RECOVERY OF A LOUISIANA COASTAL MARSH 3 YEARS AFTER *IN SITU* BURNING OF A HYDROCARBON PRODUCT SPILL

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ABSTRACT: *The high degree of physical disturbance associated with conventional response options to oil spills in wetlands is driving the investigation of alternative cleanup methodologies. In March 1995, a spill of gas condensate product onto a brackish marsh at Rockefeller Wildlife Refuge in southwestern Louisiana was removed through the use of* in situ *burning. A monitoring program was initiated to examine three treatment marshes: (1) condensate-impacted and burned, (2) condensate-impacted and unburned, and (3) a reference that was neither exposed to the condensate nor burned. The authors compared vegetation cover, stem density and biomass between the treatment marshes as parameters defining recovery of the plant community from the condensate spill and subsequent* in situ *burn. After three growing seasons, stem density, live biomass, and total cover values in the impacted-and-burned marsh had recovered to levels similar to non-burned treatments. In addition, community composition within the impacted-and-burned treatment returned to a co-dominant mix of the grasses* Distichilis spicata *(salt grass) and* Spartina alterniflora *(wiregrass) characteristic of the surrounding marsh. Recovery of the marsh at Rockefeller Wildlife Refuge was largely due to proper consideration of environmental factors at the time of the burn, especially marsh type, season and water level. The results of this* in situ *burn evaluation support the conclusion that burning can be relied upon as an effective cleanup response to hydrocarbon spills in wetlands.*

Introduction

The widespread presence of petroleum-related activities in the marshes of the U.S. Gulf of Mexico coastal zone, and the corresponding inevitability of spill events, requires the development of response options that are both efficient in removing the spilled oil and effective in minimizing damage to the sensitive marsh ecosystem, while promoting the recovery of such systems from a spill event (Adams *et al.*, 1983). Traditional methods for the cleanup of oil spills, such as the utilization of sorbent pads and the clipping and removal of oil-impacted vegetation from the site, show only limited removal efficiency and may be deleterious to the long-term recovery of the impacted marsh system (Owens *et al.*, 1993). The recognition that these cleanup methodologies can result in physical damage to both the vegetation and the underlying substrate (Lindstedt-Siva, 1979) has fueled interest in response options that are more efficient at removing the oil and less destructive to marsh structure and function (Owens *et al.*, 1993). Among these alternative methodologies is the utilization of *in situ* burning.

In March 1995, a rupture occurred in a pipeline carrying a gas-condensate product across a brackish marsh at the Rockefeller Wildlife Refuge on Louisiana's southwest coast. The decision was made to conduct an *in situ* burn on the product spill, and a 3-year, experimentally-based response investigation was initiated. The extent of recovery from the burn event was determined by comparing the impacted area with untreated reference sites. Plant species composition, percent cover, stem density and biomass served as the criteria for comparison. The response of the marsh vegetation after the third growing season following the burn event is reported here.

The first year's results (Pahl *et al.*, 1997) suggested that the impacted-and-burned marsh had not yet recovered to the plant community structure of the surrounding non-impacted marsh. As expected, burning initially resulted in the complete removal of the aboveground vegetation and re-set succession within the burnt area. Initial revegetation within the impacted-and-burned marsh was dominated by the subclimax sedge *Scirpus robustus*, while the non-impacted marsh was dominated by the climax graminoid species *Distichilis spicata* and *Spartina patens*. It was both the initial colonization of the burn site by *S. robustus* and its persistence within the burned area that led to lower percent cover, stem density, and aboveground live biomass values as compared to the surrounding non-impacted marsh after the end of the first growing season. However, the frequency of *S. robustus* within the impacted-and-burned marsh decreased during the growing season, while the frequency of the graminoid species, particularly *D. spicata*, concomitantly increased. The authors therefore concluded after the first year of recovery that, although the spill site still exhibited subclimax herbaceous vegetation, the community structure of the impacted-and-burned marsh appeared to be approaching the climax structure of the unburned marsh (Pahl *et al.*, 1997). The major objective of the Year 3 assessment, reported herein, was to determine if the vegetation structure of the impacted marsh had yet recovered to that of the non-impacted reference marshes.

Materials and methods

Site description. Rockefeller Wildlife Refuge includes approximately 31,000 hectares (76,000 acres) of natural and managed marshes in Cameron Parish, Louisiana, in the Mississippi River Chenier Plain. The hydrocarbon spill was located within the Price Lake impoundment, a 3,000 hectare (7,500 acre) wetland under water-level management with a salinity of 3–8 parts per thousand (ppt). The pipeline itself ruptured approximately 100 m north of a hurricane levee that forms the southern boundary of the Price Lake impoundment (Figure 1). The spill occurred from the blowout of a 40 cm (16 in), concrete-encased transport line carrying a gas-condensate product, API gravity 40–42 (Henry, 1996), from offshore facilities operated by Mobil Oil Company to production facilities north of the refuge. The total condensate-impacted area comprised approximately 20 hectares (50 acres) surrounding the blowout site. The marsh at the impact site is dominated by salt grass (*Distichilis spicata* (L.) Greene) and wire grass (*Spartina patens* (Aiton) Muhl.), with inclusions of leafy three-square (*Scirpus robustus* Pursh).

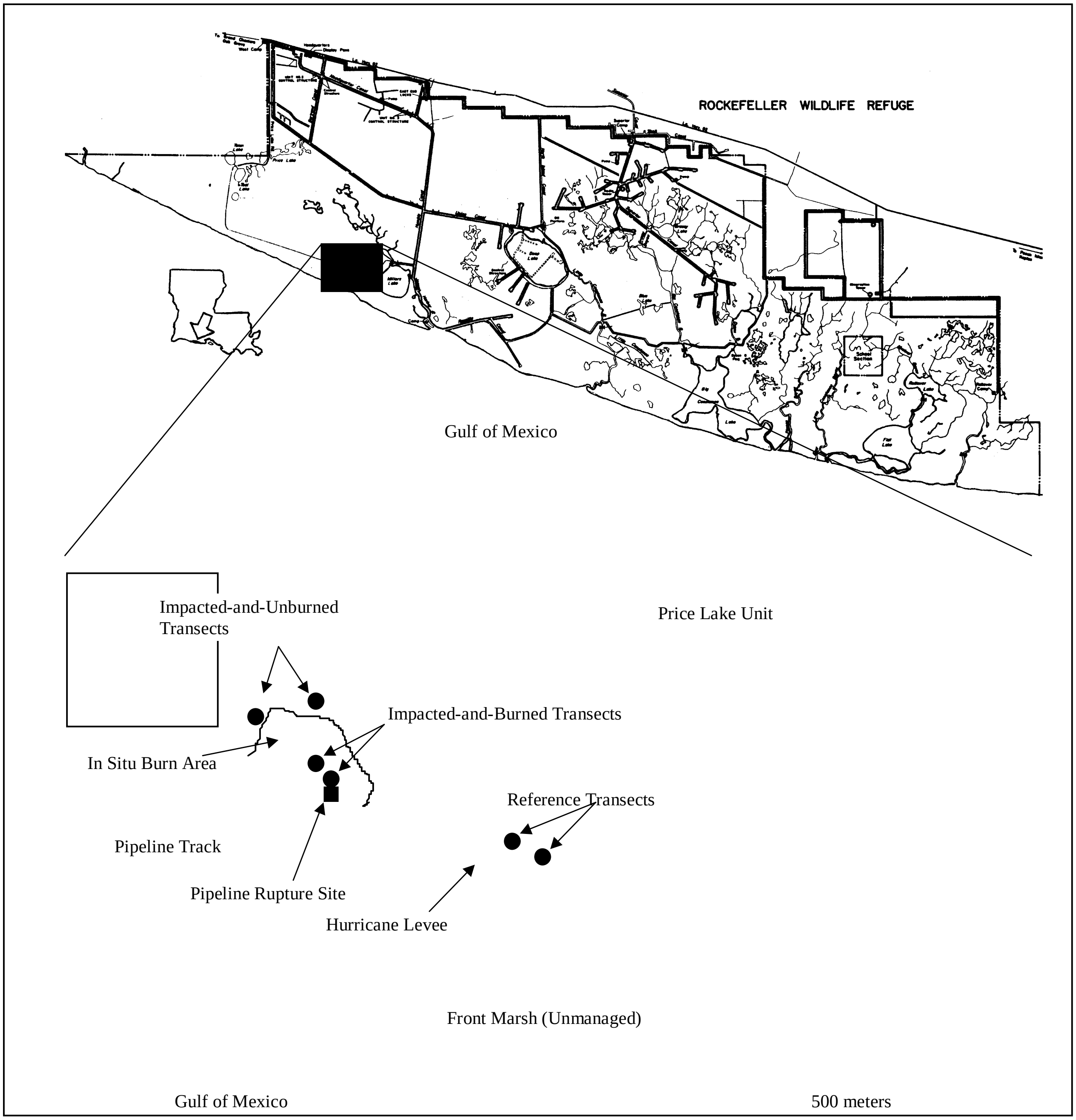

Figure 1. Location of the treatment assignments in relation to the pipeline rupture and primary impact zone within the Price Lake Unit of Rockefeller Wildlife Refuge in southwest Louisiana. Refuge map courtesy of the Louisiana Department of Wildlife and Fisheries.

Experimental design and sample collection. The monitoring program employed a completely randomized experimental design with three treatments: (1) condensate-impacted and burned, (2) condensate-impacted and unburned, and (3) condensate-non-impacted and unburned (reference). It should be noted that the impacted-and-unburned treatment marsh was established after the *in situ* burn, and was delineated by the presence of a visible sheen of product on the surface, outside the burn area. Within each treatment marsh, two 50-meter transects were established, with 5 random sampling points within each transect, for a total of 10 sampling points within each treatment marsh. Vegetation samples and cover data were taken in July and October 1995, July and November 1996, and July and October 1997, to follow the seasonal response of the vegetation within each treatment throughout the 3-year monitoring period.

Vegetative stem density and biomass. Vegetative growth was determined by clipping at ground level all vegetation within a 0.25 m^2 quadrat placed randomly around each sampling point. Material from each quadrat was separated by species and by live and dead component, the number of stems of each component counted, and dry mass measured.

Vegetative cover. Total and species-specific vegetative cover were determined within permanent 1 m^2 quadrats using a modification of the Braun-Blanquet Cover-Abundance Scale, described in Pahl *et al.* (1997). The use of numeric data as opposed to categorical data allowed mean percent cover to be calculated for each treatment at each sampling date.

Statistical analysis. The fall 1997 data presented here were analyzed as a one-way analysis of variance of the three treatments outlined above. Significant differences between treatment means were determined using the JMP V.3.1.5 statistical software package (SAS Institute, 1995). Unless otherwise specified, significant differences are at $P = 0.05$.

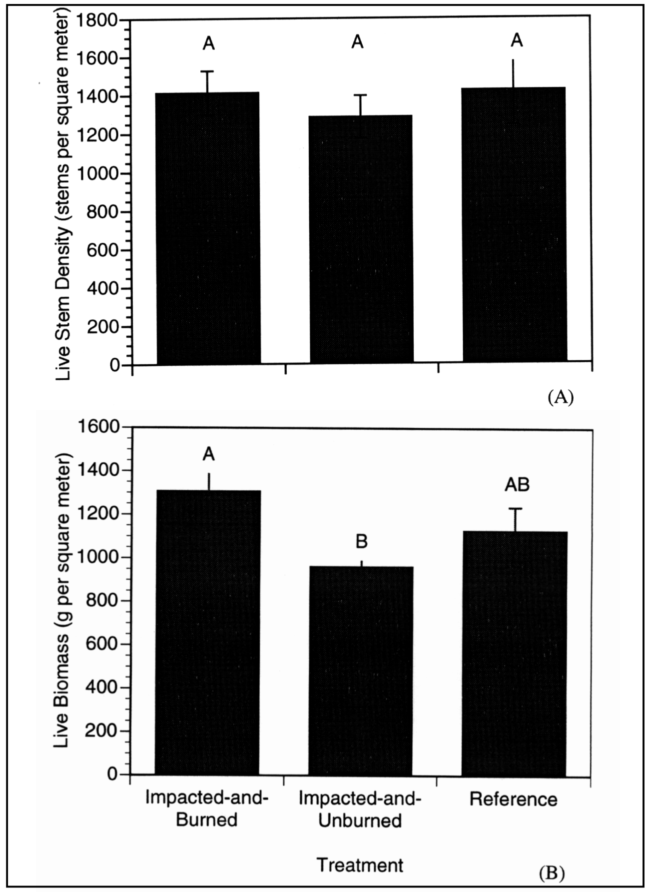

Figure 2. Live stem density (A) and live biomass (B) response by treatment in the fall of 1997. Different letters represent significant differences between treatments at $\alpha = 0.05$. For live stem density, treatment not significant ($P = 0.7480$); for live biomass, treatment significant ($P=0.0415$).

Results

Vegetative stem density and biomass. Live stem density within the impacted-and-burned treatment marsh was not significantly different from the two unburned treatments after 3 years of recovery (Figure 2a). Live biomass within the impacted-and-burned treatment was significantly higher than in the impacted-and-unburned treatment, but not significantly different from live biomass values in the reference marsh (Figure 2b).

Vegetative cover. Total vegetative cover was Class 5 (75–100%) in all treatment plots in the fall of the third growing season, with the exception of one plot in the impacted-and-unburned marsh, which was Class 4 (50–75%). The community structure of the impacted-and-burned marsh (Figure 3), was similar to that of the surrounding unburned marshes. Specifically, after 3 years community composition within the impacted-and-burned treatment returned to a more natural assemblage where *Distichilis spicata* and *Spartina patens* are co-dominants and *Scirpus robustus* is only a minor constituent.

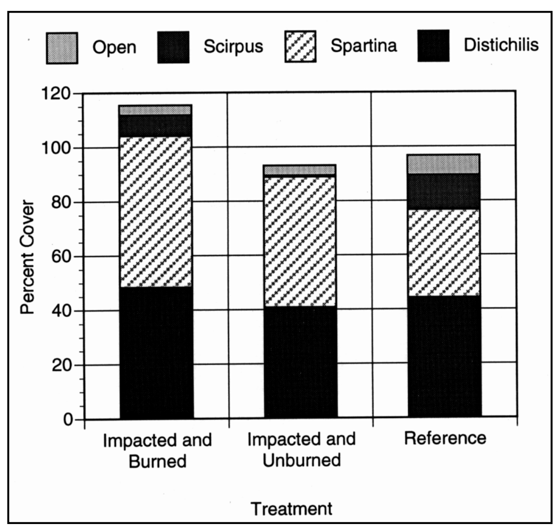

Figure 3. Species-specific percent cover response by treatment in the fall of 1997. Values for cumulative percent cover greater than 100% are an artifact of assigning the Braun-Blanquet cover classes a numerical midpoint for mean percent cover determination.

Discussion

After the end of the first growing season, the authors concluded that one of the primary reasons for the lower stem density, biomass and percent cover values within the impacted-and-burned treatment marsh as compared to the impacted-and-unburned and reference marshes was the colonization of the burn area by, and persistence of, the sedge *Scirpus robustus* (Pahl *et al.*, 1997), which has more robust stems and produces less dense stands than either of the co-dominant graminoid species (*Distichilis spicata* or *Spartina patens*). However, after 3 years post-burn, stem density, biomass and percent cover values for the impacted-and-burned marsh have recovered to those of the surrounding unburned marshes. Figure 3 demonstrates that this is largely due to the return of a community structure co-dominated by *D. spicata* and *S. patens*, with *S. robustus* relegated to a sub-dominant within the marsh.

Using these growth and community structure criteria, the authors can say with confidence that recovery has been achieved in the brackish marsh vegetation at Rockefeller Wildlife Refuge 3 years following the application of *in situ* burning. These results can be compared to those from the Chiltipin Creek oil spill and *in situ* burn, where Tunnell *et al.* (1995) defined recovery as occurring when the treated marsh exhibits the same frequency of climax vegetation species as the surrounding unimpacted marsh, and predicted that such a recovery would require 8.6 years following burning.

These results should also be compared to Sell *et al.*'s (1995) comprehensive survey of the potential for salt marshes to recover ecologically from oiling, that found that 75% of salt marshes surveyed recovered within 5 years regardless of whether cleaning was attempted or not. However, there were several extreme cases cited in which recovery was prolonged, and the authors believe that this spill was such an extreme case. The highly aromatic gas-condensate product that spilled at Rockefeller Wildlife Refuge was extremely toxic and resulted in obvious discoloration and mortality of the aboveground tissues of exposed plants. Had that product been allowed to penetrate into the subsurface peat, their would have been similar mortality in the belowground roots and rhizomes. Without the potential for belowground regrowth within the spill area, recovery would only have been possible through vegetative expansion of plants from the surrounding marshes into the spill area—a process that would have taken much longer than the 3 years seen at this site.

Conclusions

- The use of *in situ* burning was necessary to prevent excess physical damage to both the plants and the marsh substrate, and to prevent the exposure of marsh plant belowground tissue to a highly toxic gas-condensate product that would have impinged on the ability of that tissue to facilitate vegetative regrowth within the spill-impacted area.
- After 3 years following *in situ* burning, the community structure within the impacted-and-burned marsh has recovered to that of the surrounding reference marshes, thereby facilitating vegetative recovery.

Biography

James Pahl is a graduate assistant in the Louisiana State University Department of Oceanography and Coastal Sciences, where he is presently enrolled in a Ph.D. program. He has a B.A. in Biology (1993) from St. Mary's College of Maryland.

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