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Shoreline Surveys of Oil-Impacted Marsh in Southern Louisiana, July to August 2010

By Raymond F. Kokaly, David Heckman, JoAnn Holloway, Sarai Piazza, Brady Couvillion, Gregory D. Steyer, Christopher Mills, and Todd M. Hoefen

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Shoreline Surveys of Oil-Impacted Marsh in Southern Louisiana, July to August 2010

By Raymond F. Kokaly,[1] David Heckman,[2] JoAnn Holloway,[1] Sarai Piazza,[2] Brady Couvillion,[2] Gregory D. Steyer,[2] Christopher Mills,[1] and Todd M. Hoefen[1]

Abstract

This report describes shoreline surveys conducted in the marshes of Louisiana in areas impacted by oil spilled from the Deepwater Horizon offshore oil drilling platform in the Gulf of Mexico. Three field expeditions were conducted on July 7-10, August 12-14, and August 24-26, 2010, in central Barataria Bay and the Bird's Foot area at the terminus of the Mississippi River delta. This preliminary report includes locations of survey points, a photographic record of each site, field observations of vegetation cover and descriptions of oil coverage in the water and on plants, including measurements of the distance of oil penetration from the shoreline. Oiling in Barataria Bay marshes ranged from lightly oiled sections of stems of the predominant species *Spartina alterniflora* and *Juncus roemerianus* to wide zones of oil-damaged canopies and broken stems penetrating as far as 19 m into the marsh. For the 34 survey points in Barataria Bay where

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dimensions of oil damaged zones were measured, the depth of the oil-damaged zone extended, on average, 6.7 m into the marsh, with a standard deviation of 4.5 m. The median depth of penetration was 5.5 m. The extent to which the oil-damaged zone stretched along the shore varied with location but often extended more than 100 m parallel to the shoreline. Oil was observed on the marsh sediment at some sites in Barataria Bay. This oiled sediment was observed both above and a few centimeters below the water surface depending on the level of the tide. *Phragmites australis* was the dominant vegetation in oil-impacted zones in the Bird's Foot area of the Mississippi River delta. Oiling of the leaves and portions of the thick stems of *P. australis* was observed during field surveys. In contrast to the marshes of Barataria Bay, fewer areas of oil-damaged canopy were documented in the Bird's Foot area. In both areas, oil was observed to be persistent on the marsh plants from the earliest (July 7) to the latest (August 24) surveys. At sites repeatedly visited in Barataria Bay over this time period, oiled plant stems and leaves, laid over by the weight of the oil, broke and were removed from the vegetation canopy, likely due to tidal action. In these areas, a zone of 2-5 cm high plant stubble remained at the edge of the marsh. Signs of both further degradation and recovery were observed and varied with site. Oil damage to the marsh at some sites resulted in complete reduction of live vegetation cover and erosion of exposed sediments, while other damaged zones had signs of regrowth of vegetation in up to 10 percent of the areal coverage.

Introduction

More than 500 km of Louisiana's marsh shoreline has been oiled from the MC-252 incident, including over 100 km of heavy to moderate oiling (http://www.fws.gov/home/dhoilspill/). The physical and chemical effects of oil spills can have both short- and long-term impacts on wetland function, including the interruption of benthic

biogeochemical processes and decreased primary production (Lin and Mendelssohn, 1996; Pezeshki and others, 2000). The loss of habitat integrity could occur with these changes (Lin and Mendelssohn, 2009). Oil contamination can decrease primary production, leading to plant mortality, and increase susceptibility to marsh collapse (Ko and Day, 2004).

The field surveys were intended to document the extent of oil coverage, inventory the plant species affected, assess the initial impact, and serve as validation data for remote sensing studies. They were a collaborative effort by the USGS-National Wetlands Research Center Coastal Restoration Field Station (NWRC-CRFS, Baton Rouge, LA) and the USGS Crustal Geophysics and Geochemistry Science Center (Denver, CO). Three field expeditions were conducted, July 7-10, August 12-14, and August 24-26, 2010. Two areas were surveyed, in order to assess conditions over a range of vegetation types: central Barataria Bay and the Bird's Foot area at the terminus of the Mississippi River delta, hereafter Bird's Foot delta (fig. 1). Central Barataria Bay was visited during all three surveys but the Bird's Foot delta was surveyed in only the first two.

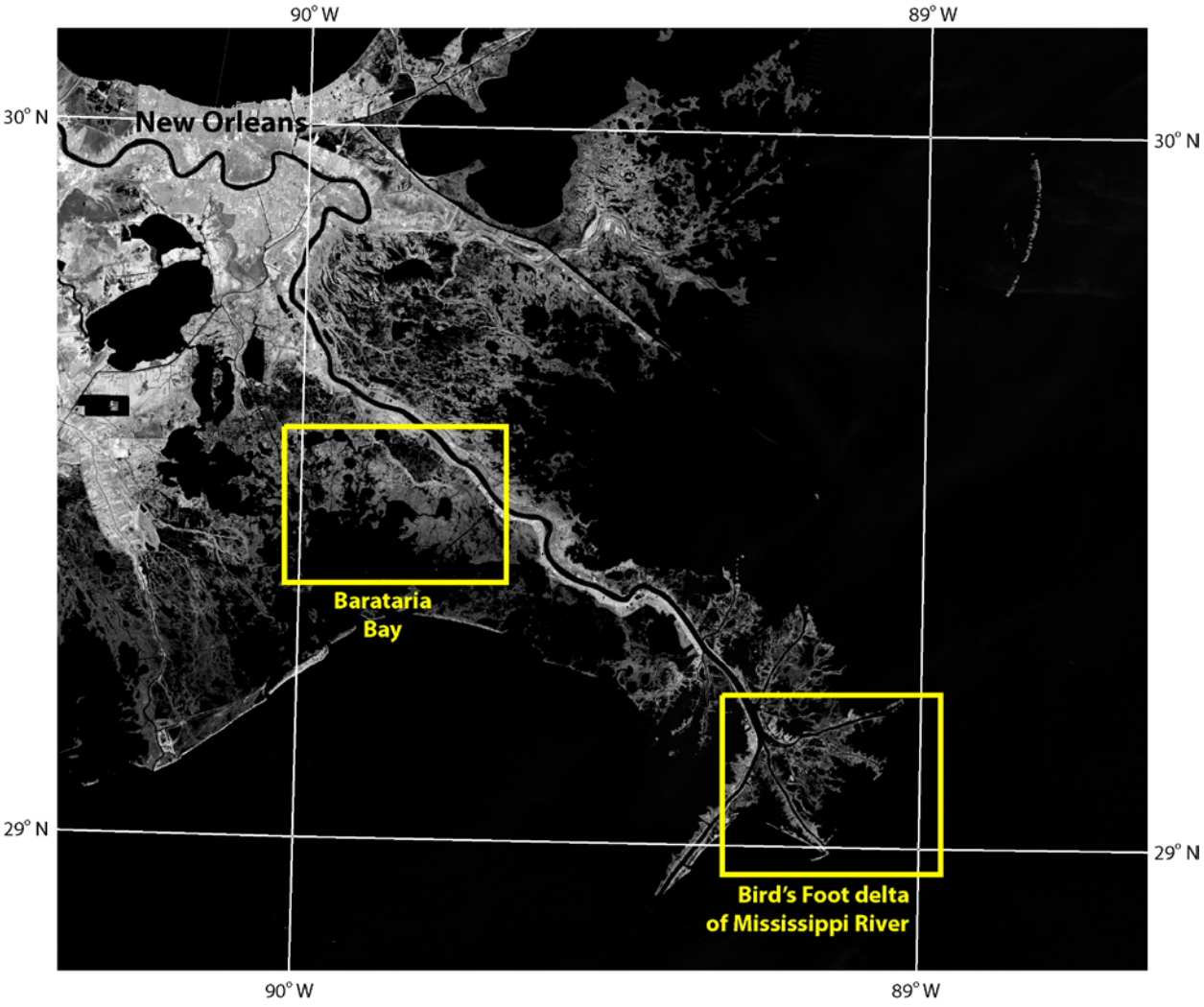

Figure 1. Shoreline survey areas in the marshes of Louisiana.

Shoreline Survey Methods

Initial survey points in Barataria Bay and Bird's Foot delta were selected based on heavily oiled areas indicated in Deepwater Horizon Shoreline Cleanup Assessment Team (SCAT) maps in early July (SCAT maps are available from *http://www.data.gov/restorethegulf/* and *http://gomex.erma.noaa.gov/erma.html*). Site locations in Barataria Bay were limited to gaps in the protective boom that were large enough to allow boat access to the shore. Shallow water depths prevented boat access to portions of the shoreline in both areas. In the early July survey,

photographs and field notes describing the locations of survey points (latitude and longitude using WGS-84 datum); the presence, nature and extent of oil, impacts on plant cover, and vegetation species composition were noted at survey points. Visual estimates of the depth of oil penetration into the marsh were made. The field sites fell into two categories: 1) sites at which detailed survey observations and measurements were made, including observations of oil on the marsh surface, these were labeled with a "DWO-2-" identifier tag at the start of the site name, and 2) sites at which only basic visual surveys were taken. Sites with detailed observations and measurements were labeled with a "DWO-2-" identifier tag at the start of the site name and sites with visual surveys only begin with "OBS-2-". The second part of the site name indicates the area of the site: Barataria Bay (BAT) or Bird's Foot Delta (DEL). For example, the site name "DWO-2-BAT-01" indicates a field survey location in Barataria Bay, visited during the July 7-10, 2010 survey, at which detailed observations were made.

The later surveys conducted in August were performed to expand the spatial coverage of the survey area and to obtain more detailed information on the depth of oil penetration into the marsh vegetation from the shoreline. The survey sites were guided by areas of extensive oil occurrences found in preliminary analyses (Kokaly, -unpub. data, 2011) of imaging spectrometer data from the Airborne Visible and Infrared Imaging Spectrometer (AVIRIS; Green and others, 1998) collected July 31, 2010. A field data sheet for sites was used to gather information (see Appendix A) and measurements of the depth of oil penetration into the marsh and linear extent along the shore were made using a tape measure (meter scale) or a laser rangefinder (Nikon ProStaff). Site locations were again limited to gaps in the protective boom and sufficient water depth for boat access. The field sites were labeled as previously described except that a "3" or "4" was used to indicate the August 12-14, 2010 or August 24-26, 2010 survey, respectively.

Shoreline Observations and Measurements

July 7-10, 2010

In this section, the site locations of a field campaign conducted from July 7-10, 2010, are reported. Figures 2 and 3 show the distribution of the survey sites in Barataria Bay and the Bird's Foot delta, respectively. The geographic coordinates and survey dates are given in table 1, along with observations of vegetation, indication of the presence/absence of oil and characterizations of its physical state (for example, as a coating on plants or as a sheen in the water), and descriptions of oil impacts on vegetation.

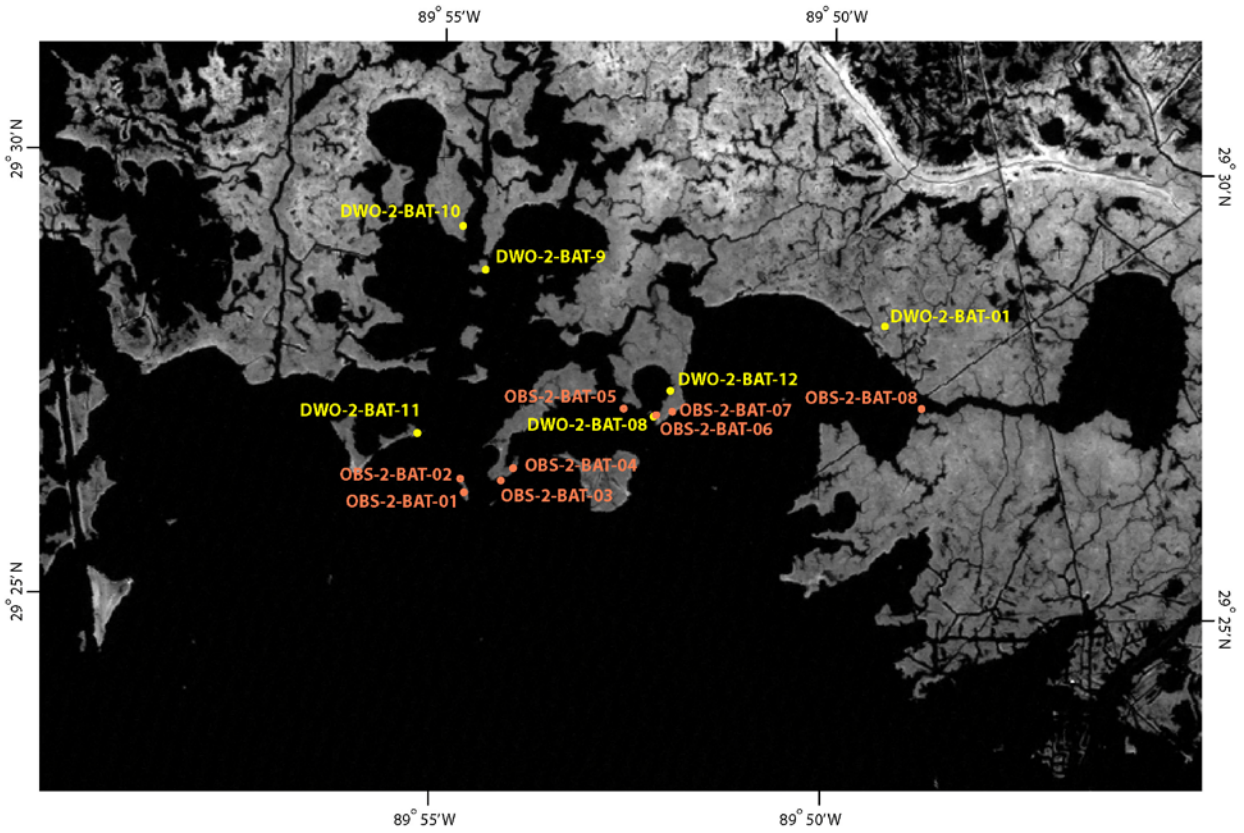

Figure 2. Barataria Bay survey points, July 7-10, 2010.

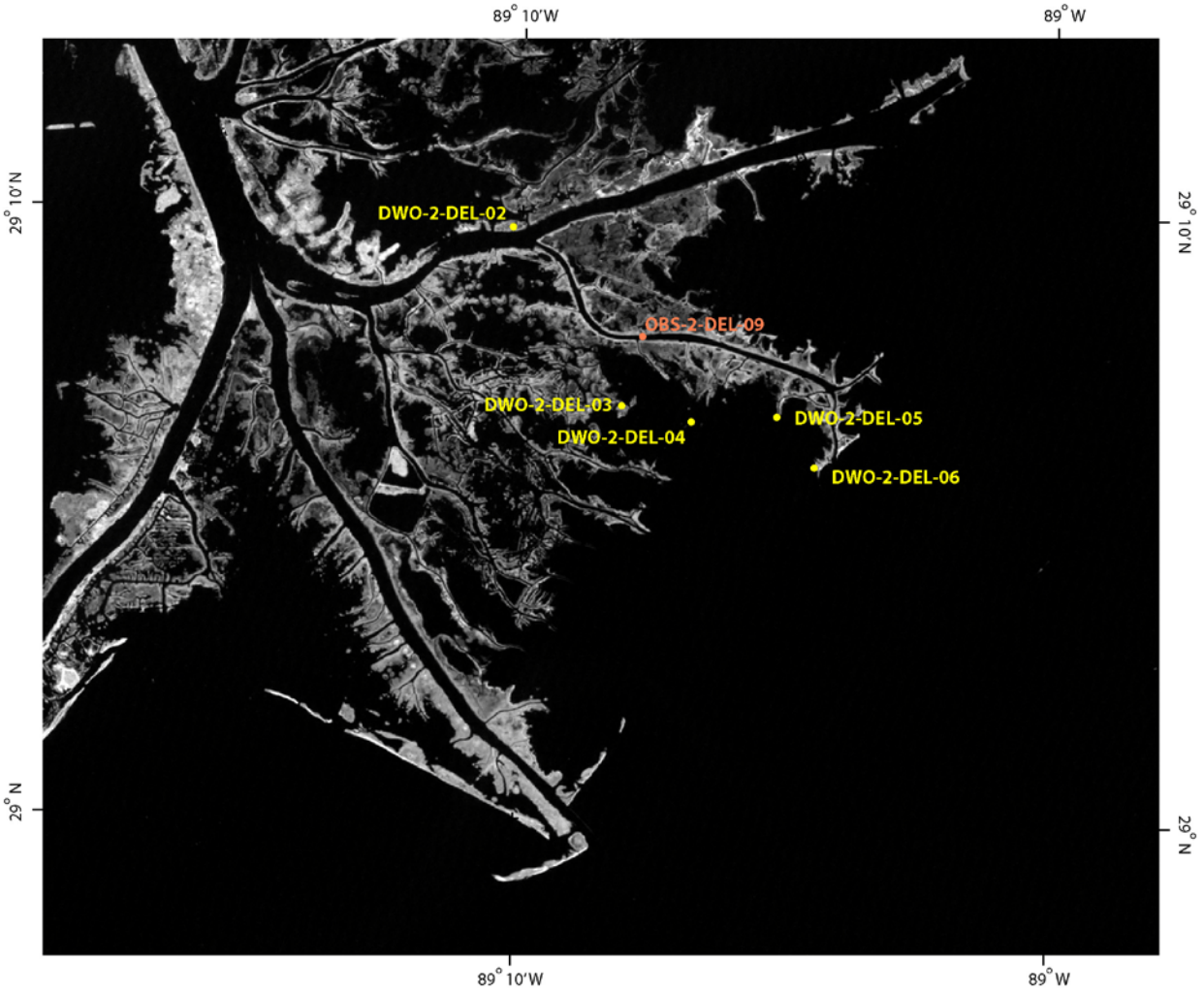

Figure 3. Bird's Foot delta survey points, July 7-10, 2010.

Table 1. Survey point locations, July 7-10, 2010.

Survey point	Latitude (deg. N)	Longitude (deg. W)	Date surveyed	Field observations and measurements
DWO-2-BAT-01	29.47053	89.82187	July 7, 2010	No visible oil on plants, boardwalk or in water. Water level high. *Spartina patens* and *Juncus roemerianus*. Photos of the site are shown in figures 4 and 5.
DWO-2-DEL-02	29.16225	89.16990	July 8, 2010	No visible oil on plants or water. *Phragmites australis*. Photos of the site are shown in figures 6-8.
DWO-2-DEL-03	29.11413	89.13436	July 8, 2010	No visible oil on plants or in water. *Phragmites australis*. Nearby, water hyacinth (*Eicchornia crassipes*) was present. The boat was moved to the opposite bank to measure water hyacinth at 29.11428 deg. N, 89.13380 deg. W. Photos of

				the site are shown in figures 9 and 10.
DWO-2-DEL-04	29.10971	89.11301	July 8, 2010	Thick oil coating on leaves and stems of *Phragmites australis* from the water level to 60 cm above the water. Oil is viscous, brown, and has a paint-like odor. The oil coating looks like peanut butter. Vegetation is still green beneath the oil coating. Photos of the site are shown in figures 11 and 12.
DWO-2-DEL-05	29.11139	89.08627	July 8, 2010	Oil coating on leaves and stems of *Phragmites australis.* Appears less heavily oiled than DWO-2-DEL-04. Leaves near the water line appear to have been stripped off, possibly due to the weight of the oil and/or water movement by tides or storms. Photos of the site are shown in figures 13 and 14.
DWO-2-DEL-06	29.09761	89.07430	July 8, 2010	No visible oil, but *Phragmites australis* laid over in some areas. Photos of the site are shown in figures 15 and 16.
DWO-2-BAT-08	29.45243	89.87058	July 10, 2010	Oil coating on leaves and stems of *Juncus roemerianus* and *Spartina alterniflora.* Plants in oil-impacted zone are brown in color with broken and bent stems. The zone of laid over vegetation extends up to 2.1 m (estimated) from the water's edge. Some green leaves on upright stems are scattered through the oiled zone. Photos of the site are shown in figures 17 and 18.
DWO-2-BAT-09	29.47919	89.90727	July 10, 2010	Oil coating on leaves and stems of *Spartina alterniflora* and *Juncus roemerianus.* Plants in oil-impacted zone have broken and bent stems and submerged portions of oil-coated plants are light to medium brown in color but dark brown/black in color on portions above the water. The zone of oiled and laid over vegetation extends up to 4.6 m (estimated) from the water's edge. The stems and leaves of the plants beyond that zone appear oiled at their base for another 1.5 m (estimated) but their stems do not appear broken. Silver sheen was seen in the water within the oiled marsh and at the marsh edge. Live mud crabs (*Sesarma reticulatum*) were observed to be coated with oil. Photos of the site are shown in figures 19-22.
DWO-2-BAT-10	29.48729	89.91235	July 10, 2010	No visible oil on plants or in water. *Juncus roemerianus* and *Spartina alterniflora.* Near subsequent survey point DWO-4-BAT-10. Photos of the site are shown in figures 23 and 24.
DWO-2-BAT-11	29.44825	89.92104	July 10, 2010	Heavily oiled marsh vegetation and sediment. *Spartina alterniflora* and *Juncus roemerianus*. A dark red oil residue, slimy in texture, was found on the marsh bottom, below the water. Plants in oil-impacted zone have broken and bent stems which are dark brown/black in color. The zone of oiled and laid over

				vegetation extends up to 7 m (estimated) from the water's edge. Near subsequent survey points DWO-3-BAT-01 and DWO-4-BAT-01. Photos of the site are shown in figures 25-27.
DWO-2-BAT-12	29.45734	89.86714	July 10, 2010	No visible oil on plants or in water. *Spartina alterniflora* and *Juncus roemerianus.* Plants appear very healthy. Near subsequent survey points DWO-3-BAT-02 and DWO-4-BAT-12. Photos of the site are shown in figures 28 and 29.
OBS-2-BAT-01	29.43735	89.91075	July 10, 2010	Oiled coastline observed from off-shore coordinates. Oil-impacted plants appear black/dark brown and have bent/broken stems. A photo of the site is shown in figure 30.
OBS-2-BAT-02	29.43989	89.91163	July 10, 2010	Oiled coastline observed from off-shore coordinates. Oil-impacted plants appear black/dark brown and have bent/broken stems. Photos of the site are shown in figures 31 and 32.
OBS-2-BAT-03	29.43974	89.90292	July 10, 2010	Oiled coastline observed to the north from off-shore coordinates. Oil-impacted plants appear black/dark brown and have bent/broken stems. A photo of the site is shown in figure 33.
OBS-2-BAT-04	29.44211	89.90037	July 10, 2010	Heavily oiled coastline observed to the north and west from off-shore coordinates. Oil-impacted plants appear black/dark brown and have bent/broken stems. The zone of oiled and laid over vegetation is estimated to extend 6.1 m on average, with some zones of deeper oil penetration, estimated at 9.1 to 15.2 m. No photos of this survey point were taken.
OBS-2-BAT-05	29.45377	89.87701	July 10, 2010	Oiled coastline observed to the north from off-shore coordinates. Oil-impacted plants appear black/dark brown and have bent/broken stems. No photos of this survey point were taken.
OBS-2-BAT-06	29.45272	89.87004	July 10, 2010	Lightly oiled coastline. Oil-impacted plants have black/dark brown oil residue on portions of their stems. No photos of this survey point were taken.
OBS-2-BAT-07	29.45344	89.86660	July 10, 2010	Oiled coastline observed to the north and west from off-shore coordinates. Oil-impacted plants appear black/dark brown and have bent/broken stems. No photos of this survey point were taken.
OBS-2-BAT-08	29.45506	89.81328	July 10, 2010	No visible oil in the water. No photos of this survey point were taken.
OBS-2-DEL-09	29.13313	89.12869	July 8, 2010	No oil observed on the plants or in the water. The water on the edge of the marsh, near this coordinate, is covered by an extensive area of bulltongue. Photos of the site are shown in figures 34 and 35.

Field Photos July 7-10, 2010

Figure 4. DWO-2-BAT-01 photo 1 taken on July 7, 2010. Site vegetation included *Spartina patens* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 5. DWO-2-BAT-01 photo 2 taken on July 7, 2010. Site vegetation included *Spartina patens* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 6. DWO-2-DEL-02 photo 1 taken on July 8, 2010. Site vegetation included *Phragmites australis*.

Oil was not observed at this site.

Figure 7. DWO-2-DEL-02 photo 2 taken on July 8, 2010. Site vegetation included *Phragmites australis*.

Oil was not observed at this site.

Figure 8. DWO-2-DEL-02 photo 3 taken on July 8, 2010. Site vegetation included *Phragmites australis*.

Oil was not observed at this site.

Figure 9. DWO-2-DEL-03 photo 1 taken on July 8, 2010. Site vegetation included *Phragmites australis* and *Eicchornia crassipes*. Oil was not observed at this site.

Figure 10. DWO-2-DEL-03 photo 2 taken on July 8, 2010. Site vegetation included *Phragmites australis* and *Eicchornia crassipes*. Oil was not observed at this site.

Figure 11. DWO-2-DEL-04 photo 1 taken on July 8, 2010. Site vegetation included *Phragmites australis*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 12. DWO-2-DEL-04 photo 2 taken on July 8, 2010. Site vegetation included *Phragmites australis*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 13. DWO-2-DEL-05 photo 1 taken on July 8, 2010. Site vegetation included *Phragmites australis*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 14. DWO-2-DEL-05 photo 2 taken on July 8, 2010. Site vegetation included *Phragmites australis*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 15. DWO-2-DEL-06 photo 1 taken on July 8, 2010. Site vegetation included *Phragmites australis*. Oil was not observed at this site.

Figure 16. DWO-2-DEL-06 photo 2 taken on July 8, 2010. Site vegetation included *Phragmites australis*. Oil was not observed at this site.

Figure 17. DWO-2-BAT-08 photo 1 taken on July 10, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 18. DWO-2-BAT-08 photo 2 taken on July 10, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 19. DWO-2-BAT-09 photo 1 taken on July 10, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 20. DWO-2-BAT-09 photo 2 taken on July 10, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 21. DWO-2-BAT-09 photo 3 taken on July 10, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 22. DWO-2-BAT-09 photo 4 taken on July 10, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 23. DWO-2-BAT-10 photo 1 taken on July 10, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oil was not observed at this site.

Figure 24. DWO-2-BAT-10 photo 2 taken on July 10, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oil was not observed at this site.

Figure 25. DWO-2-BAT-11 photo 1 taken on July 10, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 26. DWO-2-BAT-11 photo 2 taken on July 10, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 27. DWO-2-BAT-11 photo 3 taken on July 10, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 28. DWO-2-BAT-12 photo 1 taken on July 10, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 29. DWO-2-BAT-12 photo 2 taken on July 10, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 30. OBS-2-BAT-01 photo 1 taken on July 10, 2010. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 31. OBS-2-BAT-02 photo 1 taken on July 10, 2010. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 32. OBS-2-BAT-02 photo 2 taken on July 10, 2010. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 33. OBS-2-BAT-03 photo 1 taken on July 10, 2010. Oiled vegetation was observed at this site, including oil-damaged canopy.

Figure 34. OBS-2-DEL-09 photo 1 taken on July 8, 2010. Vegetation included bulltongue. Oil was not observed at this site.

Figure 35. OBS-2-DEL-09 photo 2 taken on July 8, 2010. Vegetation included bulltongue. Oil was not observed at this site.

August 12-14, 2010

Figures 36 and 37 show the distribution of the survey points visited during the August 12-14, 2010 field campaign in Barataria Bay and the Bird's Foot delta, respectively. The geographic coordinates and survey dates are given in Table 2, along with observations of vegetation, indication of the presence/absence of oil and characterizations of its physical state (for example, as a coating on plants or as a sheen in the water), and descriptions of oil impacts on vegetation.

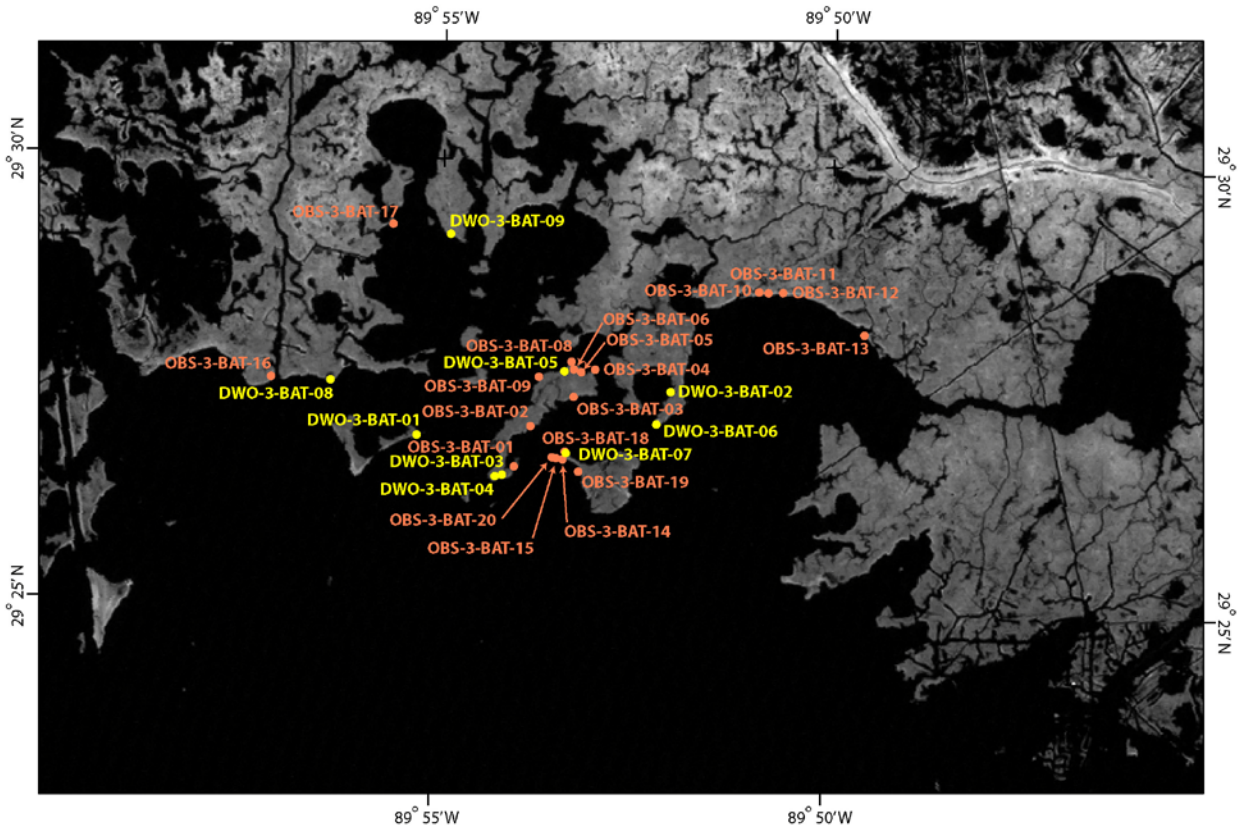

Figure 36. Barataria Bay survey points, August 12-14, 2010.

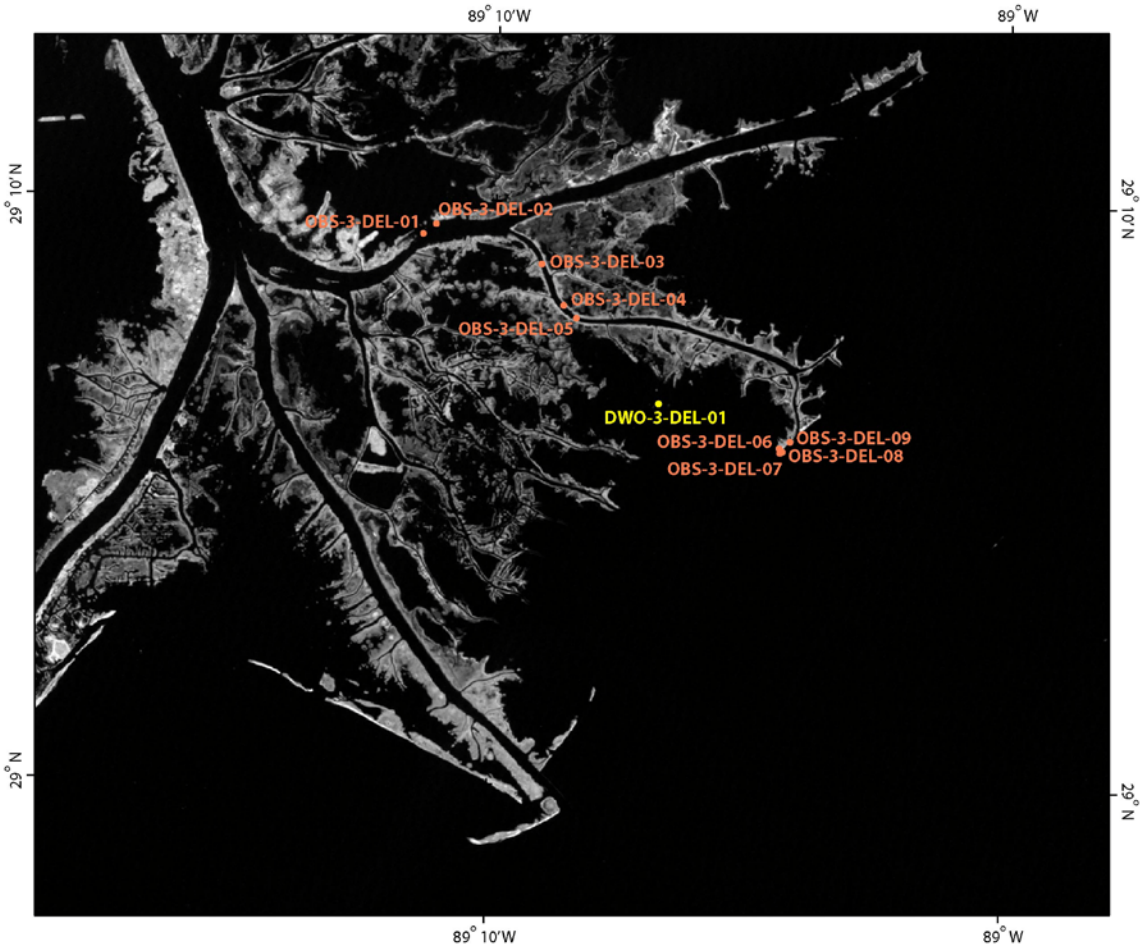

Figure 37. Bird's Foot delta survey points, August 12-14, 2010.

Table 2. Survey point locations, August 12-14, 2010.

Survey Point	Latitude (deg. N)	Longitude (deg. W)	Date Surveyed	Field Observations and Measurements
DWO-3-BAT-01	29.44824	89.92121	Aug. 12, 2010	Oil-impacted zone contains oil residue on the stems of *Juncus roemerianus* and *Spartina alterniflora*. The majority of the surface in oil-impacted zone is covered by dead, broken and bent plant stems which are dark brown/black in color with a thin oily coating. The oiling observed along this east-west shoreline extends 13.5 m to the east and 36 m to the west of the survey point. From the water's edge, the first 1.5 m of the oiled zone is primarily exposed marsh bottom and plant stubble (dead stems) of 2.5 cm height. The zone of oiled and laid over vegetation extends 9.5 m into the marsh from the water's edge; beyond this zone the stems appear oiled (dark

				brown/black) at the base of the green plants. In the first 5.3 m of the oiled zone, cover is predominantly brown/black laid over stems. Beyond 5.3 m, green *S. alterniflora* is growing within the brown, oiled stems. The brown stems appear to be primarily (90 percent) *J. roemerianus* in contrast to the greater proportion of *S. alterniflora* in the living canopy beyond the oiled zone. This survey point is near previously surveyed point DWO-2-BAT-11 and subsequently surveyed point DWO-4-BAT-01. Photos of the site are shown in figures 38-40.
DWO-3-BAT-02	29.45733	89.86718	Aug. 12, 2010	No oil was observed on plants or in the water. *Spartina alterniflora* and *Juncus roemerianus.* Plants appear healthy. This survey point is near previously surveyed point DWO-2-BAT-12 and subsequently surveyed point DWO-4-BAT-12. Photos of the site are shown in figures 41-43.
DWO-3-BAT-03	29.44113	89.90277	Aug. 12, 2010	Heavily oiled marsh vegetation, *Spartina alterniflora* and *Juncus roemerianus*. Plants in oil-impacted zone have a heavy oil coating on broken and bent stems which are dark brown/black in color. Thick red emulsion is visible at the base of plant stems and floating in the water near stems along with a silver sheen of oil. The oiling observed extends 60 m to the east and 55 m to the west of the survey point, throughout the small cove in which the survey point is located. The zone of oiled and laid over vegetation extends up to 14 m into the marsh from the water's edge; at the edge of this zone, the bottom 30 cm of the green plant stems appear oiled (dark brown/black). This survey point is near previously surveyed point OBS-2-BAT-03 and subsequent survey point DWO-4-BAT-03. Photos of the site are shown in figures 44-46.
DWO-3-BAT-04	29.44083	89.90429	Aug. 12, 2010	Oil-impacted zone contains oil residue on the stems of *Juncus roemerianus* and *Spartina alterniflora*. The oiling observed along this east-west shoreline extends 4.6 m to the east and 6.1 m to the west of the survey point. The oil coating appears to be lighter than that observed at DWO-3-BAT-03. The brown/black, oiled zone of laid over vegetation extends 3.7 m into the marsh from the water's edge. No oil sheen observed in the water. No photos of this survey point were taken.
DWO-3-BAT-05	29.46075	89.88996	Aug. 12, 2010	Oiled marsh vegetation: *Spartina alterniflora*, *Juncus roemerianus,* and *Distichlis spicata.* This survey point is within a narrow channel of slow moving water, approximately 8 m in width. Oil is present on the first 20 cm of the

				stem above the water line; however, the thick vegetation cover (greater than 95 percent) prevents observation of how deep the oiling goes below the water level. The canopy is intact and plants are not laid over. The zone of oiled stems extends less than 1 m into the marsh from the water's edge, in which some of the *S. alterniflora* plants are standing dead, dry stems and leaves. Red oil emulsion was observed in the water around the oiled plant stems. Photos of the site are shown in figures 47 and 48.
DWO-3-BAT-06	29.45121	89.87007	Aug. 13, 2010	Oil-impacted zone contains oil residue on the stems of *Juncus roemerianus* and *Spartina alterniflora*. The oil-damaged canopy zone consisted of plants with a heavy oil coating on broken and bent stems which are dark brown/black in color. The oiling observed along this portion of shoreline extends 10 m to the east and 20 m to the west of the survey point. A thick brown-red oil emulsion was found at the base of the stems. The oil-damaged canopy extended from the water's edge to 7 m into the marsh, where green plants of *S. alterniflora* were growing between the oiled stems. These green plants growing between the broken stems were coated with oil along the base of their stems. The depth of penetration of oil on the stems extended to 14 m into the marsh from the water's edge. Within the oiled stem zone, oil is present on the marsh bottom and the *S. alterniflora* appeared to be a darker green compared to the *S. alterniflora* deeper in the marsh. A 15 cm zone of dead, broken stems (stubble) was found at the water's edge of the marsh. This survey point is near subsequently surveyed point DWO-4-BAT-06. Photos of the site are shown in figures 49 and 50.
DWO-3-BAT-07	29.44544	89.88926	Aug. 13, 2010	Oiled marsh vegetation: *Spartina alterniflora*, *Juncus roemerianus, Distichlis spicata,* and *Iva frutescens.* Very light oiling of stems was observed in the form of a dry viscous residue. The oiled zone extended 1 m into the marsh from the water's edge. The oiling observed along this portion of shoreline extends 10 m to the east and 10 m to the west of the survey point. The canopy was mostly intact except for two 1-2 m^2 plots that contained brown, laid over plants. Photos of the site are shown in figures 51 and 52.
DWO-3-BAT-08	29.45816	89.93988	Aug. 13, 2010	Oiled marsh vegetation: *Spartina alterniflora* and *Distichlis spicata.* A band of green and dry, brown stems was observed to extend 1.5 m into the marsh from the water's edge, beyond which heavily oiled dark brown/black stems of

				laid over vegetation extended for another 5 m. The heavily oiled patch extended 10 m to the east and 10 m to the west of the survey point. A 15 cm zone of dead, broken stems (stubble) was found at the water's edge of the marsh. Photos of the site are shown in figures 53-55.
DWO-3-BAT-09	29.48593	89.91492	Aug. 13, 2010	Heavily oiled marsh vegetation: *Juncus roemerianus* and *Spartina alterniflora*. Plants in oil-impacted zone have a thick red-brown oil coating on broken and bent stems. Clumps of red emulsion are visible at the base of plant stems and floating in the water near stems along with rainbow sheen of oil. The oiling appears to be more recent compared to other survey points as evidenced by the wet, thick, shiny coating of oil on plants, a strong chemical odor, and pancake-like globules of oil in the water at the marsh edge approximately 1 mm thick. The oiling observed extends 87 m along the shore, centered on the survey point. The zone of oiled and laid over vegetation extends 5 m into the marsh from the water's edge; at the edge of this zone, the bottom 30 cm of the green plant stems appear oiled (dark brown/black). Photos of the site are shown in figures 56 and 57.
DWO-3-DEL-01	29.10932	89.11302	Aug. 14, 2010	Oiled marsh vegetation: *Phragmites australis.* This survey point is on the edge of a small island. A brown/black oil residue is present on the interval of stems/leaves between 60 - 160 cm above the water line. Above that interval, the leaves and stems appear similar to non-oiled *P. australis*. Mostly, the canopy is intact and plants are not laid over. The zone of oiled stems extends throughout the small island, covering an area of 20,000 m^2. No oil was observed in the water. Photos of the site are shown in figures 58 and 59.
OBS-3-BAT-01	29.44276	89.90034	Aug. 12, 2010	Oiled marsh vegetation: *Spartina alterniflora* and *Juncus roemerianus.* Heavily oiled zone of brown/black laid over vegetation with dead plant stubble extends 11 m into the marsh from the water's edge. Photos of the site are shown in figures 60 and 61.
OBS-3-BAT-02	29.45041	89.89697	Aug. 12, 2010	Oiled marsh vegetation: *Spartina alterniflora* and *Juncus roemerianus.* Oiled zone of brown/black laid over vegetation extends 13 m into the marsh from the water's edge. In the oiled zone there is some dead stubble, but not as much as observed at OBS-3-BAT-01, and green shoots appearing on the inshore edge. Photos of the site are shown in figures 62 and 63.
OBS-3-BAT-03	29.45601	89.88791	Aug. 12, 2010	Heavily oiled coastline observed to the north from off-shore coordinates, intact boom prevented access to the shoreline. Red oil emulsion was

				observed behind the boom (on the shoreward side). Oil-impacted plants, *Spartina alterniflora* and *Juncus roemerianus*, appear black/dark brown and have bent/broken stems and extend 13 m into the marsh from the water's edge. Plants beyond the oil-damaged canopy are coated with oil on the first 30 cm of their stems, but they are not laid over. A photo of the site is shown in figure 64.
OBS-3-BAT-04	29.46123	89.88347	Aug. 12, 2010	Oiled marsh vegetation: *Juncus roemerianus* more prevalent than *Spartina alterniflora.* Oiled zone of brown/black laid over vegetation extends 2.4 m into the marsh from the water's edge, and appears to be comprised of mostly of *J. roemerianus*. Green plants of *S. alterniflora* of 30-60 cm height occur within the oiled zone, even at the water's edge. The darker oil coating dotted the browned and broken stems but appeared to be less uniform in its coverage on the dead, dry vegetation as compared to OBS-3-4-BAT-01 to 03. Photos of the site are shown in figures 65 and 66.
OBS-3-BAT-05	29.46070	89.88642	Aug. 12, 2010	Oiled marsh vegetation: *Spartina alterniflora*, *Juncus roemerianus,* and *Distichlis spicata.* Oil is present on the first 30 cm of stems, above the water level, but the canopy is relatively intact and plants are not laid over. The zone of oiled stems extends 1.2 m into the marsh from the water's edge. Silver and dull sheen was observed in the water around the oiled plant stems. Photos of the site are shown in figures 67 and 68.
OBS-3-BAT-06	29.46119	89.88796	Aug. 12, 2010	Oiled marsh vegetation: *Spartina alterniflora* and *Juncus roemerianus.* This survey point is within a narrow channel, approximately 8 m in width. Oil is present on the first 20 cm of stems, above the water level, but the canopy is relatively intact and plants are not laid over. Above the oiled portion of stems, the *S. alterniflora* appears brown, yellow or light green in color. The zone of oiled stems extends 2.4 m into the marsh from the water's edge and is nearly all *S. alterniflora*. Some scattered *J. roemerianus* occurs in the oiled zone, but is mostly present deeper in the marsh. Silver and heavy dull sheen was observed in the water around the oiled plant stems. Photos of the site are shown in figures 69 and 70.
OBS-3-BAT-08	29.46251	89.88849	Aug. 12, 2010	Oiled marsh vegetation: *Juncus roemerianus* more prevalent than *Spartina alterniflora.* Very light amount of oil coating on stems of plants, primarily in the form of a dried, brown residue on plant stems in the interval between 30 cm and 60 cm above the marsh bottom. The canopy is mostly intact, but there are a few

				small areas of laid over plants. No dark brown/black residue was observed. No oil sheen was observed in the water. Photos of the site are shown in figures 71 and 72.
OBS-3-BAT-09	29.45964	89.89536	Aug. 12, 2010	No oil was observed on the plants, *Spartina alterniflora* and *Juncus roemerianus*, or in the water. From the previous survey point OBS-3-BAT-08 to this point, the amount of oiling varied from the light coating on a portion of stems to no observed oil. In addition, no oil-damaged canopies were observed between these points. Photos of the site are shown in figures 73 and 74.
OBS-3-BAT-10	29.47639	89.84872	Aug. 13, 2010	Oiled marsh vegetation: *Spartina alterniflora* and *Spartina patens.* A band of green and dry, brown stems was observed to extend 4 m into the marsh from the water's edge. The dead, brown plants were predominantly *S. patens*, while the green plants in the oiled zone are *S. alterniflora*. A 1 m zone of dead, broken stems (stubble) was found at the water's edge of the marsh. Photos of the site are shown in figures 75 and 76.
OBS-3-BAT-11	29.47626	89.84681	Aug. 13, 2010	Oiled marsh vegetation: *Spartina patens.* This survey point is at a patch of heavily oiled plants covered with black/brown oil residue. This patch measures 3 m (perpendicular to the shoreline) by 7 m (parallel to the shoreline). This patch of laid over vegetation is set back 3 m from the marsh edge and separated from the water by an area of exposed shell-rich marsh bottom containing scattered oiled and dried plants. Photos of the site are shown in figures 77 and 78.
OBS-3-BAT-12	29.47636	89.84371	Aug. 13, 2010	Oiled marsh vegetation: *Phragmites australis* and *Spartina patens.* Oiled zone of brown/black laid over vegetation extends 4 m into the marsh from the water's edge. The heavily oiled patch extended 14 m along the shoreline, centered on the survey point. A 30 cm zone of dead, broken stems (stubble) and exposed marsh sediment was found at the water's edge of the marsh. Behind the oiled zone is a patch of *P. australis* that stretches 10 m deep into the marsh and 30 m in length parallel to the shore. Another patch of *P. australis* with approximately the same dimensions lies 10 m to the east of the patch behind the oiled zone. To the east of the oiled zone at this survey point, only a few patches of oiled and laid over vegetation were observed, much smaller in size than the oiled zone at this survey point.

OBS-3-BAT-13	29.46878	89.82607	Aug. 13, 2010	Oiled marsh vegetation: *Spartina alterniflora*, *Juncus roemerianus*. Narrow, less than 1 m, zone of oil-impacted plants with an oil coating on broken and bent stems which are brown in color. No photos of this survey point were taken.
OBS-3-BAT-14	29.44436	89.89001	Aug. 13, 2010	Oiled coastline observed to the north from off-shore coordinates, intact boom prevented access to the shoreline. Oiled marsh vegetation: *Spartina alterniflora*, *Juncus roemerianus,* and *Distichlis spicata*. Plants in oil-impacted zone have a heavy oil coating on broken and bent stems which are dark brown/black in color. The oil-damaged canopy extended 10 m into the marsh from the water's edge. No photos of this survey point were taken.
OBS-3-BAT-15	29.44454	89.89134	Aug. 13, 2010	Oiled coastline observed to the north from off-shore coordinates, intact boom prevented access to the shoreline. Oiled marsh vegetation: *Phragmites australis*. Plants in oil-impacted zone have a heavy oil coating on broken and bent stems which are dark brown/black in color. The width of the zone of oil-damaged plants was not determined. A photo of the site is shown in figure 81.
OBS-3-BAT-16	29.45853	89.95261	Aug. 13, 2010	No oiled plants were observed from this off-shore survey point. No laid over vegetation or black/brown oil residue at the base of stems was observed. No photos of this survey point were taken.
OBS-3-BAT-17	29.48758	89.92726	Aug. 13, 2010	No oiled plants were observed from this off-shore survey point. No laid over vegetation or black/brown oil residue at the base of stems was observed. No photos of this survey point were taken.
OBS-3-BAT-18	29.44553	89.88928	Aug. 13, 2010	A small, 1 m by 1 m, patch of oiled vegetation, brown and laid over stems, was observed at this survey point. No photos of this survey point were taken.
OBS-3-BAT-19	29.44206	89.88648	Aug. 13, 2010	Oiled coastline observed to the north from off-shore coordinates, intact boom prevented access to the shoreline. Oiled marsh vegetation: predominantly *Spartina alterniflora*, *Juncus roemerianus,* and *Distichlis spicata*. Plants in oil-impacted zone have a heavy oil coating on broken and bent stems which are dark brown/black in color. From this survey point to OBS-3-BAT-20, the oil-damaged canopy extended from 2 to 10 m into the marsh from the water's edge, typically measured as 8 m using laser rangefinder. A photo of the site is shown in figure 82.
OBS-3-BAT-20	29.44461	89.89213	Aug. 13, 2010	Oiled coastline observed to the north from off-shore coordinates, intact boom prevented

				access to the shoreline. Oiled marsh vegetation: predominantly *Spartina alterniflora*, *Juncus roemerianus,* and *Distichlis spicata*. Plants in oil-impacted zone have a heavy oil coating on broken and bent stems which are dark brown/black in color. From survey point OBS-3-BAT-19 to this point, the oil-damaged canopy extended from 2 to 10 m into the marsh from the water's edge, typically measured as 8 m using laser rangefinder. A photo of the site is shown in figure 83.
OBS-3-DEL-01	29.15681	89.19048	Aug. 14, 2010	No oil was observed at this survey point. The coordinates are to the east of a large area, 20 by 20 m, covered by water hyacinth (*Eicchornia crassipes*). On the edge of the water hyacinth is another aquatic plant water lily (*Nymphaea* sp.) that lies flat on the water surface with a lobed leaf. A photo of the site is shown in figure 84.
OBS-3-DEL-02	29.15964	89.18626	Aug. 14, 2010	No oil was observed at this survey point. The coordinates are within a large area, 20 by 20 m, covered by water lily (*Nymphaea* sp.). A photo of the site is shown in figure 85.
OBS-3-DEL-03	29.14866	89.15174	Aug. 14, 2010	No oil was observed at this survey point. The marsh on either side of this off-shore coordinate is covered by marsh covered by *Phragmites australis.* No photos of this survey point were taken.
OBS-3-DEL-04	29.13699	89.14441	Aug. 14, 2010	No oil was observed at this survey point. The coordinates are within a large area, 14 by 20 m, covered by *Sagittaria platyphylla*. The aquatic plant lies at the edge of the marsh covered by *Phragmites australis.* Photos of the site are shown in figures 86 and 87.
OBS-3-DEL-05	29.13337	89.14020	Aug. 14, 2010	No oil was observed at this survey point. The marsh to the north side of this off-shore coordinate was covered by *Phragmites australis.* No photos of this survey point were taken.
OBS-3-DEL-06	29.09711	89.07356	Aug. 14, 2010	No oil was observed at this survey point on a 20 m by 10 m area of exposed sand beach. Dead cane from *Phragmites australis* was observed over a quarter of the beach. Water hyacinth (*Eicchornia crassipes*) plants were growing at the water's edge. The beach was surrounded by dense *P. australis.* A photo of the site is shown in figure 88.
OBS-3-DEL-07	29.09582	89.07335	Aug. 14, 2010	The area just north of these off-shore coordinates may have been impacted by oil. A 14 m deep zone of stubble from *Phragmites australis* stretches for 80m along the water's edge. Due to the shallowness of the water near shore and the water conditions, the shoreline could not be accessed. At the edge of the marsh, both dead, brown and live, green *P. australis* was

				observed, along with green water hyacinth (*Eicchornia crassipes*) growing sparsely. Many of the *P. australis* at the edge of the marsh were laid over and brown and dry. No oil was observed in the water. A photo of the site is shown in figure 89.
OBS-3-DEL-08	29.09615	89.07251	Aug. 14, 2010	This area looked similar to OBS-3-DEL-07, however, the stubble zone showed less evidence of oil. Abundant dry cane from *Phragmites australis* was observed. Due to the shallowness of the water near shore and the water conditions, the shoreline could not be accessed. No oil was observed in the water. No photos of this survey point were taken.
OBS-3-DEL-09	29.09904	89.07007	Aug. 14, 2010	No oil was observed at this survey point. The shoreline to the north side of this off-shore coordinate is a deep (23 m) beach that stretches more than 50 m to the east and west along the shore. No oil was observed in the water. A photo of the site is shown in figure 90.

Field Photos August 12-14, 2010

Figure 38. DWO-3-BAT-01 photo 1 taken on August 12, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 39. DWO-3-BAT-01 photo 2 taken on August 12, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 40. DWO-3-BAT-01 photo 3 taken on August 12, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 41. DWO-3-BAT-02 photo 1 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 42. DWO-3-BAT-02 photo 2 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 43. DWO-3-BAT-02 photo 3 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 44. DWO-3-BAT-03 photo 1 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 45. DWO-3-BAT-03 photo 2 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 46. DWO-3-BAT-03 photo 3 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 47. DWO-3-BAT-05 photo 1 taken on August 12, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Distichlis spicata*. Oiled stems were observed at this site.

Figure 48. DWO-3-BAT-05 photo 2 taken on August 12, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Distichlis spicata*. Oiled stems were observed at this site.

Figure 49. DWO-3-BAT-06 photo 1 taken on August 13, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 50. DWO-3-BAT-06 photo 2 taken on August 13, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 51. DWO-3-BAT-07 photo 1 taken on August 13, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, *Distichlis spicata*, and *Iva frutescens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 52. DWO-3-BAT-07 photo 2 taken on August 13, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, *Distichlis spicata*, and *Iva frutescens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 53. DWO-3-BAT-08 photo 1 taken on August 13, 2010. Site vegetation included *Spartina alterniflora* and *Distichlis spicata*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 54. DWO-3-BAT-08 photo 2 taken on August 13, 2010. Site vegetation included *Spartina alterniflora* and *Distichlis spicata*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 55. DWO-3-BAT-08 photo 3 taken on August 13, 2010. Site vegetation included *Spartina alterniflora* and *Distichlis spicata*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 56. DWO-3-BAT-09 photo 1 taken on August 13, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 57. DWO-3-BAT-09 photo 2 taken on August 13, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 58. DWO-3-DEL-01 photo 1 taken on August 14, 2010. Site vegetation included *Phragmites australis*. Oiled vegetation was observed at this site, including some oil-damaged canopy.

Figure 59. DWO-3-DEL-01 photo 2 taken on August 14, 2010. Site vegetation included *Phragmites australis*. Oiled vegetation was observed at this site, including some oil-damaged canopy.

Figure 60. OBS-3-BAT-01 photo 1 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 61. OBS-3-BAT-01 photo 2 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 62. OBS-3-BAT-02 photo 1 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 63. OBS-3-BAT-02 photo 2 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 64. OBS-3-BAT-03 photo 1 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 65. OBS-3-BAT-04 photo 1 taken on August 12, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 66. OBS-3-BAT-04 photo 2 taken on August 12, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 67. OBS-3-BAT-05 photo 1 taken on August 12, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Distichlis spicata*. Oiled stems were observed at this site.

Figure 68. OBS-3-BAT-05 photo 2 taken on August 12, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Distichlis spicata*. Oiled stems were observed at this site.

Figure 69. OBS-3-BAT-06 photo 1 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled stems were observed at this site.

Figure 70. OBS-3-BAT-06 photo 2 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled stems were observed at this site.

Figure 71. OBS-3-BAT-08 photo 1 taken on August 12, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 72. OBS-3-BAT-08 photo 2 taken on August 12, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 73. OBS-3-BAT-09 photo 1 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 74. OBS-3-BAT-09 photo 2 taken on August 12, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 75. OBS-3-BAT-10 photo 1 taken on August 13, 2010. Site vegetation included *Spartina alterniflora* and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 76. OBS-3-BAT-10 photo 2 taken on August 13, 2010. Site vegetation included *Spartina alterniflora* and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 77. OBS-3-BAT-11 photo 1 taken on August 13, 2010. Site vegetation included *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 78. OBS-3-BAT-11 photo 2 taken on August 13, 2010. Site vegetation included *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 79. OBS-3-BAT-12 photo 1 taken on August 13, 2010. Site vegetation included *Phragmites australis* and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 80. OBS-3-BAT-12 photo 2 taken on August 13, 2010. Site vegetation included *Phragmites australis* and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 81. OBS-3-BAT-15 photo 1 taken on August 13, 2010. Site vegetation included *Phragmites australis*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 82. OBS-3-BAT-19 photo 1 taken on August 13, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Distichlis spicata*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 83. OBS-3-BAT-20 photo 1 taken on August 13, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Distichlis spicata*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 84. OBS-3-DEL-01 photo 1 taken on August 14, 2010. Site vegetation included *Eicchornia crassipes* and *Nymphaea* sp. Oil was not observed at this site.

Figure 85. OBS-3-DEL-02 photo 1 taken on August 14, 2010. Site vegetation included *Nymphaea* sp. (foreground) and *Eicchornia crassipes*. Oil was not observed at this site.

Figure 86. OBS-3-DEL-04 photo 1 taken on August 14, 2010. Site vegetation included *Sagittaria platyphylla* (foreground) and *Phragmites australis*. Oil was not observed at this site.

Figure 87. OBS-3-DEL-04 photo 2 taken on August 14, 2010. Site vegetation included *Sagittaria platyphylla* (foreground) and *Phragmites australis*. Oil was not observed at this site.

Figure 88. OBS-3-DEL-06 photo 1 taken on August 14, 2010. Site vegetation included *Phragmites australis* and *Eicchornia crassipes*. Oil was not observed at this site.

Figure 89. OBS-3-DEL-07 photo 1 taken on August 14, 2010. Site vegetation included *Phragmites australis* and *Eicchornia crassipes*. Damage to the plant canopy, apparently from oil, was observed at this site.

Figure 90. OBS-3-DEL-09 photo 1 taken on August 14, 2010. Site vegetation included *Phragmites australis*. Oil was not observed at this site.

August 24-26, 2010

Figure 91 shows the distribution of the survey points visited during the August 24-26, 2010, field campaign in Barataria Bay. Because the previous two surveys indicated more extensive oiling in Barataria Bay relative to the Bird's Foot Delta, the Bird's Foot Delta was not surveyed in late August. This allowed a greater number of oiled sites to be visited with the limited resources available to conduct the survey. The geographic coordinates and survey dates are given in table 3, along with observations of vegetation, indication of the presence/absence of oil and characterizations of its physical state (for example, as a coating on plants or as a sheen in the water), and descriptions of oil impacts on vegetation.

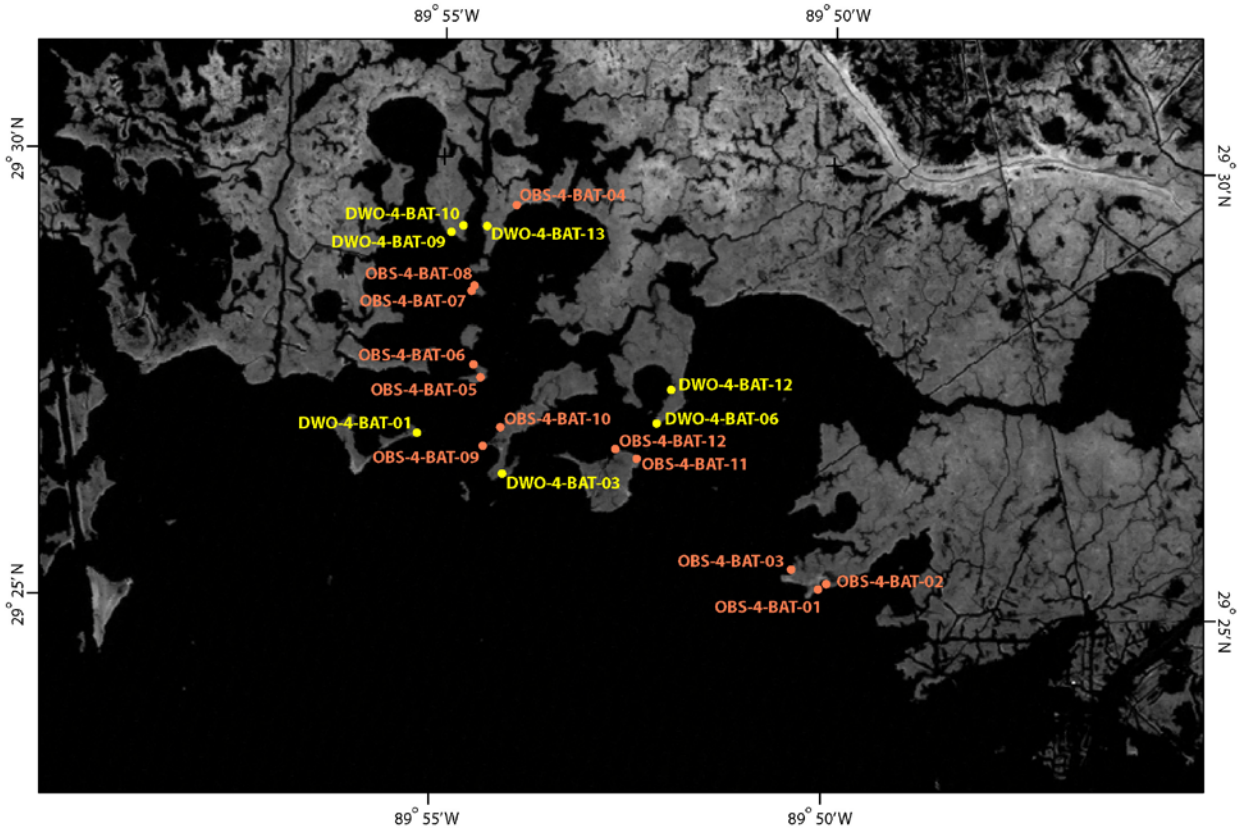

Figure 91. Barataria Bay survey points, August 24-26, 2010.

Table 3. Survey point locations, August 24-26, 2010.

Survey Point	Latitude (deg. N)	Longitude (deg. W)	Date Surveyed	Field Observations and Measurements
DWO-4-BAT-01	29.44831	89.92112	Aug. 24, 2010	Oiled marsh vegetation: *Spartina alterniflora*, *Juncus roemerianus*, and *Spartina patens*; 12 m heavily oiled zone containing dead, broken and bent stems and stubbled grass. Approximately 10 percent *S. alterniflora* regrowth was observed. Erosion of coastline was evident. This survey point is near previous survey points DWO-2-BAT-11 and DWO-3-BAT-01. Photos of the site are shown in figures 92 and 93.
DWO-4-BAT-03	29.44109	89.90274	Aug. 26, 2010	Oiled marsh vegetation: *Spartina alterniflora* and *Juncus roemerianus*. Heavily oiled grasses along 19 m deep zone with negligible regrowth, containing broken and bent stems, and visible oil sheen. Dispersant appears to have been used at this site. Shoreline has been eroded. Near previous survey point DWO-3-BAT-03. Photos of the site are shown in

				figures 94 and 95.
DWO-4-BAT-06	29.45116	89.86999	Aug. 24, 2010	Oiled marsh vegetation: *Juncus roemerianus, Distichlis spicata*, and *Spartina alterniflora*; 9 m oiled zone, containing stubbled grass, broken and bent stems, and patches of oil in sediment. Algae were not observed. Regrowth of *D. spicata* was observed; shoreline erosion. Near previous survey point DWO-3-BAT-06. Photos of the site are shown in figures 96-99.
DWO-4-BAT-09	29.48598	89.91483	Aug. 24, 2010	Oiled marsh vegetation: *Juncus roemerianus, Spartina patens*, *Spartina alterniflora*, and trace amounts of *Distichlis spicata*; 4-5 m oiled zone, heavily oiled, brownish black coating on bent grasses, minimal regrowth near edge of non-oiled vegetation; oil sheen in water. Near previous survey point DWO-3-BAT-09. Photos of the site are shown in figures 99 and 100.
DWO-4-BAT-10	29.48723	89.91228	Aug. 25, 2010	No oil was observed on the plants, *Juncus roemerianus* and *Spartina alterniflora*; unimpacted site. Near previous survey point DWO-2-BAT-10. A photo of the site is shown in figure 101.
DWO-4-BAT-12	29.45748	89.86707	Aug. 24, 2010	No oil was observed on the plants, *Spartina alterniflora* and *Juncus roemerianus*; unimpacted site. Near previous survey point DWO-2-BAT-12 and DWO-3-BAT-02. A photo of the site is shown in figure 102.
DWO-4-BAT-13	29.47919	89.90720	Aug. 25, 2010	Oiled marsh vegetation: *Spartina alterniflora*, *Juncus roemerianus*, and *Distichlis spicata;* 7 m oiled zone with 4-5 m of oil-stained and bent grasses, grasses with intact stems oiled at their base extend an additional 1-2 m inland. Regrowth covering 10 percent of the oiled zone was observed. Photos of the site are shown in figures 103 and 104.
OBS-4-BAT-01	29.42089	89.83468	Aug. 26, 2010	Oiled marsh vegetation: *Spartina alterniflora*; 11 m oiled zone; 4 m from water edge sparsely populated, remainder heavily oiled, laid over with stubble. Minor *S. alterniflora* regeneration, deeper green regrowth relative to unaffected vegetation; oil sheen in water. A photo of the site is shown in figure 105.
OBS-4-BAT-02	29.42191	89.83297	Aug. 26, 2010	Oiled marsh vegetation: *Spartina alterniflora*, *Juncus roemerianus*, and *Spartina patens*; heavily oiled and dead 12 m zone, stubbled grass with approximately 10 percent *S. alterniflora* regrowth; oil sheen in water; erosion of coastline evident. Photos of the site are shown in figures 106 and 107.
OBS-4-BAT-03	29.42450	89.84051	Aug. 26, 2010	No oil was observed from this off-shore survey point. Vegetation included *Phragmites australis*, *Iva frutescens*, *Spartina alterniflora*, *Solidage* sp., and *Distichlis spicata*. Shoreline could not be accessed due to intact boom. In front of the marsh vegetation was a zone of

				dark brown sediment reworked by wave/tidal activity. No visual evidence of oil impact. Photos of the site are shown in figures 108 and 109.
OBS-4-BAT-04	29.49129	89.90100	Aug. 26, 2010	Oiled marsh vegetation: *Spartina alterniflora* and *Juncus roemerianus;* 8 m oil-impacted zone containing oil-coated plants with bent stems. Regrowth of *S. patens* and *D. spicata* was observed. Oil sheen was observed in the water. Photos of the site are shown in figures 110 and 111.
OBS-4-BAT-05	29.45898	89.90786	Aug. 26, 2010	Oiled marsh vegetation: *Juncus roemerianus* and *Spartina patens,* and trace *Phragmites australis*; 3-6 m zone of oiled, laid over vegetation extending for ~20m along shore where boom has broken. Regrowth of *S. patens* over ~10 percent of oiled area was observed; regrowth is a darker green color relative to less-impacted grass. Oyster shells sporadically deposited along oiled shoreline. Photos of the site are shown in figures 112 and 113.
OBS-4-BAT-06	29.46134	89.90941	Aug. 26, 2010	No visible oiling. Dominant plants: *Juncus roemerianus* and *Spartina* sp. along water's edge. Photos of the site are shown in figures 114 and 115.
OBS-4-BAT-07	29.47507	89.91019	Aug. 26, 2010	Oiled marsh vegetation: *Juncus roemerianus* and *Spartina alterniflora;* 3-5 m wide zone across >60 m of shoreline. The oiled zone is patchy with sporadic areas of oiled and laid over plants rather than a continuous oil coating. Regrowth of *Spartina alterniflora,* having a brighter green color relative to less-impacted grasses, was observed. Photos of the site are shown in figures 116 and 117.
OBS-4-BAT-08	29.47607	89.90960	Aug. 26, 2010	No visible oiling. Off-shore survey point. Unable to access site due to intact boom. Shoreline vegetation dominated by *Spartina* sp. and *Juncus roemerianus.* A photo of the site is shown in figure 118.
OBS-4-BAT-09	29.44618	89.90702	Aug. 26, 2010	Off-shore survey point. Site access was restricted by intact boom. Heavy oiling was observed. The oiled zone is bounded by regrowth of *Spartina* sp. A photo of the site is shown in figure 119.
OBS-4-BAT-10	29.44975	89.90336	Aug. 26, 2010	No visible oiling. Site access restricted by intact boom. Dominant vegetation: *Juncus roemerianus* and *Spartina* sp. Photos of the site are shown in figures 120 and 121.
OBS-4-BAT-11	29.44450	89.87408	Aug. 26, 2010	Oiled marsh vegetation: *Juncus roemerianus* and *Spartina alterniflora*; ~10 percent cover by bent grasses with a heavy oil coating; regrowth throughout the oiled zone was darker green in color compared to adjacent unimpacted zone. In the oiled zone, ~60 percent of the area of regrowing grasses was submerged at the time

				of the survey. Photos of the site are shown in figures 122 and 123.
OBS-4-BAT-12	29.44618	89.87867	Aug. 26, 2010	No visible oiling. Dominant plants: *Juncus roemerianus* and *Spartina* sp. with stands of *Phragmites australis*. A photo of the site is shown in figure 124.

Field Photos August 24-26, 2010

Figure 92. DWO-4-BAT-01 photo 1 taken on August 24, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus* and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 93. DWO-4-BAT-01 photo 2 taken on August 24, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus* and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 94. DWO-4-BAT-03 photo 1 taken on August 26, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 95. DWO-4-BAT-03 photo 2 taken on August 26, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 96. DWO-4-BAT-06 photo 1 taken on August 24, 2010. Site vegetation included *Juncus roemerianus*, *Distichlis spicata* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 97. DWO-4-BAT-06 photo 2 taken on August 24, 2010. Site vegetation included *Juncus roemerianus*, *Distichlis spicata* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 98. DWO-4-BAT-06 photo 3 taken on August 24, 2010. Site vegetation included *Juncus roemerianus*, *Distichlis spicata* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 99. DWO-4-BAT-09 photo 1 taken on August 24, 2010. Site vegetation included *Juncus roemerianus*, *Spartina patens*, *Spartina alterniflora*, and *Distichlis spicata*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 100. DWO-4-BAT-09 photo 2 taken on August 24, 2010. Site vegetation included *Juncus roemerianus*, *Spartina patens*, *Spartina alterniflora*, and *Distichlis spicata*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 101. DWO-4-BAT-10 photo 1 taken on August 25, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oil was not observed at this site.

Figure 102. DWO-4-BAT-12 photo 1 taken on August 24, 2010. Site vegetation included *Spartina alterniflora* and *Juncus roemerianus*. Oil was not observed at this site.

Figure 103. DWO-4-BAT-13 photo 1 taken on August 25, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Distichlis spicata*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 104. DWO-4-BAT-13 photo 2 taken on August 25, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Distichlis spicata*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 105. OBS-4-BAT-01 photo 1 taken on August 26, 2010. Site vegetation included *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 106. OBS-4-BAT-02 photo 1 taken on August 26, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 107. OBS-4-BAT-02 photo 2 taken on August 26, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

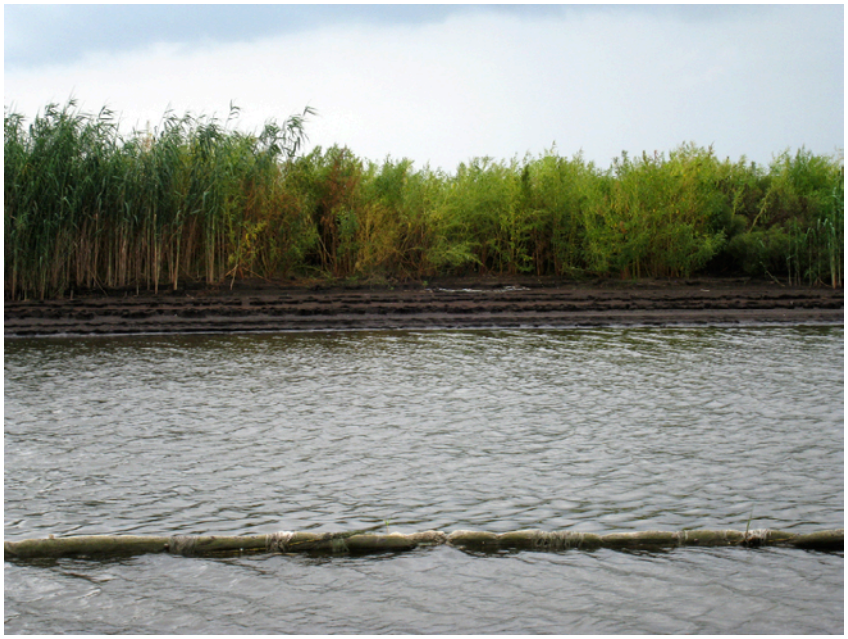

Figure 108. OBS-4-BAT-03 photo 1 taken on August 26, 2010. Site vegetation included *Phragmites australis, Iva frutescens, Spartina alterniflora, Solidage* sp*., and Distichlis spicata*. Oil was not observed at this site.

Figure 109. OBS-4-BAT-03 photo 2 taken on August 26, 2010. Site vegetation included *Phragmites australis, Iva frutescens, Spartina alterniflora, Solidage* sp*., and Distichlis spicata*. Oil was not observed at this site.

Figure 110. OBS-4-BAT-04 photo 1 taken on August 26, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, *Distichlis spicata*, and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 111. **OBS-4-BAT-04 photo 2 taken on August 26, 2010. Site vegetation included *Spartina alterniflora*, *Juncus roemerianus*, *Distichlis spicata*, and *Spartina patens*. Oiled vegetation and oil-damaged canopy were observed at this site.**

Figure 112. **OBS-4-BAT-05 photo 1 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.**

Figure 113. OBS-4-BAT-05 photo 2 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 114. OBS-4-BAT-06 photo 1 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina* sp. Oil was not observed at this site.

Figure 115. OBS-4-BAT-06 photo 2 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina* sp. Oil was not observed at this site.

Figure 116. OBS-4-BAT-07 photo 1 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 117. OBS-4-BAT-07 photo 2 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 118. OBS-4-BAT-08 photo 1 taken on August 26, 2010. Site vegetation included *Spartina* sp. and *Juncus roemerianus*. Oil was not observed at this site.

Figure 119. OBS-4-BAT-09 photo 1 taken on August 26, 2010. Site vegetation included *Spartina* sp. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 120. **OBS-4-BAT-10 photo 1 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina* sp. Oil was not observed at this site.**

Figure 121. **OBS-4-BAT-10 photo 2 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina* sp. Oil was not observed at this site.**

Figure 122. OBS-4-BAT-11 photo 1 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 123. OBS-4-BAT-11 photo 2 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina alterniflora*. Oiled vegetation and oil-damaged canopy were observed at this site.

Figure 124. OBS-4-BAT-12 photo 1 taken on August 26, 2010. Site vegetation included *Juncus roemerianus* and *Spartina* sp. Oil was not observed at this site.

Summary of Results and Discussion

The study area for identifying oil impacts was confined to small areas within Barataria Bay and the Bird's Foot delta, although the area of oil impact in coastal Louisiana was much larger. The Barataria sites were dominated by the grass-like perennials *Spartina alterniflora* and *Juncus roemerianus*. Both of these species are adapted to saline environments and are typically less than 2 m tall at maturity (U.S. Department of Agriculture, Natural Resources Conservation Service, 2010). In contrast, the dominant vegetation at the Bird's Foot delta sites was *Phragmites australis*, a reed that grows best in environments with fresher water (less than 10 ppt salinity) and can get up to 4 m tall (U.S. Department of Agriculture, Natural Resources Conservation Service, 2010).

All of the Bird's Foot delta sites were within a small eastern portion of the delta. Only two of the 14 sites surveyed showed obvious signs of oiling. The oil that was present was

considered heavy with a consistency of peanut butter. Oiling was observed above the waterline (for example, from 60 to 160 cm) illustrating the effects of water level fluctuation. Because oil can stay on the water surface for long periods of time, water level fluctuations enable oil to be transported deeper into the vegetated zone. Thus, oil can potentially influence not only the marshes adjacent to the shoreline, but also more interior marshes that are connected to larger water bodies through canals and trenasses.

In Barataria Bay, observed impact to the marsh ranged from no visible oil to heavy oil coatings on plants and broken, damaged canopies. At some heavily oiled sites, red oil: water emulsions were observed both on top of and below the water surface. In successive sampling trips, an oil layer (up to 1 mm thick) was observed submerged and on the surface of the marsh sediment in several locations indicating that oil may have settled out of the water column or been left on the surface when the tide went out. Laid over, broken, and fractured aboveground vegetation were observed throughout the oiled sites within Barataria Bay. The different growth structure of the grasses compared to the reed (for example, height and robustness of stems) make the grasses more likely to break under the added weight of a thick oil coating.

Oil-damaged canopy extended to a maximum of 19 m inland (the widest oil damaged zone was at survey point DWO-4-BAT-03). For the Barataria Bay survey areas, figure 125 shows the magnitude of observed oil impacts in four classes, indicated by colors: green indicates that oil was not observed, yellow indicates oil was found on stems of upright and intact plants, orange indicates that oil-damaged canopy was observed but the depth of penetration of the oil-damaged zone was not measured, and red indicates oil-damaged canopy was observed and its extent measured, with the adjacent number indicating the depth (in meters) that the oil damage extended into the marsh.

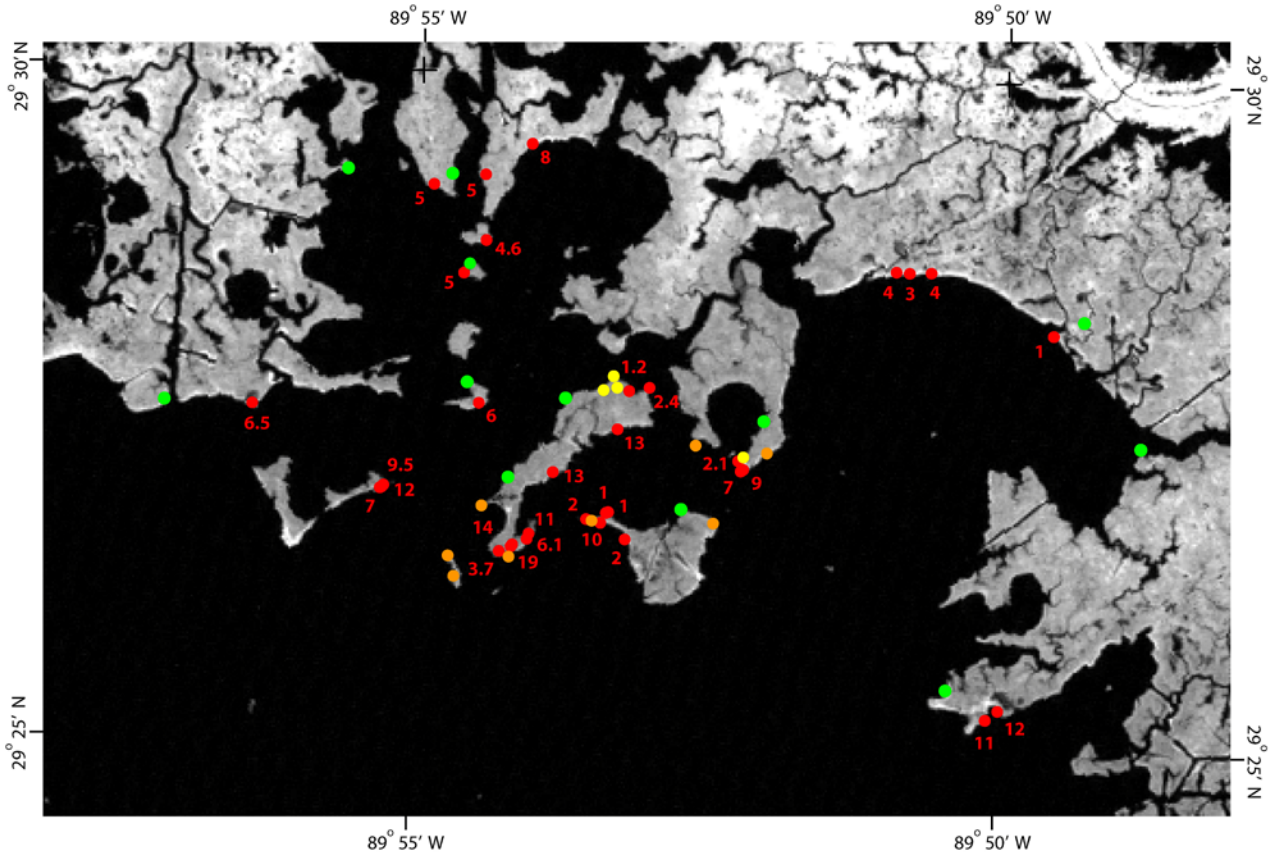

Figure 125. Survey points in Barataria Bay, oil damage indicated by color codes: green indicates that oil was not observed, yellow indicates oil was found on stems of plants, orange indicates that oil-damaged canopy was observed but the depth of penetration of the oil-damaged zone was not measured, and red indicates oil- damaged canopy was observed and the adjacent number indicates the extent (in meters) that the oil damage extended into the marsh.

Oil was not observed at 15 of the 61 survey points in Barataria Bay. The presence of oil on plant stems, but not oil-damaged canopy, was observed at four survey points. Oil-coated vegetation with accompanying damaged canopy in the form of broken and laid over vegetation, was observed at a total of 42 survey points. For the 34 survey points with measurements of oil-damaged canopies, the mean depth of penetration of the oil-damaged zone was 6.7 m, with a

standard deviation of 4.5 m. The median depth of penetration was 5.5 m. The greatest oil damage to plant canopies occurred on small islands in the southern portion of the surveyed area. By comparison, the oil damage to plant canopies was reduced at survey points on the northern sides of these islands. Many of the survey points that lacked visible observation of oil occurred on the northern sides of islands or in protected coves. Survey points at which oil impacts were limited to oiling of stems were similarly situated. On the island with the widest oil impact zones, survey points in a narrow interior waterway (DWO-3-BAT-05 and OBS-3-BAT-06) were also found to contain plants with oiled stems and water contaminated with oil sheen and red-brown oil water emulsions.

The extent to which the oil-damaged zone stretched along the shore varied with location but often extended more than 100 m parallel to the shoreline. Although the distance of oil inundation inland seems relatively narrow, many hectares of coastal marshes were directly impacted by the initial oil inundation due to the vast lengths of shoreline that were oiled. Initial observations indicate that oiling intensity generally decreased with increasing distance inland from the shoreline, thereby supporting a possible hypothesis that the first 10 to 12 m of marsh are potentially at greatest risk for loss. Oil sheen was also observed in the water at many sites, suggesting oil constituents may be available for further transport into the marsh by tides and wind, which may cause future impacts.

Next Steps

A subsequent research study has been initiated to track above and belowground vegetation characteristics within central Barataria Bay. Specific information about above and belowground biomass and aboveground species composition will identify whether the initial dieback of oiled vegetation influences longer term health and sustainability of oiled marshes.

Coastal Louisiana marshes typically experience high subsidence rates; thus, organic matter production and mineral sedimentation are important in maintaining marsh elevation and sustainability (Kennish, 2001, DeLaune and others, 2003). If the initial dieback of aboveground vegetation reported in this study leads to successive decreases in belowground biomass, the marsh may not be able to maintain sufficient elevation to prevent excessive inundation, and marsh loss could occur (Hartman, 1988, Nyman and others, 1993, DeLaune and others, 1994, Turner and others, 2004, Spalding and Hester 2007). Conversely, if vegetation recolonization occurs quickly, the belowground component should respond positively, and the marsh may maintain sufficient elevation to avoid loss. In this scenario, the oil spill may function as a temporary disturbance from which the marsh may quickly recover. At this point, it is difficult to predict the long term impact of a sudden dieback of large swaths of shoreline vegetation, but through continued research and monitoring of marsh health, recovery in oiled areas can be assessed.

The field data collected as part of the long term study will also serve as ground-truth data for existing and future remotely sensed data collections including two AVIRIS flights which will occur in spring and summer 2011. The observations presented in the current study are helping to validate and calibrate oil impacts observed from the AVIRIS flights that occurred in summer 2010. In the future, field observations and AVIRIS data will be used to track changes in marsh condition and composition as well as wetland loss in oil-impacted areas.

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Appendix A

Shoreline Impact Assessment Site Summary

Date:		Time:		Area:	
Latitude:		Longitude:		Bay:	
Site Width:		Site Length:			
Pictures (photo number):	North:		East:		
	South:		West:		
Previous site/sample at location					
Primary Type of Vegetation:					
Percent Vegetation Living:					
Vegetation Height					
Vegetation Description:					
Bottom Type:					
Water Depth Edge:		Water Depth @1-m into marsh:			
Water Conductivity:		Water pH:			
Oil Present on Vegetation:					
Depth Oil Penetration into Marsh:					
Description of Oil and Impact on marsh and coastline:					

Additional Information/Pictures: