

FIELD ASSESSMENT OF THE IMPACTS OF *DEEPWATER HORIZON* OILING ON COASTAL MARSH VEGETATION OF MISSISSIPPI AND ALABAMA

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Abstract: The *Deepwater Horizon* incident, which occurred in April 2010, resulted in significant oiling of coastal habitats throughout the northern Gulf of Mexico. Although the most substantial oiling of coastal salt marshes occurred in Louisiana, oiling of salt marshes in Mississippi and Alabama was documented as well. A field study conducted in Mississippi and Alabama salt marshes as a component of the *Deepwater Horizon* Natural Resource Damage Assessment determined that >10% vertical oiling of plant tissues reduced live vegetation cover and aboveground biomass (live standing crop) relative to reference sites in this region through fall 2012. This reduction of live vegetation cover and aboveground biomass appears to have largely resulted from diminished health and vigor of *Juncus roemerianus*, a key salt marsh species in Mississippi and Alabama. Fewer significant reductions in live vegetation cover and aboveground biomass were detected by the fall 2013 sampling, suggesting that vegetation in oiled salt marshes in this region may have begun to recover. This is corroborated by low levels of *Deepwater Horizon* oil contamination in these salt marsh soils. However, these findings should be interpreted in the context of the restricted sampling intensity of the present study. *Environ Toxicol Chem* 2016;35:2791–2797. © 2016 The Authors. *Environmental Toxicology and Chemistry* Published by Wiley Periodicals, Inc. on behalf of SETAC.

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INTRODUCTION

The *Deepwater Horizon* oil well failure in the northern Gulf of Mexico in April 2010 was the largest spill in American waters and oiled various intertidal habitat types throughout the northern Gulf of Mexico, including coastal salt marshes [1]. Because of their proximity to the oil source and geographically extensive nature, the salt marshes of Louisiana, particularly those within the Mississippi River deltaic plain, experienced some of the heaviest oiling recorded during the spill [1]. However, substantial oiling was also documented in Mississippi and Alabama coastal salt marshes [1]. An assessment of *Deepwater Horizon*–associated impacts on coastal wetland vegetation that initially focused on Louisiana habitats was implemented as a portion of the overall Natural Resource Damage Assessment for the *Deepwater Horizon* incident [2].

Beyond the differences in the degree of *Deepwater Horizon* oiling experienced by Mississippi–Alabama salt marshes compared with those of Louisiana, these habitats are also generally considered ecologically distinct from Louisiana deltaic salt marshes in terms of their hydrogeomorphic setting and typical vegetation community composition [3]. Therefore, a companion coastal wetland vegetation assessment study in Mississippi and Alabama, the results of which are reported

herein, was performed to broaden the documentation of potential impacts of *Deepwater Horizon* oiling to salt marshes in this region.

Salt marshes of northwest Florida, Alabama, and Mississippi are generally regarded as microtidal (<2 m range) and exhibit a relatively consistent macrophyte community [3]. This plant community typically consists of a low-elevation fringe of *Spartina alterniflora* at the seaward edge, a broad expanse of *Juncus roemerianus* as the next zone inland, followed by a high marsh habitat that can include such dominant species as *Distichlis spicata* and *Spartina patens* [3]. This is in contrast to the marshes of the Mississippi River deltaic plain occurring just to the west, where *S. alterniflora* occurs in broad monospecific expanses with *J. roemerianus* and *Avicennia germinans* occurring intermittently as the codominant species [4,5]. This variation in the prevalence of specific salt marsh plant species may reflect subtle differences in soil biogeochemistry engendered by the more irregular flooding of the northeast Gulf of Mexico marshes compared with those of the Mississippi River deltaic plain [3]. The contrasting hydrologic regimes of these 2 regions evince differences in coastal geomorphology, with the northeast Gulf of Mexico marshes occurring on relatively stable substrates and those of the Mississippi River deltaic plain experiencing a high degree of subsidence as deltaic sediments compact through time [6].

Although the general mechanisms by which plant injury from oiling, such as direct chemical toxicity, physical smothering of tissues, and indirect impacts through alteration of the local environment, occur are largely consistent across plant species, the susceptibility of individual plant species to oiling can vary substantially [7,8]. Further, the degree to which any particular oil type causes injury is dependent not only on the scenario under which it occurs (e.g., seasonality, degree of

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weathering, extent and intensity of exposure) but also on the specific chemical nature of the oil and its alteration by weathering processes [7]. The dominant salt marsh plant species of the northeast Gulf of Mexico marshes, *J. roemerianus* and *S. alterniflora*, have been the subject of an extensive number of oiling studies [7,9–11], including several specific to *Deepwater Horizon* oiling [12,13]. Overall, both of these species have been shown to demonstrate some tolerance to oiling [10,11]. However, recent assessments indicate that *J. roemerianus* has a greater sensitivity to oiling associated with *Deepwater Horizon* sources than *S. alterniflora* [13]. Such findings highlight the need for a specific field evaluation of northeastern salt marshes in the Gulf of Mexico to effectively assess the impact to these valuable ecosystems that occurred as a result of the *Deepwater Horizon* oil spill.

The overall objective of the present field study was to determine the impacts of *Deepwater Horizon* oiling of aboveground plant tissues on the salt marsh vegetation of Mississippi and Alabama using a similar assessment framework as was implemented for the Natural Resource Damage Assessment of coastal wetland vegetation in Louisiana. The specific hypothesis tested was that increased vertical oiling of plant tissues associated with the *Deepwater Horizon* incident resulted in reduced salt marsh vegetation productivity, with live vegetation cover and aboveground biomass as proxies for this important ecosystem service. Polycyclic aromatic hydrocarbon (PAH) levels in soils were also analyzed to evaluate lingering exposure effects of oil contamination as a variable affecting the capacity of vegetation recolonization in these salt marsh areas.

MATERIALS AND METHODS

Study approach

The protocols employed in this coastal wetland vegetation assessment closely follow the approach implemented for Louisiana salt marshes [2]. For brevity, the results focus on only those metrics most relevant to ecological processes, including vegetation cover and standing crop. Initially, 59 “preassessment” survey points were collected in a spatially explicit manner along the Mississippi and Alabama coast over the period from 22 June to 9 September 2010 that detailed the habitat type and *Deepwater Horizon* oiling characteristics at these points [14]. These survey points were used to select sites for the coastal wetland vegetation injury assessment initiated in spring 2011 and were binned into the following classes based on the vertical extent of plant oiling: 0% to 0%, 0% to $\leq 10\%$, 11% to $\leq 50\%$, 51% to $\leq 90\%$, and 91% to $\leq 100\%$. The 0% to 0% plant oiling class contained sites where oiling was not observed on either vegetation or soil (i.e., reference sites). Because of the small number of oiled preassessment points in this region, all oiled sites were selected for establishment of coastal wetland vegetation assessment stations and 10 sites were selected as reference sites (Figure 1). The final numbers of sites in each plant oiling class were as follows: 0% to 0%, 10; 0% to $\leq 10\%$, 1; 11% to $\leq 50\%$, 6; 51% to $\leq 90\%$, 0; and 91% to $\leq 100\%$, 2. Only the 0% to 0%, 11% to $\leq 50\%$, and 91% to $\leq 100\%$ plant oiling classes were, therefore, retained for analysis because of there only being a single site in the 0% to $\leq 10\%$ and no sites in the 51% to $\leq 90\%$ plant oiling classes. Note that although no prespill data were available for the oiled sites to implement a before–after control–impact (BACI) analysis, the use of sites with visual confirmation of oiling and the closest reference sites available from the preassessment study provide strong evidence

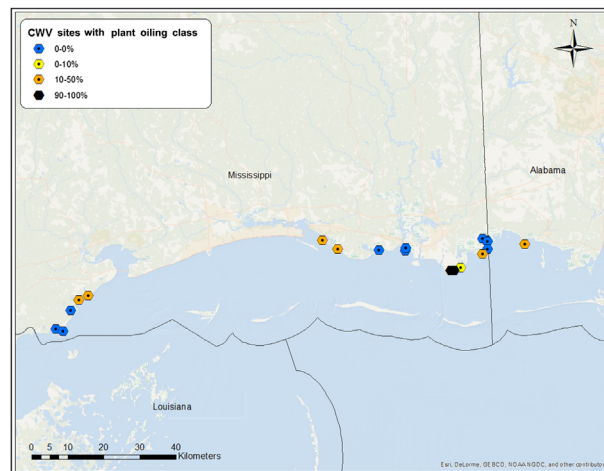


Figure 1. Location of the coastal wetland vegetation sites in Mississippi and Alabama. CWV = coastal wetland vegetation.

that the observed impacts are the result of oiling rather than any other correlated factors.

At each coastal wetland vegetation site, a 20-m transect was established perpendicular to the shoreline and pairs of plots were established with plot centers located at 1.5 m (zone 1), 10 m (zone 2), and 16 m (zone 3) inland from the shoreline, where the transect was initiated. Cover plots for nondestructive assessments, 1 m² in area, were established to the left of the transect line looking inland, whereas productivity plots for destructive assessment (1 m × 2 m) were established to the right of the transect line looking inland. Productivity plots were subdivided into 8 subplots (0.5 m × 0.5 m) for sequential harvesting of peak standing crop over time.

Variables measured

Although a large number of vegetation and soil metrics were characterized during the assessment, only the key metrics representing vegetation cover and productivity and soil oiling are presented. For a complete review of the sampling approach, vegetation and soil metrics, and analytical procedures, readers are referred to the coastal wetland vegetation sampling plan for the *Deepwater Horizon* oil spill [2]. Live and dead vegetation cover was visually estimated by species (1% increments up to 10%, 5% increments thereafter) in the 1-m² cover plots by Natural Resource Damage Assessment teams consisting of natural resource trustee and responsible party representatives. A 0.25-m² subplot was randomly selected within the 1 m × 2 m productivity plots in each sampling season, and aboveground biomass was collected by Natural Resource Damage Assessment teams by clipping all vegetation rooted within the subplot immediately above the soil surface, placing into labeled bags, and storing on ice until processing. Vegetation was sorted into live and dead partitions by species and wet weights determined. Subsamples of each partition were then taken, dried to a constant weight, and used to calculate the dry weight of the entire partition based on the ratio of dry subsample to wet subsample mass. Soil cores, 7.2 cm in diameter, were collected to a depth of 10 cm from immediately outside cover plots and from the assigned productivity subplots for determination of soil properties following standard methods [2]. Soil samples for petroleum hydrocarbon characterization were collected by nitrile gloved hand to a depth of 2 cm from each plot, preserved, and analyzed at an approved laboratory following case-wide protocols [2]. Total PAH concentration was calculated by

summing the values for the 54 semivolatile organic compounds listed in Supplemental Data, Table S1.

Statistical analyses

Factorial analysis of variance of plant oiling class and zone was performed within a sampling season to evaluate the statistical significance of individual variables. Species-specific vegetation cover and biomass were binned into 3 categories, *J. roemerianus*, *S. alterniflora*, and “other species,” for ease of visualization. The “other species” category consisted primarily of *Spartina patens*, *Distichlis spicata*, and *Salicornia* spp. at both reference and oiled sites and was not subjected to statistical analysis. A priori contrasts of reference versus >10% oiling and of reference versus >90% oiling were employed within the plant oiling class by zone interaction to determine statistical significance. The alpha level for all statistical comparisons was set at 0.1, and all statistical tests were applied in a 1-tailed framework except soil bulk density and organic matter, which employed a 2-tailed approach. For any given variable, statements regarding percentage reductions with oiling were all calculated relative to values of that variable in reference marsh sites, but the raw means and standard errors for each oiling class, including the reference, are presented in the figures.

RESULTS

Vegetation cover

Reductions in total live cover with oiling were detected primarily in zones 1 and 2 in the first 2 yr of the present study and became more prevalent in zone 3 toward the end of the study. In spring 2011, total live vegetation cover in zone 1 (51%) was significantly reduced by 51% when aboveground tissues were exposed to >90% oiling and by 54% in fall 2011 with >10% oiling (Figure 2; $p = 0.02$ and $p = 0.01$, respectively). In zone 2, oiling of aboveground tissues of >10% significantly reduced total live vegetation cover by 21% in spring 2011 and 31% in fall 2011 (Figure 2; $p = 0.09$ and $p = 0.05$) and >90% oiling significantly reduced total live vegetation cover by 47% in fall 2012 (Figure 2; $p = 0.02$). Total live vegetation cover in zone 3 was significantly reduced by 80% in fall 2011 with >90% oiling (Figure 2; $p = 0.01$). Greater than 10% oiling in zone 3 significantly reduced total live vegetation cover by 39% in fall 2012 and 32% in fall 2013 (Figure 2; $p = 0.03$ and $p = 0.06$, respectively).

Juncus roemerianus was an important constituent of the plant community and frequently displayed greater impacts from oiling than *S. alterniflora*. Reference marsh live cover values of *J. roemerianus* in spring 2011 typically ranged from 25% to 35%. Oiling levels of >10% significantly reduced live cover of *J. roemerianus* in zone 1 by 91% and 88% in spring 2011 and fall 2011 (Figure 3; $p < 0.01$ and $p = 0.04$, respectively). In zone 2, >10% oiling significantly reduced *J. roemerianus* live cover by 92% in spring 2011, 88% in fall 2011, 79% in fall 2012, and 91% in fall 2013 (Figure 3; $p < 0.01$, $p < 0.01$, $p = 0.01$, and $p < 0.01$, respectively). *Juncus roemerianus* live cover in zone 3 with >10% oiling was significantly reduced by 97% in spring 2011, 86% in fall 2011, 81% in fall 2012, and 82% in fall 2013 (Figure 3; $p = 0.02$, $p = 0.03$, $p = 0.01$, and $p = 0.01$, respectively). Live cover of *S. alterniflora* was not significantly reduced by oiling in any zone or sampling period.

Total vegetation cover displayed significant reductions in response to oiling across zones over time. Zone 1 total vegetation cover (~85% in reference marsh sites) was significantly reduced by 34% in spring 2011 and 46% in fall

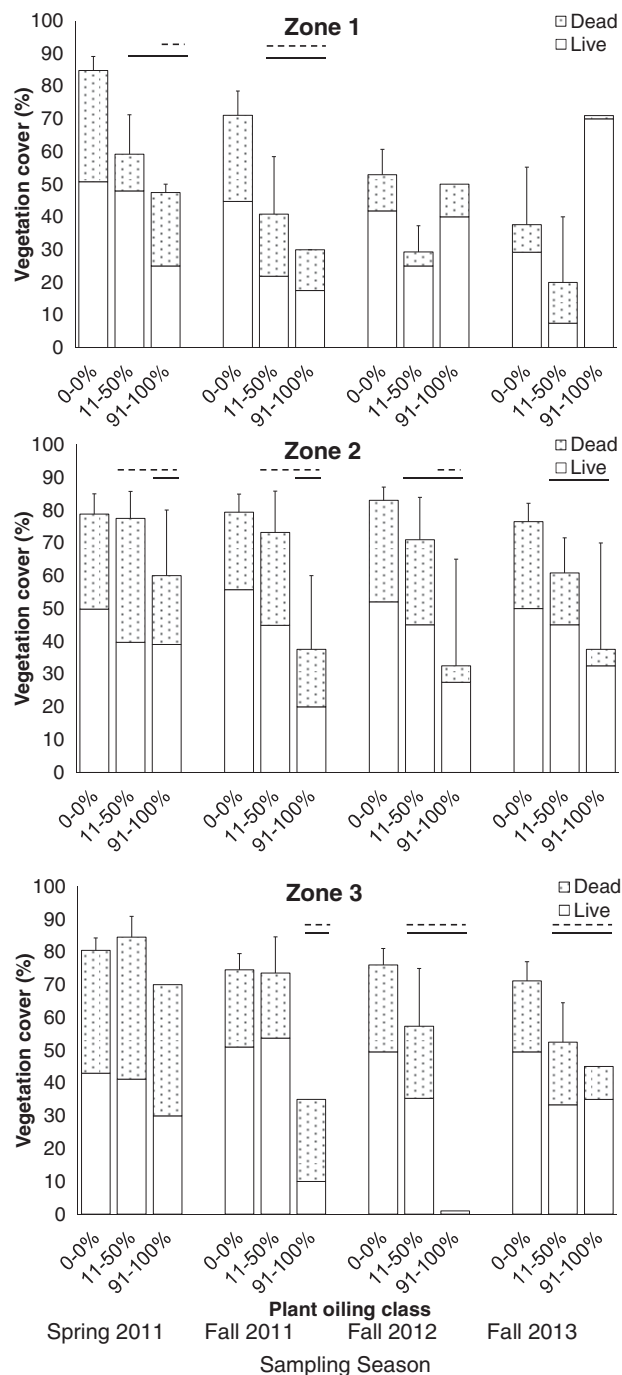


Figure 2. The effect of plant oiling class and zone within a sampling period on live, dead, and total vegetation cover (mean \pm 1 standard error). Horizontal bars represent oil class groupings that are significantly ($p \leq 0.1$) different from the reference. Significant differences in total aboveground biomass are represented by solid horizontal bars — and live aboveground biomass by dashed horizontal bars -----.

2011 with >10% oiling (Figure 2; $p < 0.01$ and $p = 0.01$). Total vegetation cover in zone 2 was significantly diminished with >90% oiling by 24% in spring 2011 and 53% in fall 2011 (Figure 2; $p = 0.07$ and $p < 0.01$, respectively) and with >10% oiling by 27% in fall 2012 and 28% in fall 2013 ($p = 0.04$ and $p = 0.05$, respectively). Total vegetation cover in zone 3 was significantly diminished by 53% in fall 2011 with >90% oiling (Figure 2; $p = 0.03$). In fall 2012 and fall 2013, >10% oiling reduced total vegetation cover by 35% and 28%, respectively (Figure 2; $p = 0.02$ and $p = 0.07$).

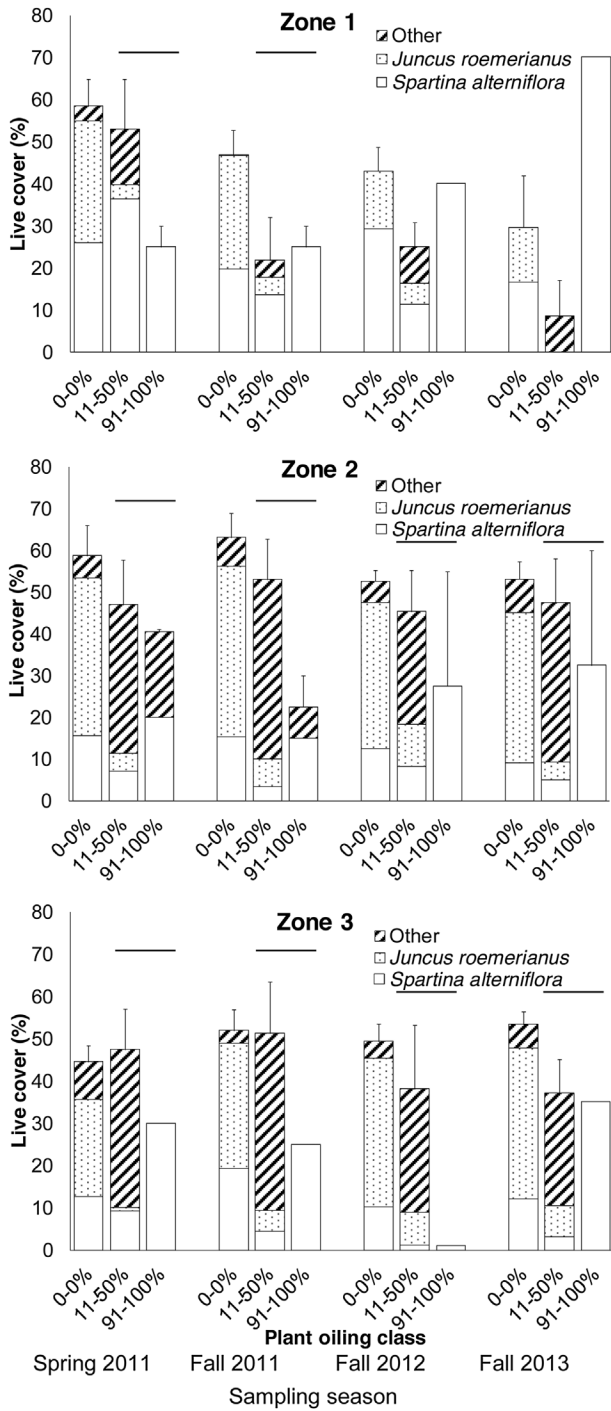


Figure 3. The effect of plant oiling class and zone within sampling period on live vegetation cover of *Spartina alterniflora*, *Juncus roemerianus*, and all other species (mean \pm 1 standard error). Solid horizontal bars — represent groupings significantly ($p \leq 0.1$) different from the reference in live *J. roemerianus* cover. No significant effect of oiling class on live *S. alterniflora* cover was detected.

Vegetation biomass

Live aboveground biomass was reduced in marshes experiencing oiling in all zones in the first 2 yr of the present study, and *J. roemerianus* and *S. alterniflora* exhibited differential live biomass accumulation in response to oiling. In fall 2011, live aboveground biomass averaged 689 g m⁻² in zone 1 reference marsh sites. Greater than 10% oiling reduced

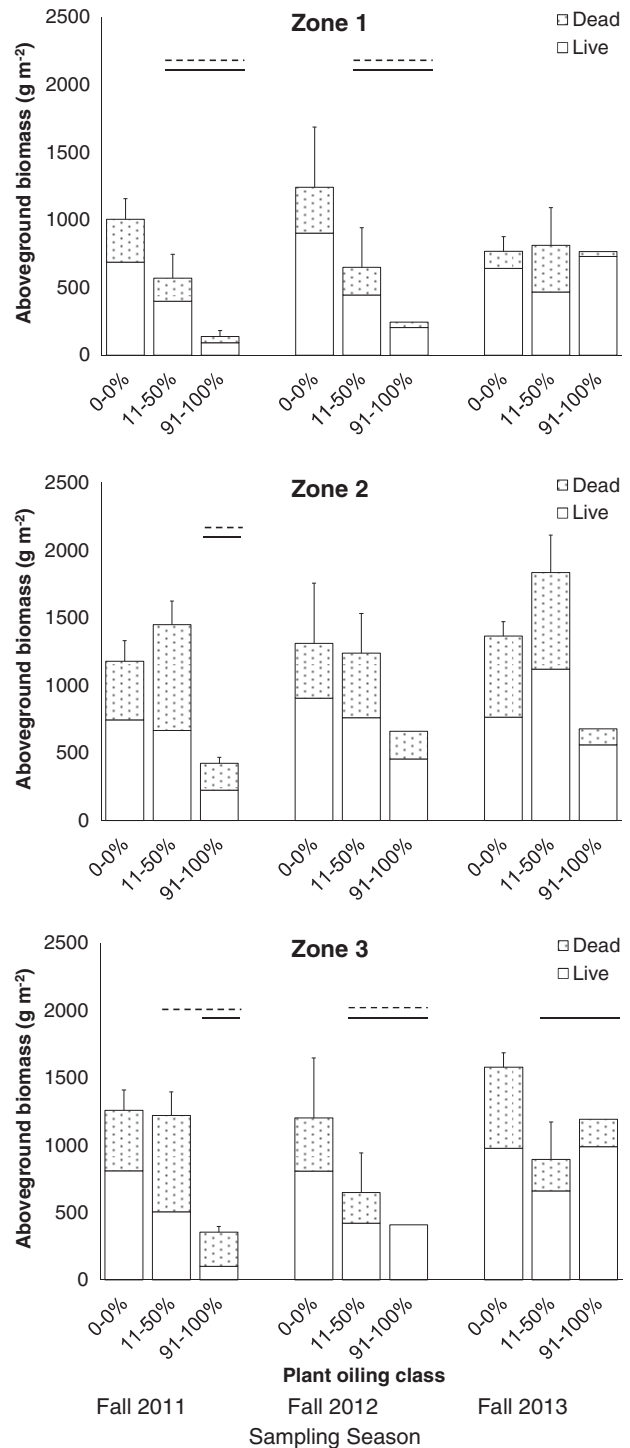


Figure 4. The effect of plant oiling class and zone within a sampling period on live, dead, and total aboveground biomass (mean \pm 1 standard error). Horizontal bars represent oil class groupings that are significantly ($p \leq 0.1$) different from the reference. Significant differences in total aboveground biomass are represented by solid horizontal bars — and live aboveground biomass by dashed horizontal bars -----.

zone 1 live aboveground biomass by 53% in fall 2011 and 56% in fall 2012 (Figure 4; $p = 0.02$ and $p = 0.05$, respectively). Greater than 90% oiling significantly reduced zone 2 live aboveground biomass by 70% in fall 2011 (Figure 4; $p = 0.03$). Live aboveground biomass was significantly reduced with >10% oiling in zone 3 by 45% in fall 2011 and by 48% in fall 2012 (Figure 4; $p = 0.02$ and $p = 0.06$, respectively). Live *J. roemerianus* biomass in zone 1 reference marsh sites

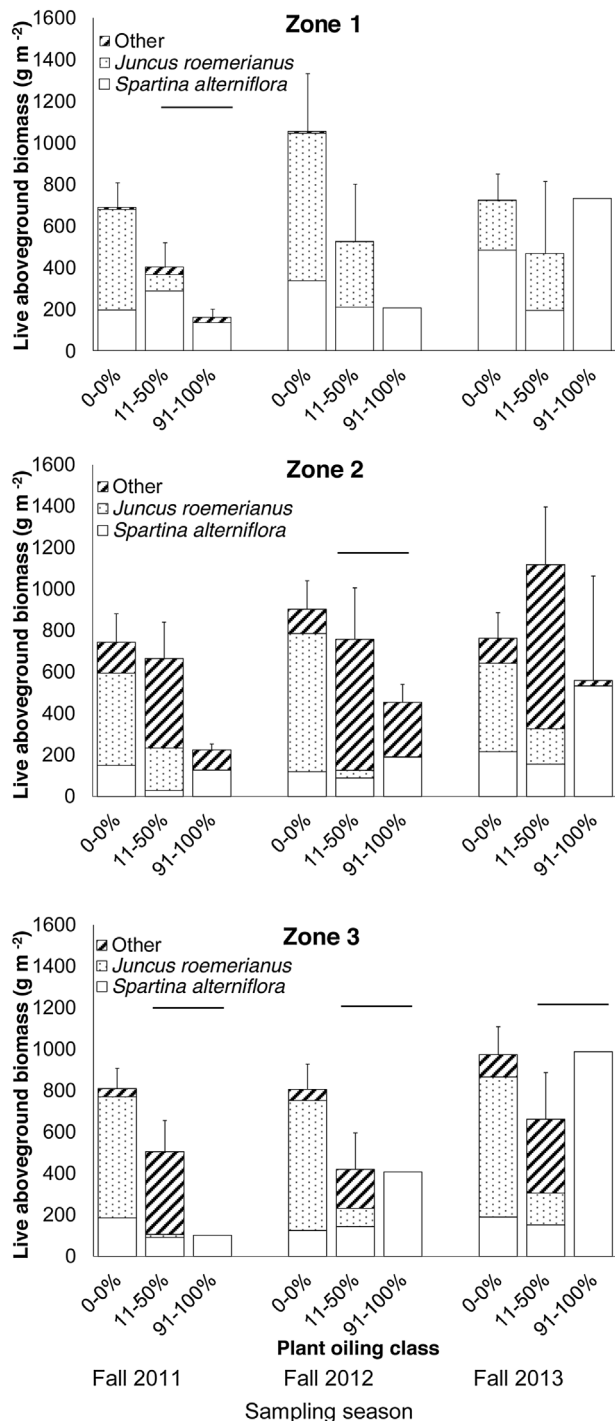


Figure 5. The effect of plant oiling class and zone within sampling period on live aboveground biomass by species (*Spartina alterniflora*, *Juncus roemerianus*, and all other species; mean ± 1 standard error). Solid horizontal bars — represent groupings significantly ($p \leq 0.1$) different from the reference in live *J. roemerianus* aboveground biomass. No significant effect of oiling class was detected for live *S. alterniflora* aboveground biomass.

averaged 482 g m² in fall 2011. Greater than 10% oiling significantly reduced *J. roemerianus* biomass in zone 1 by 86% in fall 2011 (Figure 5; $p = 0.02$) and by 96% in fall 2012 in zone 2 (Figure 5; $p = 0.01$). In zone 3, >10% oiling reduced live *J. roemerianus* biomass by 98% in fall 2011, 88% in fall 2012, and 81% in fall 2013 (Figure 5; $p < 0.01$, $p = 0.04$, and $p = 0.01$, respectively). Live *S. alterniflora* biomass was not significantly reduced by oiling in any zone or sampling period.

Reductions in total aboveground biomass with oiling were most pronounced in zones 1 and 2 in the first 2 yr of the present study, whereas zone 3 exhibited reductions across all 3 yr. Fall 2011 total aboveground biomass in zone 1 averaged 1005 g m²; >10% oiling significantly reduced zone 1 total aboveground biomass by 54% in fall 2011 and 58% in fall 2012 (Figure 4; $p = 0.05$ and $p = 0.07$, respectively). Zone 2 total aboveground biomass was significantly reduced by 64% with >90% oiling in fall 2011 (Figure 4; $p = 0.03$). Total aboveground biomass was significantly diminished in zone 3 by 72% in fall 2011 with >90% oiling (Figure 4; $p = 0.04$) and by 46% in fall 2012 and 41% in fall 2013 with >10% oiling (Figure 4; $p = 0.06$ and $p = 0.06$, respectively).

Environmental characterization

There was essentially no significant elevation of total PAHs in oiled plots compared with reference plots (Table 1). Oiled sites consistently displayed higher soil bulk densities and lower soil organic matter content than reference sites for all zones (Table 1), suggesting that oiled sites likely occurred in higher-energy shorelines areas.

DISCUSSION

Areas of coastal salt marsh in Mississippi and Alabama where vegetation was visually oiled during the *Deepwater Horizon* oil spill displayed some degree of injury. Significant reductions in overall vegetation cover and peak standing crop were detected, particularly in 2011 and 2012, in areas with >10% of vertical plant oiling and likely result from species-specific responses to oil exposure. Importantly, soil total PAH concentrations were generally not elevated at oiled sites, which is largely because of the substantial time between the visual determination of vegetation oiling during the preassessment period (22 June–9 September 2010) and the implementation of the coastal wetland vegetation assessment (17 May 2011). Over this period significant opportunities for both abiotic weathering and microbial degradation of oil would be expected, particularly given the irregular flooding regime prevalent in coastal marshes of this region [3]. This lack of residual soil contamination likely contributed to the apparent trend toward recovery in fall 2013.

Both live and total vegetation cover were consistently reduced at oiled sites, particularly in zones 1 and 2, in the first 3 sampling periods of the present study (spring 2011, fall 2011, and fall 2012), indicating that vegetation productivity in Mississippi and Alabama was reduced in the first 3 yr following oiling. Live and total aboveground biomass also reflects this trend with reductions in these metrics in fall 2011 and fall 2012. Although studies on the disruption of salt marsh vegetation photosynthetic processes from *Deepwater Horizon* oiling in Mississippi and Alabama have been performed [15], field investigations on oiling impacts to integrated growth responses in this region are limited at the time of this writing. In Louisiana, Lin and Mendelsohn [13] determined that salt marshes of northern Barataria Bay that experienced moderate and heavy *Deepwater Horizon* oiling had lower total and live aboveground biomass than reference areas 7 mo after oiling. Importantly, although some anecdotal observations of regrowth were made by Lin and Mendelsohn [13], no follow-up sampling has been published to quantify long-term trends in live standing crop in these salt marsh areas at the time of this writing.

Coastal salt marsh plant species are well known to exhibit variation in tolerance to oiling [7]. *Juncus roemerianus* is

Table 1. Effect of >10% plant oiling on soil total polycyclic aromatic hydrocarbons, bulk density, and organic matter, by sampling period and zone (mean \pm standard error)

Sampling Period	Zone	Total PAHs (ng g ⁻¹)		Bulk density (g cm ⁻³)		Organic matter (%)	
		0–0%	>10%	0–0%	>10%	0–0%	>10%
Spring 2011	1	215.1 (62.3)	257.4 (93.5)	0.71 (0.09)	1.28 (0.21)*	11.4 (2.5)	4.8 (0.9)*
	2	279.5 (71.5)	519.7 (184.1)*	0.62 (0.09)	1.20 (0.13)*	14.8 (2.4)	4.1 (1.0)*
	3	264.7 (83.2)	357.1 (63.7)	0.62 (0.06)	1.10 (0.12)*	15.6 (2.5)	6.3 (1.1)*
Fall 2011	1	253.5 (69.1)	317.7 (152.4)	1.03 (0.17)	1.52 (0.18)*	11.9 (2.1)	6.4 (1.5)*
	2	313.6 (81.6)	213.0 (64.1)	0.85 (0.14)	1.49 (0.19)*	14.1 (1.8)	4.2 (1.1)*
	3	294.3 (62.6)	326.2 (85.5)	0.78 (0.12)	1.18 (0.12)*	15.2 (2.3)	8.0 (1.9)*
Fall 2012	1	256.5 (87.3)	298.8 (146.5)	0.79 (0.11)	1.63 (0.32)*	10.0 (1.7)	6.9 (4.4)
	2	396.8 (97.7)	174.5 (36.4)	0.80 (0.12)	1.58 (0.21)*	12.1 (1.5)	4.1 (0.9)*
	3	285.0 (70.6)	526.7 (233.5)	0.70 (0.11)	1.16 (0.15)*	12.9 (2.0)	5.5 (0.7)*
Fall 2013	1	109.2 (41.1)	211.9 (110.2)	0.94 (0.20)	1.34 (0.28)	10.0 (2.2)	13.1 (7.5)
	2	416.6 (119.4)	404.5 (179.9)	0.88 (0.14)	1.80 (0.22)*	13.5 (2.1)	4.2 (1.2)*
	3	313.0 (80.9)	305.0 (78.5)	0.81 (0.13)	1.28 (0.16)*	13.4 (2.1)	7.6 (1.9)*

*Denotes significance at the $p \leq 0.01$ level.
PAH = polycyclic aromatic hydrocarbon.

generally considered the dominant plant species in salt marshes in this region [3] and was consistently an important component of our reference marshes throughout the present study's duration. Several studies have suggested that *J. roemerianus* growth processes can be substantially impacted by *Deepwater Horizon* oiling [12,13] and that *J. roemerianus* appears to be less tolerant to *Deepwater Horizon* oiling than *S. alterniflora*, a frequently codominant species in the northeast Gulf of Mexico [13]. *Juncus roemerianus* cover and biomass in the first 2 yr of the present study was greatly reduced at field sites experiencing >10% oiling compared with the reference, whereas *S. alterniflora* cover and biomass were similar between oiled and reference sites. Given that the present field study was not initiated until spring 2011, essentially 1 yr after the beginning of the *Deepwater Horizon* incident, and that total cover and biomass in the >10% oiling classes were also reduced, it is possible that existing *J. roemerianus* was greatly impacted and already largely eliminated prior to the first field sampling. In addition, the 11% to 50% plant oiling class tended to have a greater contribution of species other than *J. roemerianus* and *S. alterniflora* to live cover and aboveground biomass, which may indicate that these typically dominant species had been sufficiently impacted to allow colonization by other species to occur.

Although total live cover and live aboveground biomass (standing crop) were reduced in Mississippi–Alabama salt marshes with >10% oiling through fall 2012, by fall 2013 significant differences in these metrics were essentially confined to zone 3. This suggests that vegetation in these salt marshes may have begun some degree of recolonization and recovery. Importantly, the stable geomorphic setting of this region and the lack of significant tropical storms affecting this area during the relevant time interval of the present study would indicate that these results are not confounded by external factors. Further, essentially no significant increases of soil total PAH concentrations were detected during the present study, which is often a major factor in limiting salt marsh recovery [7,13]. This lack of persistent soil contamination is likely a primary factor in the apparent recolonization of salt marsh vegetation 3 yr postspill. Also, because this region is not undergoing accelerated subsidence [6], it is less likely that an initial reduction in vegetation productivity would limit the ability of vegetation to

later reestablish because of a loss of elevation and resultant increase in flooding stress, as has been reported in some spills [16].

The present study documents that salt marsh vegetation along the coasts of Mississippi and Alabama experienced some degree of injury associated with exposure to *Deepwater Horizon* oiling, even though the extent of exposure in this region was not as substantial as in the neighboring state of Louisiana. Specifically, significant reductions in the coverage and aboveground standing crop of salt marsh vegetation that experienced >10% vertical oiling of aboveground tissues were detected. Interestingly, these lower values for total live vegetation cover and live aboveground biomass appear to result largely from reduced live cover and biomass contributions of *J. roemerianus*. Importantly, relatively few reductions in vegetation productivity indicators were detected by the final sampling in fall 2013, indicating that some degree of recovery may have begun. It is important to note that minimal loss of study plots as a result of erosion occurred in this relatively geomorphologically stable region and that essentially no significant increases of soil hydrocarbon concentration relative to reference marshes was detected. These factors suggest that this apparent trend toward recovery is reasonable and that obfuscation by external factors is not likely. However, the limited sample size of the present study necessitates caution in the extrapolation of the results to broader areas.

Supplemental Data—The Supplemental Data are available on the Wiley Online Library at DOI:10.1002/etc.3450.

Acknowledgment—The present study relies on data collected as part of investigations being conducted cooperatively among National Oceanic and Atmospheric Administration, other federal and state natural resource agencies, and BP as part of the *Deepwater Horizon* natural resource damage assessment. The findings and conclusions in this presentation are those of the authors and do not necessarily represent the view of NOAA or of any other natural resource Trustee for the BP/*Deepwater Horizon* NRDA. The authors thank M. Zhang and J. Oehrig for statistical assistance and G. Fricano, C. Sasser, and several anonymous reviewers for beneficial manuscript reviews.

Data availability—Data are available through the National Oceanographic and Atmospheric Administration *Deepwater Horizon* oil spill searchable database web tool at <https://dwhdiver.orr.noaa.gov>.

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