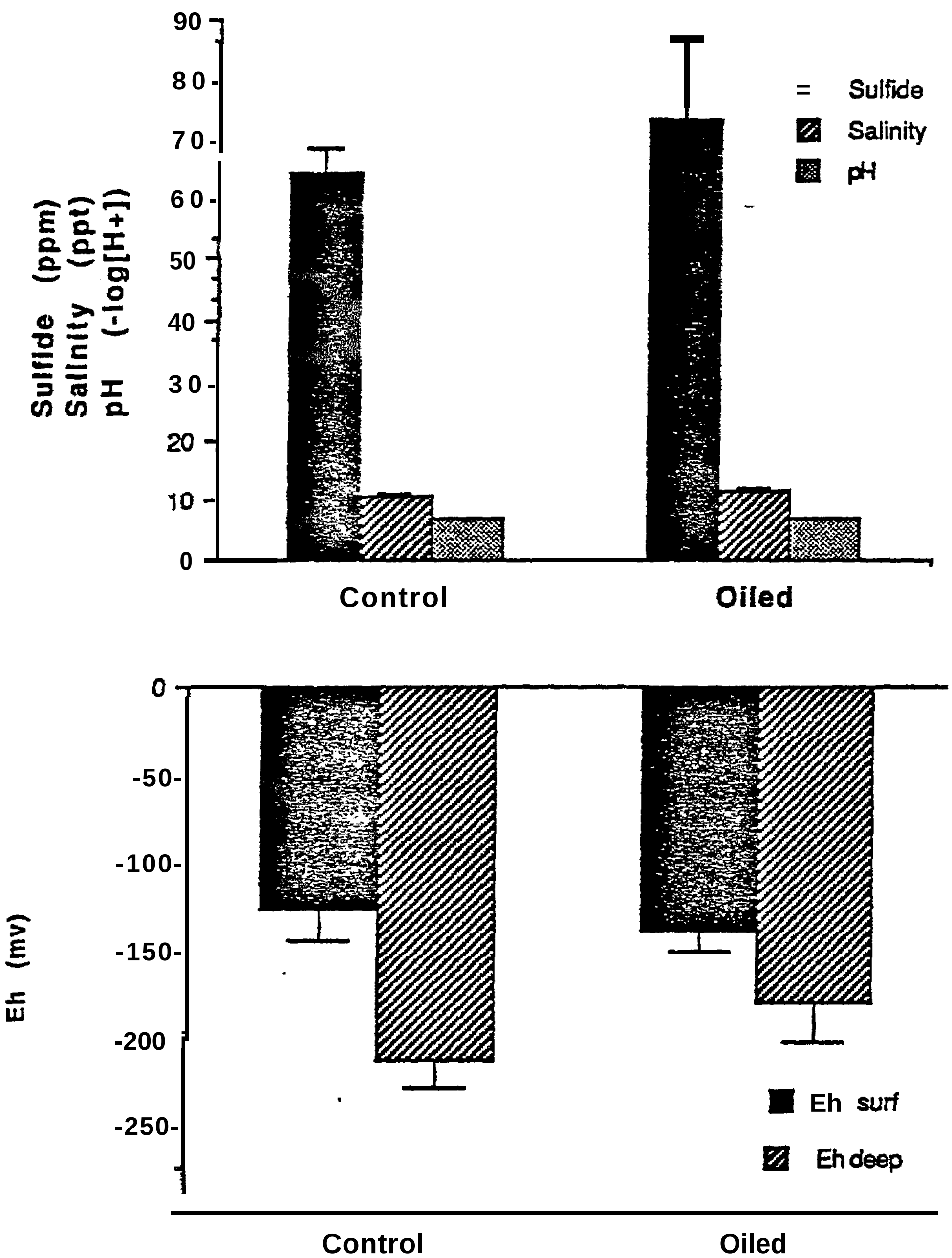
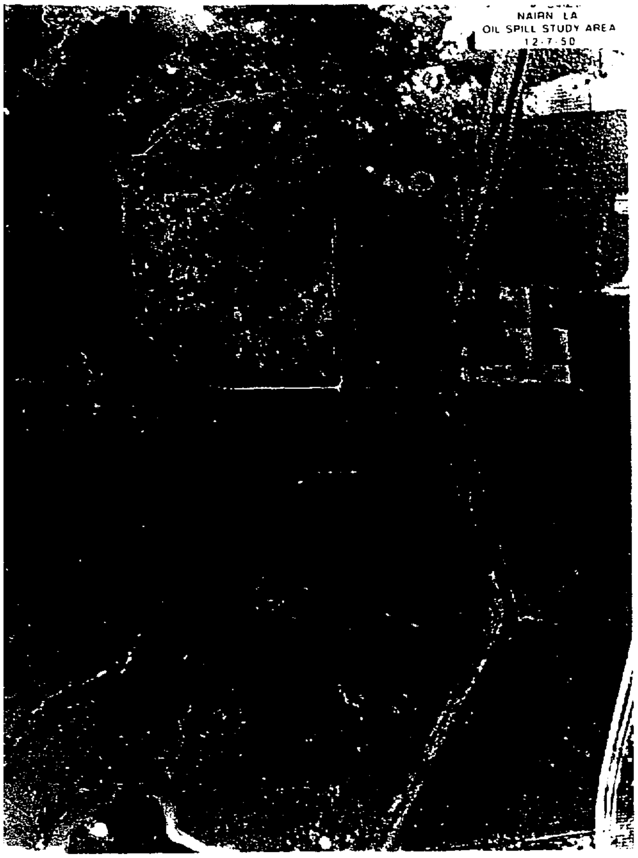


Figure 8. Interstitial water sulfide, **salinity**, and **pH**, and **soil redox** potential (mean **with** standard error) in the control and oiled plots used in assessing **plant** photosynthetic response *(August* 1990; n = 12).

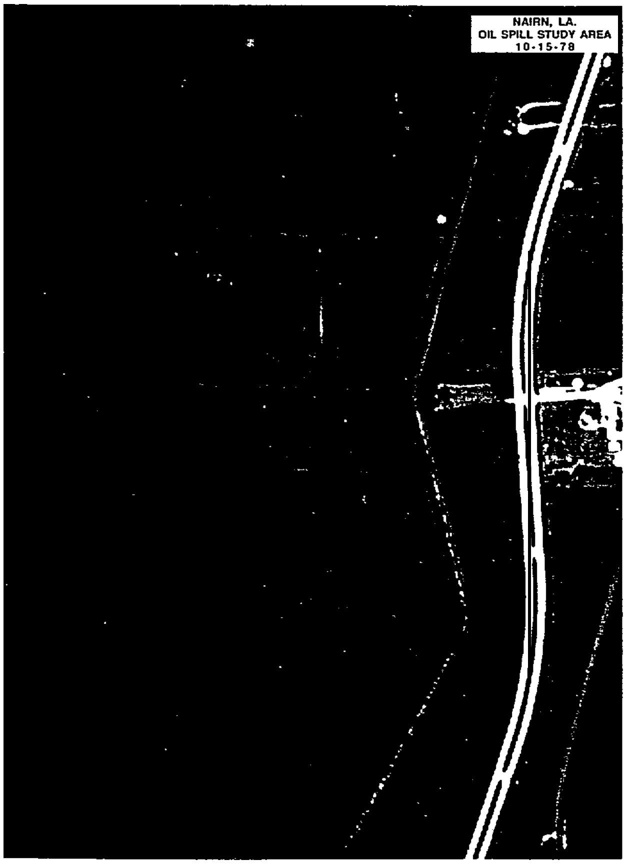
Figure 9. Examples of historical and recent aerial photography which were acquired and assessed with respect to photointerpretation and mapping requirements (1950-1985).

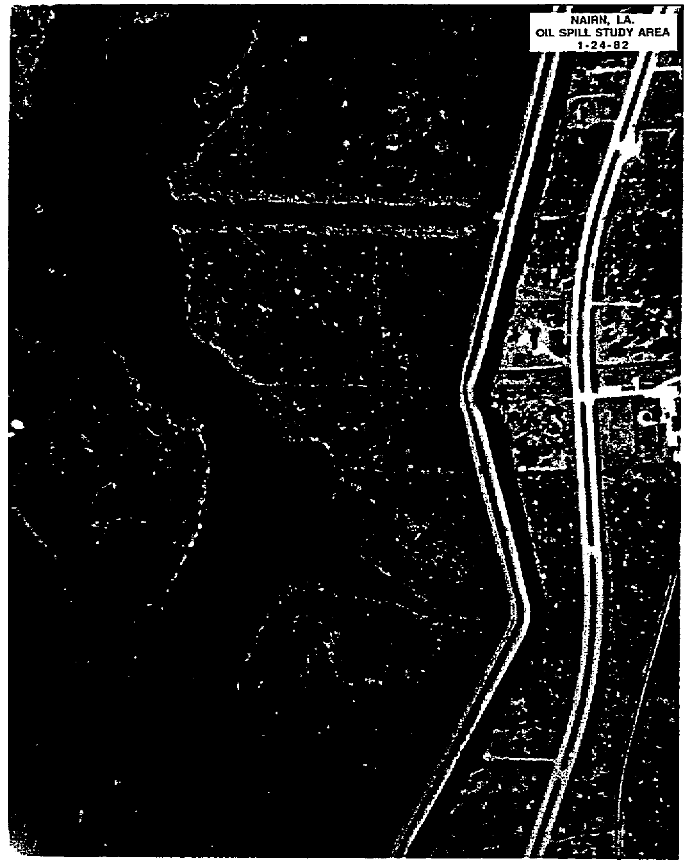

NAIRN LA
OIL SPILL STUDY AREA
12-7-50


NAIRN LA
OIL SPILL STUDY AREA
3-22-60


NAIRN LA
OIL SPILL STUDY AREA
10-18-69


NAIRN LA
OIL SPILL STUDY AREA
11-30-70


NAIRN, LA.
OIL SPILL STUDY AREA
10-15-78


NAIRN, LA.
OIL SPILL STUDY AREA
1-24-82

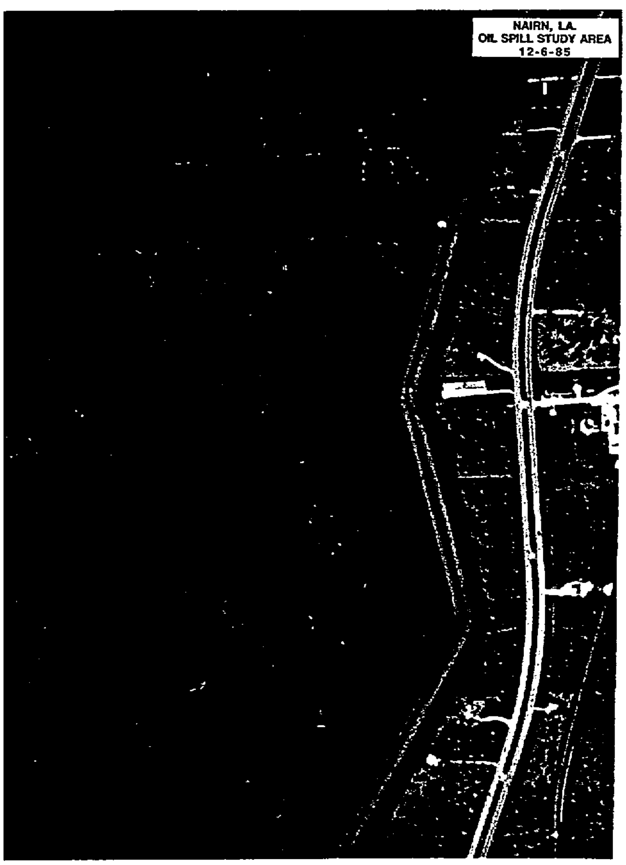
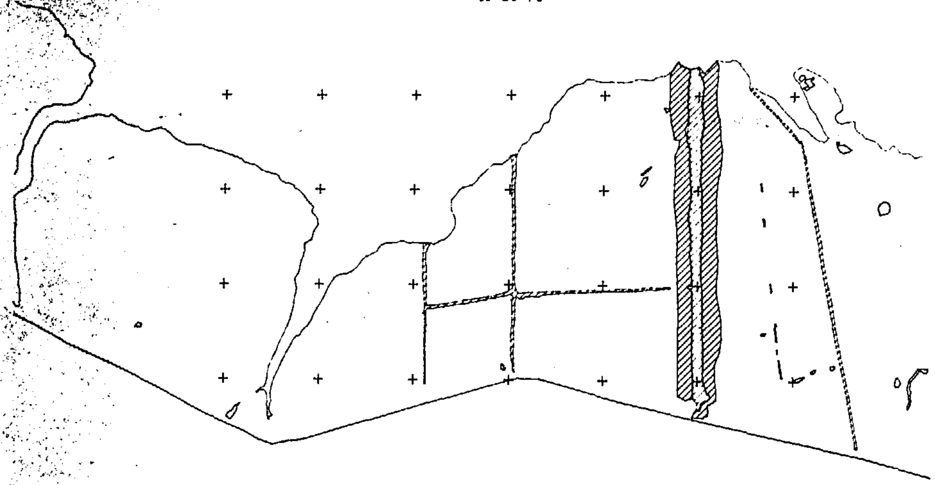
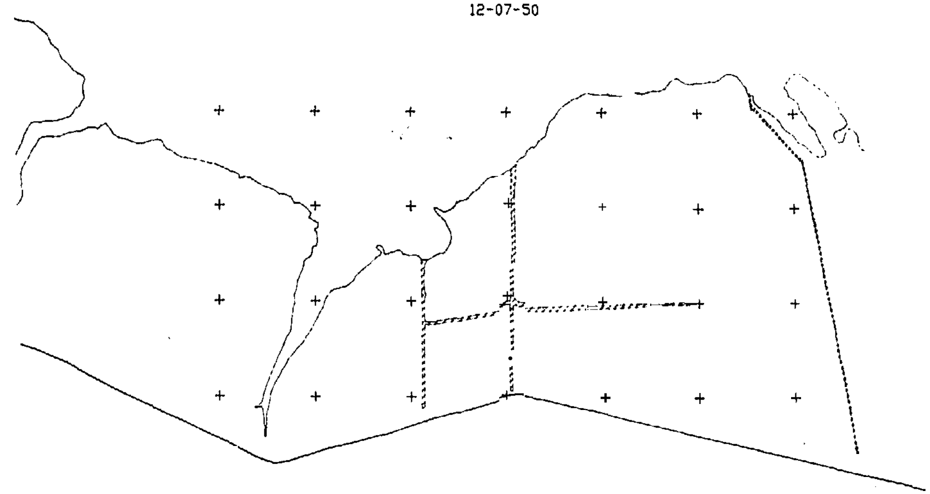

NAIRN, LA.
OIL SPILL STUDY AREA
12-6-85

Figure 10. Examples of photointerpreted maps which represent historical and recent marsh conditions in and around the spill site (19501990).

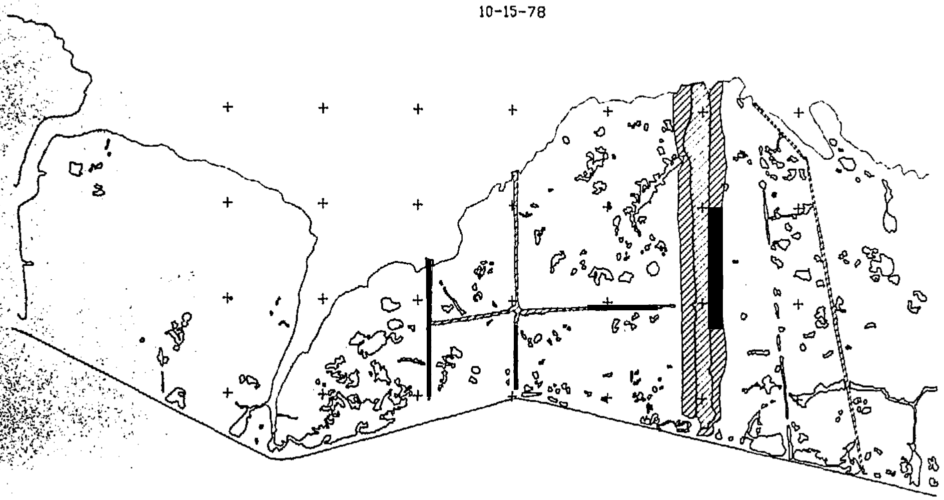
OIL SPILL STUDY
NAIRN, LOUISIANA
11-30-70



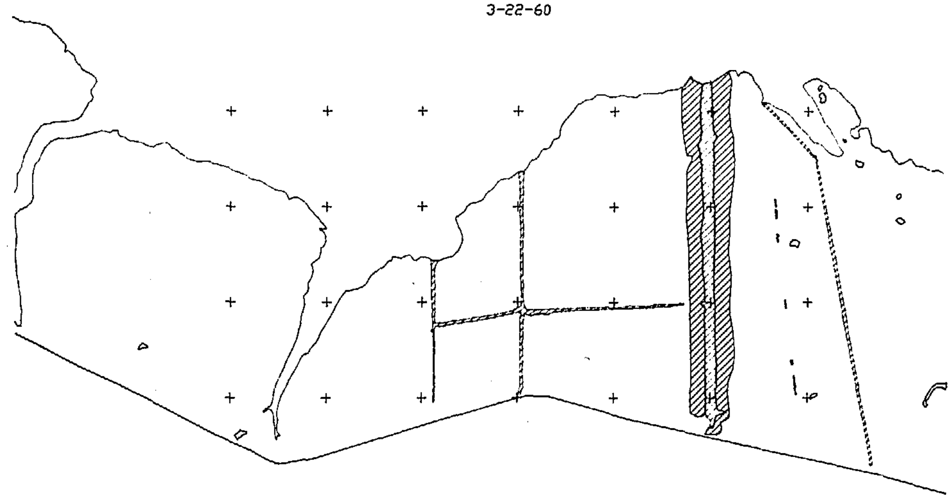
OIL SPILL STUDY
NAIRN, LOUISIANA
12-07-50



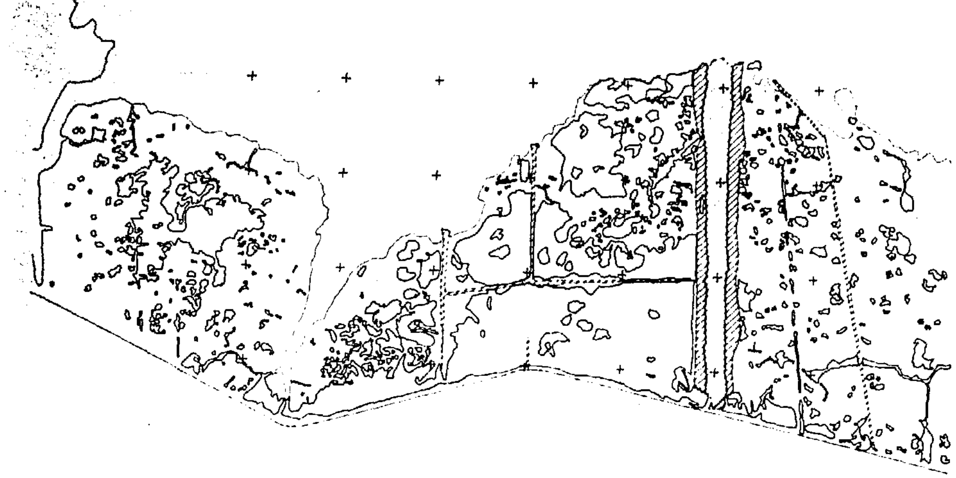
OIL SPILL STUDY
NAIRN, LOUISIANA
10-15-78



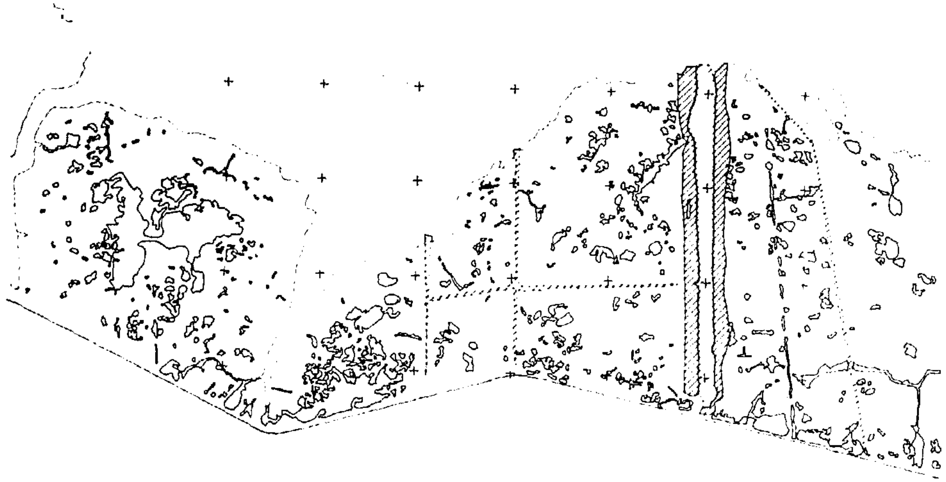
OIL SPILL STUDY
NAIRN, LOUISIANA
3-22-60



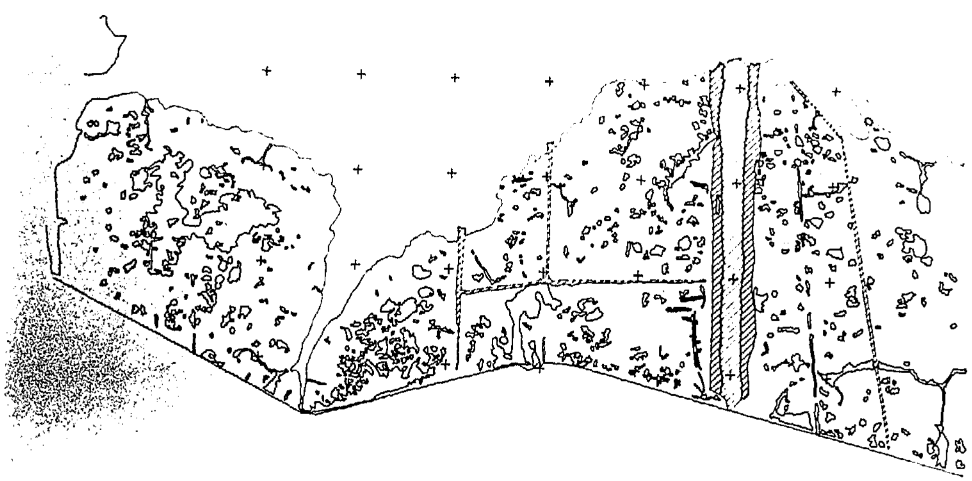
OIL SPILL STUDY
NAIRN, LOUISIANA
10-15-86



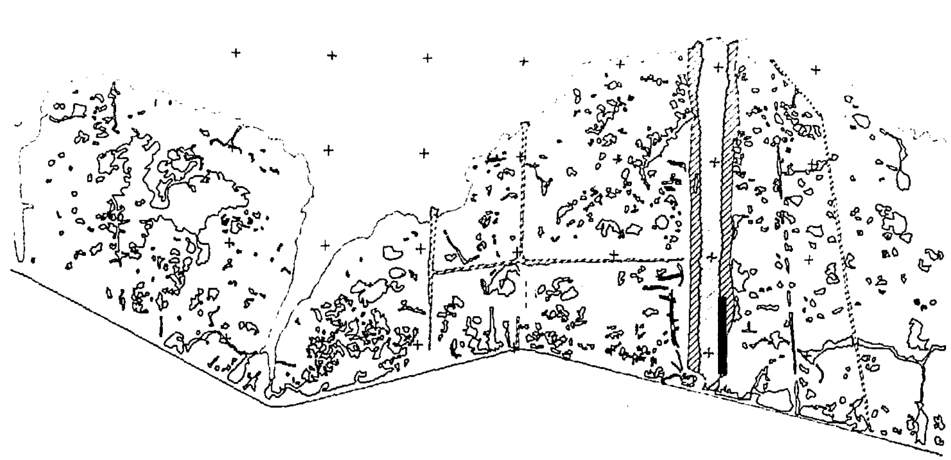
OIL SPILL STUDY
NAIRN, LOUISIANA
1-24-82



OIL SPILL STUDY
NAIRN, LOUISIANA
6-24-90



OIL SPILL STUDY
NAIRN, LOUISIANA
6-13-85



1978, a significant amount of marsh loss had occurred. Therefore, the historical imagery also revealed that portions of the impacted marsh and surrounding area appeared to have been in various stages of deterioration before the spill occurred.

C) The 1985 oil spill had caused a significant amount of marsh dieback by 1986. Marsh dieback continued from the first flight after the oil spill in 6/13/85 until 1986. However, by 10/20/90 a significant amount of plant regrowth had occurred in the areas where water depth tended to be shallow (as indicated by mud flats in imagery acquired at low tide).

D) Background internal marsh loss (except for that caused by canal dredging) and shoreline erosion appeared to have slowed considerably since 1982 (Figs. 9 and 10).

RELATED PUBLICATIONS AND PRESENTATIONS

Presentations

Mendelssohn, I. A., J. Hill, and M.W. Hester. "Long-term recovery of a brackish marsh from an oil spill in coastal Louisiana." December 5, 1989. Minerals Management Service Information Transfer Meeting, Gulf of Mexico OCS Region, New Orleans, LA.

Mendelssohn, I. A. "Oil effects on wetlands." January 31, 1990. Louisiana Environmental Health Association, 1990 Annual Education Conference, Alexandria, LA.

Publications

Mendelssohn, I. A., M. W. Hester, C. Sasser, and M. E. Fischel. 1990. The effect of a Louisiana crude oil discharge from a pipeline break on the vegetation of a southeast Louisiana Brackish marsh. Oil and *Chemical Pollution* 7:1-15.

REVISED SCHEDULE

No revisions in the project schedule are necessary.